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DELIVERABLE 1.2

REPORT ON THE STATE OF THE ART IMPLEMENTATION OF AN INTEGRATED PILOT APPROACH

Work Package 1

Framework and Facilitation of Systems Learning and Upscaling Multi-Use

July 31st, 2020

Project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement no 862915

Grant Agreement number	**862915**
Project title	**UNITED: multi-Use platforms and co-locatioN pilots boostIng cost-effecTive, and Eco-friendly and sustainable proDuction in marine environments**
Deliverable title	Report on the State of the art implementation of an integrated pilot approach
Deliverable number	1.2
Deliverable version	Original Submission
Contractual date of delivery	June 30th, 2020
Actual date of delivery	July 31st, 2020
Document status	Submitted version
Document version	Version 1.0
Online access	Yes
Diffusion	Public
Nature of deliverable	Report
Work Package	WP1 – Framework and Facilitation of Systems Learning and Upscaling Multi-Use
Partner responsible	WINGS
Contributing Partners	WUR, SUBMARINER, FuE, UGent, WINGS, SPOK, ACTeon
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Abstract	This deliverable has created an extensive literature review on already developed multi-use solutions, with the goal to match

	the knowledge already gained by the previous existing projects and to map them with the identified barriers risks as well as opportunities of the UNITED pilots. A state-of the –art report on the exististing technological solutions is included in order to shape the requirements for implementation of the multi-use activities for each pilot. A societal profie of each pilot is also created, by reporting the results of five interviews, carried out by the pilot leads to key business stakeholders of the pilots.
Keywords	State-of-the-art technologies, multi-use challenges, risks, barriers, multi-use requirements, societal profile, local community view, key stakeholder

TABLE OF CONTENTS

Contents

ACRONYMES

H2020	Horizon 2020 (European Commission funding programme)
H2Ocean	Development of a Wind-Wave Power Open-Sea Platform Equipped for Hydrogen Generation with Support for Multiple Users of Energy (FP7-Ocean 2011 funded project, 2012-2014)
H&S	Health and safety
MARIBE	Marine Investment for the Blue Economy (Horizon 2020 funded project, 2015-2016)
MERMAID	Innovative Multi-purpose Off-shore Platforms: Planning, Design and Operation (FP7-Ocean 2011 funded project, 2012-2016)
MU	Multi-use
MUPS	Multi-use platforms
MUSES	Multi-Use in European Seas (Horizon 2020 funded project, 2016-2018)
O&M	Operations and maintenance
ORECCA	Off-shore Renewable Energy Conversion platforms – Coordination Action
OWF	Offshore Wind Farm
SOMOS	Technical Standards for Safe Production of Food and Feed from marine plants and Safe Use of Ocean Space (Lloyd's Register Foundation funded project, 2016-2018)
Space@Sea	Horizon 2020 funded project, 2017-2020
TRL	Technology Readiness Level
TROPOS	Modular Multi-use Deep Water Offshore Platform Harnessing and Servicing Mediterranean, Subtropical and Tropical Marine and Maritime Resources (FP7-Ocean 2011 funded project, 2012-2015)
UNITED	Multi-Use offshore platforms demoNstrators for boostIng cost-effecTive and Eco-friendly pro-Duction in sustainable marine activities (Horizon 2020 funded project, 2020-2023)
WinWind	Project funded by Dutch Topsector Energy, 2018-2020
WP	Work Package
MUCL	Multi-Use Co-Location
BPNS	Belgian part of the North Sea
IMTA	Integrated Multi-Trophic Aquaculture
DACS	Data Acquisition and Control Systems
FAVV	Federaal Agentschap voor de Veiligheid van de Voedselketen (Federal Agency for the Safety of the Food Chain)
MTD	Maritime Technology Division
UGent	Ghent University

NSF	North Sea Farm Foundation
ARC	Aquaculture and Artemia Reference Centre
RBINS	Royal Belgian Institute of Natural Sciences
EIA	Environmental Impact Assessment
MSP	Marine Spatial Plan
MW	MegaWatt
VVM	"Vurdering af Virkninger på Miljøet" stands for *Environmental Impact Report*
EDULIS	Offshore mussel culture in wind farms project collaboration
AquaLast	within the support program "Applied Environmental Research", Grant Number FV 174
FIOV	Flandres Queen Mussel
MytiFit	Health of offshore cultivated blue mussels
NutriMat	Nutritional Material from Fouling Organisms
WINSEAFUEL	Environmental Lifecycle and Sustainability Assessment
SYMAPA	Synergy between Mariculture & Passive Fisheries
TunaDive	Seashell Dive Centre Malta
VAWT	Vertical-Axis Wind Turbine
WEC	Wave Energy Converter
AWI	Alfred-Wegener-Institut
ISEA	Integrated Socio-Economic Assessment
IMARE	Institute of Marine Engineers
BMWI	Federal Ministry of Economics and Technology
BMBF	Federal Ministry for Education and Research
SUBVE	The Senator for Environment, Construction, Transport and European Affairs
EMFF	European Maritime and Fisheries Fund
EU	European Union
DSS	Decision Support System
BPNS	Belgian part of the North Sea

MTD	Maritime Technology Division of UGent
UCH	Underwater Cultural Heritage
FAO	Food and Agriculture Organization of the United Nations
SAR	Search and Rescue
OSPAR	the Oslo-Paris Commission
MSFD	Marine Strategy Framework Directive
GES	Good Environmental Status
EEZ	Exclusive Economic Zone
NPV	Net Present Values
IRENA	International Renewable Energy Agency
OOMU	Open Ocean Multi-Use project
NGO	Non-Governmental Organisation
ROV	Remote Operating Vehicle

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This is the second deliverable of WP1, planning to focus more on the analysis of the existing solutions now in order to produce effective roadmaps for the implementation and realization of the multi-use activities in the UNITED pilots. D1.1 has created an extensive literature review on already developed multi-use solutions. This deliverable has the goal to match the knowledge already gained by the previous existing projects and to map them with the identified barriers risks as well as opportunities of the UNITED pilots. A part of this deliverable is to create a state-of the –art report on the exististing technological solutions and to shape the requirements for implementation of the multi-use activities for each pilot. Another part this deliverable is also to start crearting a societal profie of each pilot, by reporting the results of five interviews, carried out by the pilot leads to key business stakeholders of the pilots.

1. INTRODUCTION

1.1 Deliverable scope

This deliverable aims to report the pilots'current state of the art, by reviewing the UNITED cases per pilot with a view to produce the multi-use technical requirements that are needed for the operational phase of the pilots. Furthermore, D1.2 takes as input the literature review of D1.1 and goes a step further by performing an extensive analysis of the multi-use solutions proposed and in development within the UNITED pilots by mapping them with similar multi-use solutions of previous projects from the "Oceans of tomorrow" and other relevant co-use projects. The deliverable also carries out an analysis of the challenges identified for success for each pilot, mapped with the identified challenges, risks and barriers of previous multi-use projects. Finally, in collaboration with WP5 and WP9, the deliverable reports on the interviews that were performed with the local business stakeholders in an attempt to gain insights for the potential multi-use on a beneficiary level, as well as to create a societal profile based on the opinions of the involved local business stakeholders. This deliverable plans to feed information to the other work packages in order to continue with a more focused analysis and implementation of this deliverable's work and to denote the synergies between the pilots in order to increase efficiancies and cross-over learning potential between planned and required activities.

2. MULTI-USE SOLUTIONS IN UNITED PILOTS

2.1 Description of existing solutions in UNITED pilots

Each of the pilots propose site specific solutions and designs in order to achieve the objectives of individual pilots multi-use ambitions. By generating a enhanced project plans for each of the pilots, key areas of development can be identified and both synergies and potential cross-over identified. This allows for pilots to enhance the communication and collaborative efforts to achieve similar goals. Furthermore, although different pilots may aim at implementeing different technological solutions to best achieve local goals, general implementation, training, modelling, and knowledge blocks can be effectively identified and serve for collaborative launching points within the projects and serve as reference points for future project looking to developments within United to further progress with activities outside of the project.

2.1.1 German pilot

Overview of the pilot

The multi-use solution for the German Pilot, denoted as FINO3, not been installed yet. A feasibility study, published in 2018, investigated the possibility of five different aquaculture scenarios for multiuse: mussel long line cultivation (*Mytilus edulis*), macroalgae (*Saccharina latissima*), oysters (*Ostrea edulis*), trout in cages (*Oncorhynchus mykiss*) and Integrated Multi-Trophic Aquaculture (IMTA) a combination of mussel long line cultivation with macroalgae (*Mytilus edulis* with *Saccharina latissima*). Based on the results of this investigation, the most feasible scenarios for FINO3 (considering a wide range of biological, economic and technical factors) were the cultivation of *Mytilus edulis* and *Saccharina latissima*. In addition to the 2018 study, recent reports show that Offshore Wind Farm (OWF) developers consider the combination of both mussels and macroalgae leading to an IMTA approach with extractive aquaculture being more favourable compared to fed aquaculture. Such an approach entails less frequent site visits and smaller-scale operations taking place within the OWF.

Expected outputs

Therefore, a demonstration aquaculture farm of *Mytilus edulis* and *Saccharina latissima* in combination with a monitoring concept for the platform and the aquaculture farm will be implemented to examine the described synergy effects of a multi-use concept. Furthermore, this pilot will develop a business case considering an economically viable value chain and further products that could be derived from seaweed as to ensure that seaweed production is feasible in a Multi-Use (MU) context. The planned mussel and seaweed long line cultures will be deployed in the vicinity of the research platform FINO3 and the wind parks DanTysk, Nördlicher Grund and OSB Butendiek at the beginning of 2021. The basic fundament of the platform provide an analog with the same characteristics as the turbines within the offshore wind farm. The following synergies are the focus of the multi-use application: offshore installation of wind energy and aquaculture (both mussels and macroalgae).

Existing cases / Future Potential

The following synergies focus on the multi-use of offshore installation of wind energy and aquaculture:

Logistics: Closely engaging industry, the German pilot will also assess factors that affect the financial viability of such multi-use concept, including: distance to shore, shared onshore facilities like storage space and workshop.

Transportation: The German pilot will also analyse the optimal operational interactions between the two sectors at the project level e.g. type of vessel, helicopter to be shared as a solution for reducing costs and the environmental impact.

Planning and maintenance work: Means of communication, timetables for maintenance, training requirements and procedures (emergency response) for minimizing risks at the site.

Energy: The duration of use for the monitoring and surveillance program (type of sensors, possible parameters, duration of measurements) will not be limited by the availability of batteries. The aquaculture farm will be supplied with power from the platform.

Technology: This pillar aims at demonstrating automated operation and monitoring under offshore conditions via data transmitting systems, monitoring system and software as well as emergency response. Hence, the key significance lies within the choice of the right material and the conceptual design of the construction in an offshore environment. Moreover, the optimization and scheduling of logistics, such as distribution and harvesting, transportation as well as maintenance work, needs to be planned in detail.

Economy: In order to increase the demand and viability of Multi-Use and Co-Location (MUCL) systems and stimulate the growth in this sector, economic incentives and efficiency need to be provided. The overall profitability and reduction of financial risks of multiuse offshore systems (here: renewable energy and aquaculture production), is demonstrated by assessing the economic potential of synergetic effects for users (e.g. financial yield for investors, cost saving for operators). The general objective is to increase aquaculture production while reducing the energy demand.

Environmental issues/conditions

Whenever implementing new infrastructure into an ecosystem, it is vital to track the impact as well as any positive or negative consequences resulting from that interference. Extensive environmental monitoring and observation will be accomplished by collecting automated measurement data on attractiveness for invertebrates and fishes. On the basis of extensive data collections, enhanced knowledge is generated on interactions between target culture species with other natural biota and effects of aquaculture farms in the offshore environment. In this regard it is expected, that the implemented long lines have potential positive effects.

Societal acceptance

This pillar focuses on stakeholder engagement during the course of the project to accelerate the acceptance of multi-use concepts by North Sea industries in order to allow investors, bankers and insurance policies to fully engage in this new sector. There is a need to develop possible business models and explore local cooperative ownership opportunities while also creating a positive "climate" in the public at large, particularly because offshore facilities are in need of strong support from land based stations. Moreover, such joint (multi-stakeholder) activity can also benefit both developments in regards to shared costs, better social/environmental image of involved businesses and overall increased financial yield for investors. Next to a variety of engagement options, such as interactive workshops and discussion rounds as well as informational events, multi-disciplinary education of personnel is organized to contribute to a supportive stakeholder environment.

Workshops will be conducted to demonstrate benefits and challenges to students (offshore engineering, architecture and aquaculture students) as well as other stakeholder groups in developing multi-use offshore.

Legal issues / pending licenses

Law and government: The German Federal Marine Facilities Ordinance, allows for the development of aquaculture at already existing wind power installations, as long as the aquaculture site does not become an obstacle for general maintenance. Complying with the Common Fishery Policy, Blue Growth, and national policies, reference guidelines for insurance, permissions and licences, certification for offshore staff will be created to improve the scarce information base on multiuse offshore systems. Moreover, concepts will be formulated that reduce health and safety risks of offshore MUCL systems.

Insurance: The German pilot addresses the question of how insurance premium structures, required by the insurance companies and by operational guidelines, are to be shared between the two developers (aquaculture and offshore wind) and what parameters are needed by the insurance companies to assess the risk and the insurance rate.

Security of tenure: Most OWF are licensed for around 25 years, after which all infrastructure has to be completely removed. If the aquaculture farm is successful, this requires consideration of what will happen when OWF are to be decommissioned. Because of this, at the end of the project the further usage of the installation will be carefully evaluated in order to deteremine what impacts this regulation imply for multi-use.

Following UNITED's overall five pillar structure, the studies at the German pilot address the aspects technology, economy, environment, society, law and government of which the results will feed into the related work packages WP2-6. The assessments thereof will take place through WP8 and the integration of the monitoring data into the assessment framework.

Table 1: Benefits and barriers faced by the German pilot.

	Benefits	Barriers
Technical	• Development of remote control/operation practices of plant (monitoring devices have to be automated) with high durability • Development of Data Acquisition and Control System (DACS) as well as a communication system • Identifying risks and critical points for future multi-use projects	• Lack of general technological knowledge from the industry involved in MUPs in general (outside of the scope of UNITED). • Damage due to extreme adverse environmental catastrophic events (storms or underwater earthquakes). • Risk of damage in case of mooring failure • High energetic environment, the German pilot location is not accessible at severe weather conditions. Vessels depend even more on fairly low winds and waves. • Divers (for installation) can work only with wave heights below 1m. • Automation of remote data recording via sensors and biofouling may be problematic. • Due to off shore site: time to reach the site is to long for high frequency of visits, hence maintenance of algae and Mussel culture lines has to be minimal, or automated. • Damage risks of mechanical loads, collisions with vessels/ships/fishing boats

Economic	• Development of a business case considering an economically viable value chain and further products that could be derived from seaweed as to ensure that seaweed production is feasible • Attracting other commercial actors and investors, such as retail, utilities, and established aquaculture businesses, to increase the commercial readiness level of such combinations • Multi-stakeholder activity can also benefit from both developments in regards to shared costs, better social/environmental image of involved businesses and overall increased financial yield for investor • Operational requirements can be further exploited and learning processes can be designed cost-effectively	• Lack of certainty of effects of far offshore MUP on fish or oysters in aquacultures (with regard to economic effects). • Lack of attractiveness for private investors • Lack of standardized procedures to co-use aspects related to the MUP (i.e. sharing cable equipment or ships) • High maintenance cost of aquaculture sites. • High cost of decommissioning of the MUP (potential costs after the end of the multi-use). • High insurance cost due to lack of experience in co-location/MUP projects. • High cost of operating staff. • The highest cost factor is the charter for ships: The number of suitable shipping companies with reasonable offers for such a comparable small demander, like FUE, is very limited. • Insufficient subsidies from the government • Market price of produced goods dictates a low price, hence scaling up will be necessary • Access to market/marketing strategies, which improves the possibility for a stable level of turnover for mussels/seaweed is not available
Environmental	• Environmental monitoring data provides a database to investigate the impact of MUCL on the environment at that location • Mussels and seaweed have no or even a positive impact on the environment • Protect declining fish stocks, aquaculture can represent a profitable alternative future for fishermen and can support natural fish habitats to recover	• Insufficient existence of biological data for that location, e.g. time and scale of spat fall, growth rates of mussels and seaweed • Low growth rate of algae might make it unfeasible (due to low temperature), • Growth and settling rates of mussels might be to low • Unknown possibility of harmful algae blooms • Current is too strong for mussels to attach to long lines • Current is too strong for thallus of kelp to stay attached to long line • Increased traffic by maintenances/ operating vessels → disturbance and noise • Underwater-noise disturbance of marine mammals such as wales → only when monopile is constructed and run into the seabed • Collision risks to birds and bats above water with windmills
Social	• Creating public awareness and public acceptance: The course development could finally	• Availability of skilled labour with offshore experience is scarce • Lack of consensus about the MUP from multiple stakeholders in private and public sector.

	lead to a guideline or learning manual • Explore local cooperative ownership opportunities • Attract "newcomers" to MUCL systems and develop a basis of trust for long-term cooperation and division of labour.	• Lack of trust between industries sectors directly involved in the MUP. • Lack of public awareness about implications of multi-use. • Low individual financial power and overall capacity to join MUP from local collaborators. • Conflicts of interest between different users of the sea (i.e. external tourist agencies, other energy producers, etc.). • "Bad reputation" of aquaculture • Needs improvement of market acceptance of aquaculture products.
Law & Government		• Unclear and fragmented regulation for MUPs on national/European level. • Strict security regulation that discourage setting up a MUP • The set of constrains related to safety distance to other users or distance from shore. • Separate environmental impact assessment processes (permitting) for each of the (hybrid) technologies and lack of guidance on cumulative impact assessment. • Lack of established licensing procedures for multi-use projects. • Lack of dialogue between public institutions and difficulties in identifying the administrative offices responsible for issuing permits. • Lack of cross-border cooperation in MUP projects. • Lack of established procedures for spatial planning of the sea with a focus on the interests of different stakeholders. • Uncertainty about the ability of one party to continue if the other enters its decommission phase (e.g. legal status of the activities or the share of decommissioning costs) • Lack of established safety assessment methods for MUPs • Lack of established procedures for spatial planning of the sea with a focus on the interests of different stakeholders. • Lack of knowledge "who is responsible" for the permits and long time to obtain them for future multi-use scenarios • Strict regulations on food safety analysis, testing of food quality is very expensive and time consuming • Determination analysis that there is no negative environmental impact of mussel and algae aquaculture due to sedimentation has not been done

2.1.2 Dutch pilot

Overview of the pilot

North Sea Farm (NSF) Foundation is a non-profit organization that aims to establish, promote and accelerate the seaweed sector in the North Sea region. The NSF aims to achieve this through the following two main tasks:

1. Seaweed Platform: North Sea Farm manages a network platform with over 50 contacts of which many are relevant stakeholders for seaweed. The aim of the Seaweed Platform is to connect all parties that are or want to

become involved with seaweed. In the Seaweed Platform we further aim to inform each other, share information and collaborate on various projects. The Seaweed Platform follows a horizontal approach in that it includes the complete value chain for sustainable seaweed cultivation.

2. Offshore test facilities & demonstration projects: North Sea Farm foundation makes available test farms offshore for parties that want to test various elements of offshore seaweed cultivation as well as related topics of production offshore. At the moment two test facilities are available (Texel and Scheveningen) where new initiatives can start straight away without having to apply for permits. Currently a demonstration project with seaweed is in operation at test farm Scheveningen.

Existing cases / Future Potential

Within this pilot a combination of seaweed, floating solar (400m^2) panels, nature restoration and offshore wind is planned. As a scalable version for a commercial exploitation of such a system within a wind farm. As such the transition from TRL5-TRL7 in the pilot can be demonstrated and towards the end of the project it can be pushed towards commercialization and implementation.
Site characteristics relevant to the pilot - physical boundaries conditions and hydrodynamics (weather, wind, current, wave, etc.):

- Full metocean report available for the location
- Many governmental water quality monitoring points available in the surrounding area
- Depth approximately 18-20m
- Direct access via the port of Scheveningen, approximately 15-35min sailing time (depending on vessel)

Degree of connectivity of the two activities (e.g. multi-use platform, attachment on the existing foundation, co-location with no attachment, operation synergies by using same vessels, using same monitoring systems, etc.) , spatial configuration/arrangement and placement of various components/functions:

- Highly connected
- Full 3G (current developments for full 4G coverage are currently underway).
- Direct access via the port of Scheveningen, approximately 15-35min sailing time (depending on vessel)
    - Many local contractors available to provide logistical or technical support/services
- At the moment a measurement grid is being developed on the site and around the site (real time metocean, (a)biotic sensors, etc.)

Synergies / business models developed from the multi – use

Prospective activities/functions related to co-use/multi-use (aquaculture: seaweed, shellfish, wind farm, wave/tidal energy):

- Integrated mooring/anchor design for seaweed and floating solar -desk study
- Monitoring of structural integrity of floating structures (strain, loads) and energy efficiency – field test
- Design, deployment, monitoring of behavior of cable from floating solar array to seabed to buoy – field test – no grid connection but testing some other elements with such a floating cable, movements through water etc. check with engineers
- Combined environmental monitoring including effect of structures on marine life (multi-sensor sondes, cameras, eDNA/acoustic echosounders) – field study
- Design, deployment, monitoring of behavior of cable from floating solar array to seabed to buoy – field test
- Wave dampening modelling based on various configuration of structures (seaweed, floating platforms, combinations) – desk study
- Basin testing of combined seaweed and floating solar structures – scale testing

Environmental issues/conditions

There is a need to determine impact on ecology when co-use is applied at a large scale > 100km2.

Societal acceptance

Focus should be to make them see and convince them that this "innovative" multi-use of the EU seas is a new chance for existing stakeholder groups and not a threat

Legal issues / pending licenses

Long term concession for commercial exploitation to be agreed with the government

Table 2: Summary of available structural/monitoring/ communication/ management system capabilities and benefits and barriers faced by the Dutch pilot.

Available structural/monitoring/ communication/ management system capabilities	At the moment a number of data acquisition systems are being developed: Seaweed/macro-algae • Biomass growth • Biomass growth • Light intensity • Temperature Micro-algae • Primary production [optical, periodic sample measurements] • Chlorophyl production (total algae) Mussels (bivalve) • Mussel seed collection • Mussel cultivation • Mussel cultivation Hydrodynamic: • Position accuracy (GPS) • Position accuracy (GPS) • Mooring line tension • Accelerations at anticipated critical components • Wave height and direction • Current velocity and direction Nutrients • Dissolved nutrients (Dissolved organic & inorganic uptake using stable isotopes by the seaweeds in the test farm), if feasible • Turbidity
Legal challenges to be addressed (regulations, licences, insurance policies, other sectorial policies e.g. incentive systems)	Long term concession for commercial exploitation to be agreed with the government
Social (acceptance)/socioeconomic aspects to be considered	Demonstration and acceptance required from stakeholders: focus should be to make them see and convince them that this "innovative" multi-use of the EU seas is a new chance for existing stakeholder groups and not a threat

Environmental challenges to be addressed	Determine impact on ecology when co-use is applied at a large scale > $100km^2$
Economic (feasibility) challenges to be addressed	Cost should be brought down and yield should increase – numbers are available
Expected benefit from UNITED (spatial efficiency, functional synergies, sharing permitting investment and infrastructures to reduce operational and maintenance costs, etc.)	Autonomous development of multi-use in our oceans could be realized. This means that commercial parties themselves develop these initiatives based on and thanks to the knowledge acquired in UNITED. Then these initiatives and required technological developments are no longer solely dependent on subsidy projects – and this is a really important milestone to achieve for the Blue Growth strategies.

2.1.3 Belgian pilot

Overview of the pilot

The Belgian pilot (Offshore wind, flat oyster aquaculture & restoration, & seaweed cultivation synergies) is divided in three phases (pre-operational, operational and post-operational) and will be carried out at two locations (nearshore and offshore).

In the pre-operational phase, different aquaculture systems will be tested nearshore at the site of Westdiep (Figure 1) at 5km off the coast in front of Nieuwpoort (average depth 15m). The nearshore site of Westdiep has several longlines since April 2017, being part of the Belgian projects "Value@Sea" and "Symapa" and is managed by UNITED partner Brevisco. The lines are currently used for test productions of flat oyster (*Ostrea edulis*), blue mussel (*Mytilus edulis*) and seaweed. In UNITED, the nearshore site will be used for testing different types of growing equipment for flat oyster, nature-inclusive scour protection and for sugar kelp (*Saccharina latissima*) growth. The best performing set-up will be selected and applied in the operational phase at the offshore site.

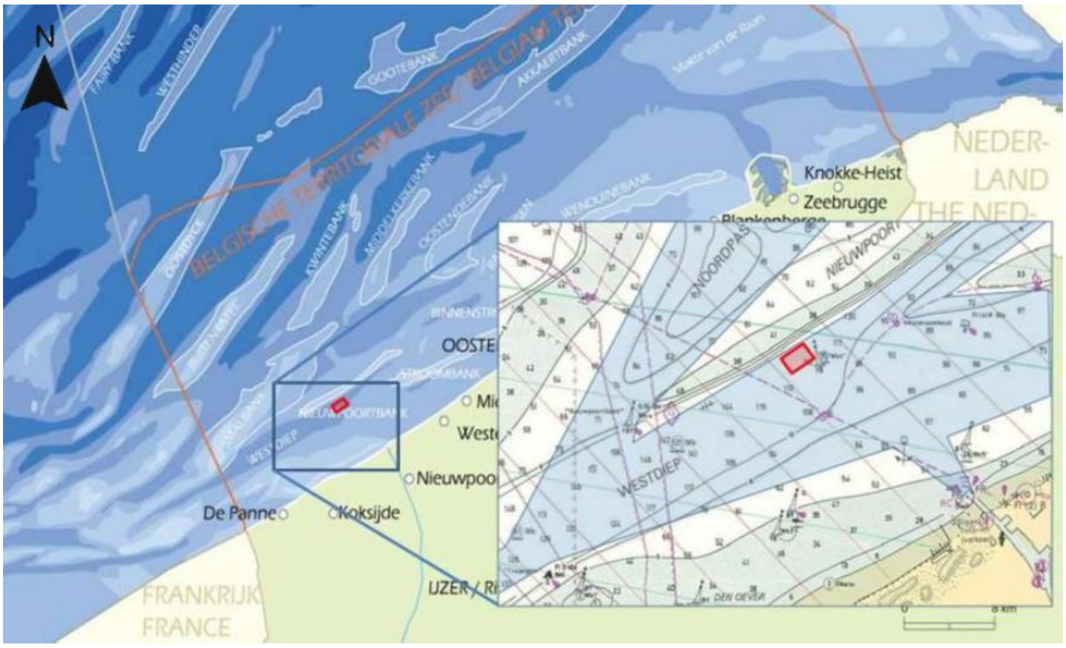


Figure 1: Map of Westdiep area, in which the pre-operational phase is prepared

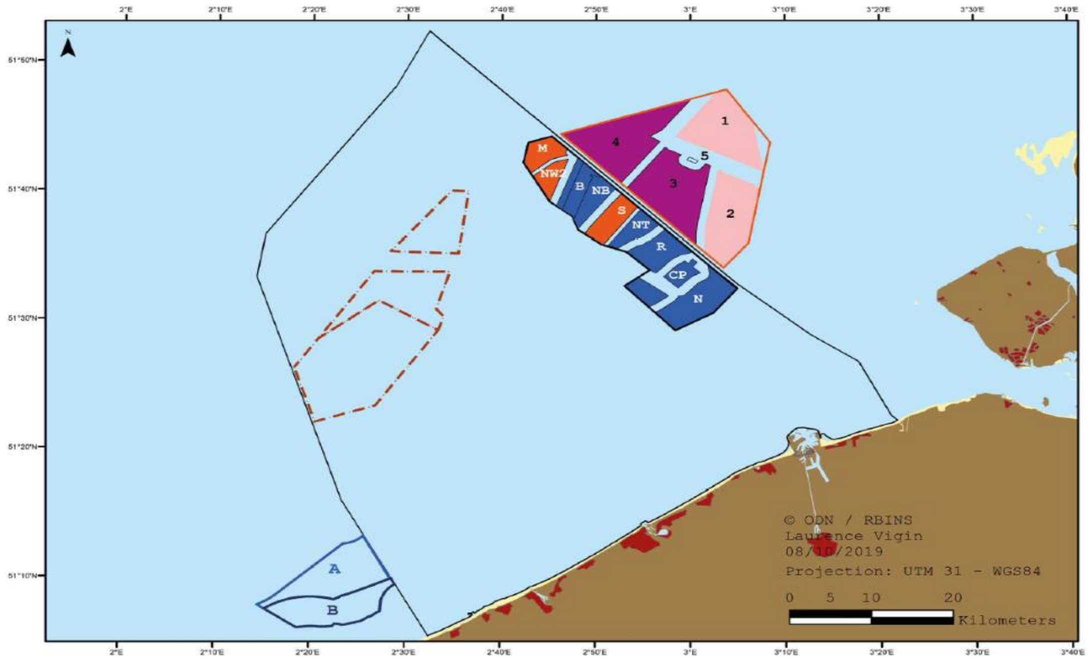


Figure 2 : Belgian part of the North Sea (BPNS) with realised and planned wind farm concessions. The location of the pilot site will be at one of the offshore wind farms (yet to be determined) operated by Parkwind (Rumes&Brabant 2019 in Degraer et al. 2

The operational phase of the Belgian pilot is situated in the Belgian part of the North Sea (BPNS), more specifically in one of the offshore wind farms (yet to be determined) operated by Parkwind. Parkwind develops, finances, builds and operates offshore wind farms in the North Sea since 2009. The vast experience of the Parkwind team builds on the success of the wind farms Belwind (56 turbines), Nobelwind (50 turbines), Northwind (72 turbines), and Northwester 2 (23 turbines) operating in total 776MW mainly in the Belgian exclusive economic zone. Each turbine is built on a monopole foundation. Around each foundation, a scour protection layer is present, and the turbines are connected with each other and with an offshore transformer station by power cables buried in the seabed, transporting the generated electricity. The offshore wind farm area is situated at the eastern border of the BPNS (Figure 2) has an average depth of 15-35m, and includes three sand banks (Bligh Bank, Lodewijkbank and Thortonbank) and adjacent gullies.

The longlines and scour protection for the Belgian pilot have not yet been installed. The operational site will be chosen based on the specific requirements for flat oyster and sugar kelp. Moreover, practical limitations, for example for the mooring of the anchors and safety boundaries, will be based on a risk analysis (still to be performed) and taken into account.

Objectives:

The primary objective of the pilot is to evaluate offshore wind farms as location for restoring native flat oyster reefs in combination with culturing flat oyster for human consumption and seaweed.

- To identify appropriate areas for oyster reef restoration in offshore wind farms where trawling activities are not allowed
- To demonstrate the possibility to develop scour protection that fulfils the technical requirements but at the same time supports the formation of small oyster reefs, which eventually can form a network of small islands of oyster spreading over several square kilometres. Choice of scour protection material is a crucial parameter
- To design a longline that supports flat oyster production in offshore conditions (based on previous experience)
- To identify appropriate seed collectors and grow-out systems for flat oyster offshore
- To develop a monitoring scheme to follow-up oyster growth in function of the environmental parameters
- To optimize the communication and time schedules between the different activities in order to improve the efficiency of installation and data collection

- To identify the synergy between oyster reef restoration, aquaculture and the production of wind energy

The secondary objective of the pilot is to compare the growth of sugar kelp grown offshore and nearshore. For that purpose, the longlines holding the oysters will be used to attach seeded seaweed materials (yet to be determined). Morphological and nutritional characteristics are known to be influenced by the dynamics of the environment and may offer opportunities to culture seaweed for specific purposes.

Expected outputs

- Simulate aquaculture of flat oyster and sugar kelp and restoration of flat oyster in the protected area of an offshore wind farm
- Potential to culture flat oyster under exposed conditions
- Potential to restore flat oyster reefs in offshore wind farms
- Seaweed quality in function of environmental conditions
- Remote monitoring as a tool to collect data
- Life cycle analysis of cultivation practices
- Develop a business case considering an economically viable value chain, and considering products that could be derived from seaweed as to ensure that seaweed production is feasible in a multi-use context.
- Synergies and added value of marine multi-use

The post-operational phase implies the decommissioning of the longlines at the end of the project.

Following UNITED's overall five pillar structure, the studies at the Belgian pilot address the aspects technology, economy, environment, society, and law and government of which the results will feed into the related work packages WP2-6.

Technology: The design of the offshore longline for flat oyster and sugar kelp will be performed by numerical analysis using an in-house tool, "MoorDyn-UGent", which is based on a lumped-mass approach (Pribadi et al., 2019) developed by the MTD-UGent team. ARC-UGent team is developing proper systems for oyster spat collection and grow-out of oyster, while the Phycology-UGent team investigates the best growth options for sugar kelp. Together with the experience of partner Jan De Nul, several scour protection materials are being tested. The key significance lies within the choice of the right material and the conceptual design of the construction in an offshore environment. Another important aspect to pinpoint are systems for disease monitoring, which will be a joint task of ARC-UGent and RBINS teams. Moreover, the optimization and scheduling of logistics, such as distribution and harvesting, transportation as well as maintenance work, needs to be planned in detail.
Economy: a business case will be set up to assess the potential of the synergistic effects and the overall profitability of multi-use offshore systems. In the Belgian pilot, this will be renewable energy, aquaculture production and flat oyster restoration. The risk/health impact on business and the economic sustainability will also be analysed. The general objective is to increase aquaculture production and restore flat oyster reefs while the share of renewable energy is increased in the overall energy production of Belgium.

- The envisaged economic products: oysters, seaweed and renewable energy.
- The provision of ecosystem services: food production, enhanced water quality, improved sediment stability and carbon sequestration, among others.
- The demands: oysters and seaweed on the Belgian market and potential for export.
    - Oysters are a regional product in Belgium, The Netherlands, France and surrounding countries.
    - Seaweed: possibilities are in food, feed additives, bio-energy, and bio-refinement

Other demands are the production of renewable energy and the provision of ecosystem services.

Environment: As new infrastructures will be implemented into the marine ecosystem; it will be vital to track any positive or negative consequences of this activity. The monitoring programme WinMon.BE has documented and evaluated the environmental impact of the construction and operational phases of Belgian offshore wind farms, providing a basis for an in-depth understanding of longer-term effects onto a variety of ecosystem components, from benthic invertebrates over fish to birds and marine mammals. However, no such information is available regarding the type of offshore multi-use that will be implemented in the operational phase of the Belgian pilot. To gather knowledge on the multi-use impacts, important parameters will be defined and monitored, in which partner RBINS plays a crucial role. The environmental impact of the multi-use system will be compared with the single-use activities to investigate if maritime multi-use offers an added value compared to single use.

Society: This pillar focuses on stakeholder engagement during the course of the project to accelerate the acceptance of multi-use concepts by North Sea industries in order to allow investors, bankers and insurance policies to fully engage in this new sector. Partner RBINS will, with their years of experience, take up the interlocutor role for stakeholder engagement. Furthermore, there is a need to develop possible business models and explore local cooperative ownership opportunities while also creating a positive image in the public at large. As investors in offshore wind farms, partners Parkwind and Colruyt will play an important role within the development of such a business model. Offshore wind energy helps Belgium to reach its target for renewable energy. In addition, offshore wind energy helps meeting the European climate objective to generate 32% of all necessary energy from renewable sources by 2030 (https://ec.europa.eu/clima/policies/strategies/2030_en). As shipping is strictly regulated, the offshore wind park area forms a unique space for integrated aquaculture and ecosystem restoration.

Law and government: This pillar will focus on the legal and governance issues related to the Belgian pilot, in particular the multiple use in a broader Belgian and EU legal context, taking into account other users of the sea (fisheries, shipping, …: access - entry prohibitions). The legal part will focus on the permit system and procedures in case of multiple use projects (single permit or multiple permits system) and insurance issues with the pilot as a case study and Belgium as the governance reference. Complying with Blue Growth, and national policies, an inventory of legal and insurances aspects, reference guidelines for insurance, permissions and licences will be created to improve the scarce information base on multi-use offshore systems.

Existing Cases / Future Potential:

An existing case performed in the offshore Belgian part of the North Sea is project EDULIS (2016 – end of 2019), in which the biological and technical aspects for mussel farming in the BPNS, more specifically in the offshore wind farms Belwind (one of the farms of Parkwind as described above) and C-Power (40 km offshore) were studied. As such, the wind farms have extensive experience with offshore longline systems and operational challenges in Belgium. The aim of the EDULIS project was to obtain a prototype for commercial offshore mussel farming using advanced longline technology. Information on financial feasibility studies, socio-economic analysis, pilot budgets of this case is available however remains confidential.

Potential: the current technology readiness level (TRL) of the Belgian pilot is 5. The pilot has a high potential to scale up the proposed combined activities because Belgian offshore wind farms are restricted for fisheries, creating ample space for aquaculture and restoration activities. The pilot aims to reach TRL 7 by the end of the project. Several research questions will be investigated concerning the design, deployment and monitoring of the planned combined activities. Prospective activities include (see also D3.1):

- Identification and supply of biological source materials.
- Understand bio-security measures regarding seaweed spores and flat oyster importation and production.
- Identification of optimal offshore equipment such as grow-out systems, longlines, scour material, seed collector, holding system, and gabions for restoration.
- Optimization of communication and time schedules between the different activities in order to improve the efficiency of the installation and data collection.
- Development of a business case and a financial analysis of integrating offshore wind and aquaculture activities.

- Monitoring of water quality variables (chlorophyll-a, suspended solids, temperature, irradiance), of oyster growth and spat fall, changes in biodiversity, fouling organisms and differences in seaweed growth and quality between nearshore and offshore sites.
- Development of a predictive model for flat oyster growth in the Belgian part of the North Sea.
- Quantification of ecosystem services associated with reef restoration.
- Identification of appropriate areas for oyster reef restoration in offshore wind farms where trawling activities are not allowed.

Synergies / business models developed from the multi – use

One of the goals of our pilot is to identify synergies between different activities and develop a business model as output of the project. The ban of fishery activities and other vessels to enter the offshore wind farms creates the perfect environment for restoration and aquaculture activities. The following synergies are expected:

- Synergies in vessel transfer for maintenance and monitoring of both the wind turbines, restoration and aquaculture activities.
- Synergies in the use of service vehicles.
- Synergies in the use of port facilities.
- Synergies in the application of safety measurements.

Environmental issues/conditions

The development of an offshore wind farm requires an environmental impact assessment (EIA) trajectory. An EIA for the aquaculture part of the Belgian pilot is not required since it is a research pilot. Commercial exploitation in the future, however, will have to conduct an EIA. Additionally, there are regulations concerning the introduction of aquaculture species and associated pathogens/diseases, defined by different institutions, including the Federal Agency for Food Safety (FAVV). Interestingly, a risk analysis needs to be conducted before installation, on the demand of the concession holder of the wind farm in which the pilot will be set up. This analysis also includes an evaluation of possible impacts on the environment of the pilot.

A multi-use assessment or assessment for aquaculture has not yet been performed for the Belgian pilot (nor for any other project in the Belgian part of the North Sea), so information on this topic is currently non-existent.

The majority of the environmental impacts identified for the Belgian pilot are already apparent at the offshore wind farm without any multi-use implemented. Aquaculture of native oyster in the Belgian pilot at an offshore wind farm adds additional hard substrates, but its scale is likely to be negligible compared to the wind turbine foundations and scour protection layers. On the one hand, additional attraction of seabirds to the aquaculture installation might increase the risk of collision with a wind turbine, especially for gull species which are already attracted to the offshore wind farms. On the other hand, the envisaged oyster reef restoration however, might increase biodiversity by providing valuable feeding, breeding and refugee areas for a range of species. Additionally, an important native habitat -oyster reefs- will be restored in the BPNS, providing valuable ecosystem services including improved water quality, increased fish production and carbon sequestration. Moreover, by combining flat oyster aquaculture and sugar kelp growth, this extractive aquaculture might purify the surrounding water from excess nutrients, leading to a sustainable way of performing.

One concern, which is not applicable for the single-use of an offshore wind farm, is the unwanted introduction of pathogens, diseases and non-native (fouling) species when introducing aquaculture individuals. These species might spread further in the BPNS by using the hard substrates and their associated fauna as stepping stones, and as such establishing themselves in the BPNS.

Advised further reading:

Degraer, S., Brabant, R., Rumes, B. & Vigin, L. (eds). 2019. Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Marking a Decade of Monitoring, Research and Innovation. Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management, 134 p.

Degraer, S., Brabant, R., Rumes, B., (Eds.) (2013). Environmental impacts of offshore wind farms in the Belgian part of the North Sea: Learning from the past to optimise future monitoring programmes. Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Marine Ecology and Management Section. 239 pp.

Existing business requirements

- Necessary permits/insurance
- Ensure a long-term market signal to increase investor confidence in investing in the sector. Policy actions can contribute to ensuring this long-term confidence in investing in the sector by putting available funding for offshore multi-use projects.
- Reducing costs (by means of automation, synergies with other activities) in the sector to increase attractiveness to investors.
- Increasing access to capital for high-risk investments in the offshore areas.

Societal acceptance

- The location of the operational phase will be in an existing offshore wind farm on the southeast side of the BPNS in one of the wind farms operated by Parkwind, approximately 50 km offshore. The advantage is that this area is not visible from the coast, however, due to this distance from the coast, it might be economically less attractive for tourist activities. The local community did benefit from the already existing offshore wind energy, which produces approximately 10 % of the Belgian total energy consumption. In general, the local community is very positive to the actual activity of the offshore wind energy. Since the implementation of the Marine Spatial Plan (MSP) of the Belgian Exclusive Economic Zone, the offshore wind farm areas are protected and secured areas which are not accessible for third parties. However, new activities, in agreement with the wind farm owners, are allowed in the offshore wind farm area, including the integration of multiple activities such as renewable energy production combined with aquaculture of flat oyster and seaweed, and restoration of flat oyster reefs, which might further increase the social acceptability of these activities.
- Socio-economic: wind energy has an important spill-over to the local economy. Parkwind employs more than 95 people (development, construction, operation and maintenance) and supports indirectly about 100 jobs (during the exploitation phase) per wind farm in supplying sectors like engineering companies, shipping companies and maintenance companies. Local hotels and other facilities take advantages from these activities. Multi-use of the site might even increase job opportunities.

Legal issues / pending licenses

- As stated previously, the development development of an offshore wind farm requires an environmental impact assessment (EIA) trajectory. An EIA for the aquaculture part of the Belgian pilot is not required since it is a research pilot. Commercial exploitation in the future, however, will have to conduct an EIA. Additionally, there are regulations concerning the introduction of aquaculture species and associated pathogens/diseases, defined by different institutions, including the FAVV. Interestingly, a risk analysis needs to be conducted before installation on the demand of the concession holder of the wind farm in which the pilot will be set up. This analysis also includes an evaluation of possible impacts on the environment of the pilot.

- Since no multi-use assessment nor assessment for aquaculture has been performed for the pilot (nor for any other project in the BPNS), information on this topic is currently non-existent.

Table 3: Benefits and barriers faced by the Belgian pilot.

	Benefits	Barriers
Technical	• Potential to culture flat oyster and sugar kelp under exposed conditions • Potential to restore flat oyster reefs in offshore wind farms • Available numerical tool "MoorDyn-UGent" for the design of the offshore longline for flat oyster and sugar kelp • Assessment of monitoring criteria/tools for multi-use sites • Identifying risks and critical points for future multi-use projects	• Damage due to extreme adverse environmental catastrophic events (such as storms or underwater earthquakes) • Sampling + monitoring at depth • Accessibility of the site due to requirement of well-equipped, specialised vessels and knowledge • Lack of general technological knowledge from the industry involved in multi-use projects in general (outside of the scope of UNITED) • Lack of infrastructure for energy provision for multi-use of space • Risk of power failure • Risk of anchoring vessels damaging power supply cables • Risk of damage in case of mooring failure • Inflexibility for the implementation planning (schedule) due to dependency on weather conditions and vessel and crew (divers) availability/safety • Biofouling may be problematic • Equipment/material has to be resistant to: anti-fouling, high forces acting on installation (waves, tides, current, storms -> mooring), high salinity -> corrosion
Economic	• Wind energy has an important spill-over to the local economy. Parkwind employs more than 95 people (development, construction, operation and maintenance) and supports indirectly about 100 jobs (during the exploitation phase) per wind farm in supplying sectors like engineering companies, shipping companies, maintenance companies. Local hotels and other facilities take advantages from these activities. Multi-use of the site might even increase job opportunities. • Development of a business case considering an economically viable value chain and further products that could be derived from seaweed as to ensure that seaweed production is feasible	• High maintenance cost of aquaculture sites and lack in knowledge on automation of these activities • High insurance cost • Lack of standardized procedures to co-use aspects related to the multi-use of space (i.e. sharing cable equipment or ships) • High cost of decommissioning of the multi-use structures (potential costs after the end of the multi-use) • High costs for grid connection • High cost of operating staff • Lack of certainty of effects of offshore multi-use activities on fish or oysters in aquacultures (with regard to economic effects). • Market potential and profit of the aquaculture profits

	• Attracting other commercial actors and investors, such as retail, utilities, and established aquaculture businesses, to increase the commercial readiness level of such combinations • Multi-stakeholder activity can also benefit from both developments in regards to shared costs, better social/environmental image of involved businesses and overall increased financial yield for investors • Operational requirements can be further exploited and learning processes can be designed cost-effectively	
Environmental	• An important native habitat – oyster reefs – will be restored in the BPNS, providing valuable ecosystem services including improved water quality, increased fish production and carbon sequestration • By combining flat oyster aquaculture and sugar kelp growth, this extractive aquaculture might purify the surrounding water from excess nutrients, leading to a sustainable way of performing aquaculture • Environmental monitoring data provides a database to investigate the impact of multi-use activities on the environment at that location	• Attraction of unwanted invasive species at the location of the multi-use site: the introduction of hard structures/substrates might attract unwanted invasive species (including fouling fauna) that prefer/need these habitats in the otherwise sandy BPNS (except for the gravel beds). Species with the highest negative impact are the non-native slipper limpet *Crepidula fornicata* and the non-native ascidians *Aplidium glabrum*, *A. nordmanni* and *Diplosoma listerianum*. These species can colonise hard substrates and proliferate under certain circumstances. Another species to consider is the native actiniarian *Metridium senile*. This species can dominate certain hard substrates, and might present excessive filter-feeding on zooplankton, including larval stages from species of interest. Additionally, the multi-use site structures present additional stepping stones for fouling (invasive) species such as certain cnidarians which need hard substrates in part of their life cycle, although this has been poorly studied in the BPNS • Unintentional introduction of the oyster parasite *Bonamia ostreae* might occur. Intentionally, only native species will be introduced in the multi-use site, but unintentional introduction of other parasites/diseases and associated fauna on the oyster shells might occur • Difficult prediction of biological data e.g. time and scale of spat fall of flat oyster (varies yearly), and unpredictable occurrence of harmful algae blooms • Harsh sea environment possibly unfavourable for flat oyster aquaculture/restoration and sugar kelp growth

		• Local organic enrichment of sediment underneath longlines, leading to local anoxic sediment patches
Social	• In general, the local community is very positive towards the actual activity of the offshore wind farms. Since the new MSP, the offshore wind farm areas are protected and secured zones and not accessible for third parties However, new activities, in agreement with the wind farm owners, are allowed in the offshore wind farm area, including the integration of multiple activities such as renewable energy production combined with aquaculture of flat oyster and seaweed, and restoration of flat oyster reefs, which might further increase the social acceptability of these activities • Creating public awareness and public acceptance. Furthermore, the new activities might attract new tourism activities. A touristic visit to the offshore wind farm is possible from e.g. Ostend. However, not to the Bligh Bank due to distance from the coast and vicinity of the shipping lane • Wind energy has an important spillover to the local economy. Parkwind employs more than 95 people (development, construction, operation and maintenance) and supports indirectly about 100 jobs (during the exploitation phase) per wind farm in supplying sectors like engineering companies, shipping companies, maintenance companies. Local hotels and other facilities take advantages from these activities. Multi-use of the site might even increase job opportunities	• The Belgian pilot site is currently not attractive to the local community due to its distance from the coast and the accessibility of the site • Availability of skilled labour with offshore experience is scarce • Lack of consensus about the multi-use site from multiple stakeholders in private and public sector upon commercial upscaling • Lack of trust between industry sectors directly involved in the multi-use site upon commercial upscaling • Lack of knowledge on the effects of multi-use, creating a "bad reputation" of aquaculture
Law & Government	• Clarity about the permit requirements in case of a scientific project combined with a private partner project • Feasibility of a single permit procedure for multiple use projects	• Uncertainty about the ability of one party to continue if the other enters its decommission phase (e.g. legal status of the activities or the share of decommissioning costs)

	• Legal clarity in case one project partner steps down • Liability for damage in case of a public/private partnership	• Lack of established safety assessment methods for multi-use of space • Strict regulations on food safety analysis, testing of food quality is very expensive and time-consuming • Determination analysis that there is no negative environmental impact of oyster and algae aquaculture due to sedimentation has not been done

2.1.4 Danish Pilot

Overview of the pilot

Middelgrunden is an offshore wind farm 3.5 km outside Copenhagen (Denmark) which was established in 2000. The offshore wind farm consists of 20 turbines (each with an installed capacity of 2 MW) and has a total capacity of 40 MW; thereby it delivers approximately 3% of the electricity consumption of the city of Copenhagen.

Two touristic attractions are offered along with the offshore farm:

1. Boat tours to the offshore wind farm

2. Lectures on the Middelgrunden Wind Turbine Cooperative and Wind Farm, organized either in an office/lecture room or on board.

Currently, the attractions are sporadically used for visits by students, companies and others interested in offshore wind. Every two years, the cooperation organizes an 'open-house' during which Cooperative members and relatives are given the opportunity to visit inside the turbine.

The attractions (lectures and boat tours) and the unique shape of the wind farm contribute to tourist attractiveness.

Existing Cases / Future Potential

The pilot aims to expand existing tourism services and to create new attractions that result from shared sea space, joint on- and offshore infrastructure and operational activities. The pilot is expected to expand tourism activities related to offshore wind farm by opening up opportunities to attract new target groups and eventually being part of the general tourism offer in Copenhagen and its region.

Planned combined activities include: i) Offshore windfarm sightseeing boat tours combined with angling or restaurant facilities. ii) Diving. iii) Leisure fishing. iv) Educational tours for locals to increase local knowledge about the importance of green energy. v) Shared onshore facilities such as an offshore related information center.

Synergies / business models developed from the multi – use

Drivers / Benefits:
Main synergy evolving from the multi-use concept is related to cost reductions due to the combination of activities. These are expected to be important. Synergies will be defined along the project.

Environmental issues/conditions

Middelgrunden as natural reef is defined to be within the 6-meter depth. The seabed consists of sand in the south, limestone in the central part and glacial deposits in the norther part. The natural reef was created about 7.500 years ago when a post glacial barrage in the Baltic Sea at level with Stockholm collapsed. The reef has been used as waste deposits for more than 200 years up to 1990. Therefore, remains of sludge with heavy metals like Cu, Pb, Ca Zn and Hg can be found in spots equalling the dump volume of a boat load.

The authorities are recommending the Reef as "not suitable for sailing" as the seabed is changing all the time caused by waves and current. In some areas you can find big boulders where the sea depth is only 1 meter.

Leisure boats do not always respect this recommendation as there was found 17 ship wrecks of newer type 17-23 foot boats during the scanning of the seabed along the turbine line.

An environmental impact report has not yet been conducted for the MIddlegrunden wind farm. Namely, when the VVM (environmental impact report) is made for a specific application, the project with the least environmental effect and negative impact (and/or addition of positive impacts) will naturally outweigh the competition. The Energy Authority in Denmark is normally responsible for such making decisions on such assessment.

Existing business requirements

For the current economic activities (boat trips and lectures), only a standard description of different boat trips and prices is available. Financial implications of new tourist activities that are to be developed in the pilot are not yet known. A financial analysis is foreseen in the project and aims to support the design of a viable offshore tourism offer.

Societal acceptance

No information on socio-economic impacts is readily available. A social cost-benefit analysis is foreseen in the project, including social and environmental impacts

Table 4: Summary of available structural/monitoring/ communication/ management system capabilities, benefits and barriers for the Danish Pilot

Co-use related Parameters	Description
Structural/monitoring/ communication/ management system capabilities	The existing offshore wind farm has in place the standard structural, monitoring, communication and management system capabilities that are needed for its normal operation. Tourism activities do not make use of these facilities. Some of these management system capabilities are available at the boats (fishing and leisure boats) used for the offshore wind guided tours.
Legal challenges to be addressed (regulations, licences, insurance policies, other sectorial policies e.g. incentive systems)	The need of relevant licences and insurance policies will be investigated throughout the UNITED project.
Social (acceptance)/socio-economic aspects to be considered	No information on socio-economic impacts is readily available. A social cost-benefit analysis is foreseen in the project, including social and environmental impacts
Environmental challenges to be addressed	The authorities are recommending the Reef as "not suitable for sailing" as the seabed is changing all the time caused by waves and current. Access to the pilot site needs to be carefully examined.
Economic (feasibility) challenges to be addressed	For the current economic activities (boat trips and lectures), only a standard description of different boat trips and prices is available. Financial implications of new tourist activities that are to be developed in the pilot are not yet known. A financial analysis is foreseen in the project and aims to support the design of a viable offshore tourism offer.

Expected benefit from UNITED (spatial efficiency, functional synergies, sharing permitting investment and infrastructures to reduce operational and maintenance costs, etc.)	Main synergy evolving from the multi-use concept is related to cost reductions due to the combination of activities. These are expected to be important. Synergies will be defined along the project.

2.1.5 Greek pilot

Overview of the pilot

The Greek pilot, denoted as the PATROKLOS pilot site, is situated in the 59th km of Athens-Sounio Ave., Palaia Fokaia, Attiki, Greece, in the wider area of Cape Sounio. The wider area now is protected under NATURA 2000 and the Treaty of Barcelona due to a number of significant characteristics that this pilot site has. The area is a characteristic example of Mediterranean landscape. It includes an area declared a National Park since 1971 and is regarded as an archaeological site of great importance, furthermore 68% of the area is accessible and declared public.

Existing cases / Future Potential

The current running business activities of the site is first the KASTELORIZO AQUACULTURE, a company that operates on the field of production, marketing and exploitation of fish farms with all kinds of fish, shellfish in fresh or frozen form as well as distribution of product at Greek premises and abroad. On the opposite of the aquaculture unit, there is an islet with the name "PATROKLOS". Islet PATROKLOS, has a great coastline where local people as well as tourists from the wider Attica area, enjoy swimming and spending time in the beach. Access to the islet is only by private boats, while in the summer time a private vessel transfers tourists to the islet. Islet PATROKLOS has been claimed as protected ancient are due to remnants of fortification existing there, from two walls that used to close all over the east to and the 1944 shipwreck as well. The underwater area around PATROKLOS is also a great attraction for scuba divers, as there are very interesting things to see. Some of these underwater attractions are, the shipwreck of the ship "ORIA", a car cemetery of abandoned cars and of course the beautiful seabed.

Synergies / business models developed from the multi – use

The planned activities that are going to take place in the site during the operational phase are the combined activities of the aquaculture unit with scuba diving touristic expeditions. These multi-use activities will facilitate touristic growth in the area, as well as help the aquaculture activities to gain social acceptance as well as to facilitate a long term touristic growth in the wider area. For these purposes, different scenarios have been created to combine these activities with an arrangement of a tour around the marine area stopping at aquaculture facilities, with Aquaculture farmers to describe the operational activities as speakers on the diving vessel, and doing scuba-diving tours, as the seabed within the area of the aquaculture unit carries great interest (food waste from the aquaculture pens attract many wild fish), while a common software platform (between the scuba-diving centre and the aquaculture) schedules the logistics for the co-activities.

Objectives:

- Software platform receiving data from innovative technologies to establish more effective production in terms of aquaculture (monitoring parameters, such as salinity, dissolved oxygen, water quality, water current, fish behaviour and stress levels), also to establish environmental standards are met at all times and to facilitate the synchronization of multiple operations of touristic diving boats with the aquaculture operations
- Supporting management and planning decisions for new developments, such as the extension of the aquaculture unit. These require:

- The development and deployment of the software platform that will have three main uses: 1) receive data coming from sensors and cameras installed in the site and produce valuable insights for fish production, 2) monitor the environmental footprint of the pilot site and 3) combine the scheduling of the parallel activities of both the divers and the farm operations
- The installation of equipment in the site
- Business development and minimizing costs by combining activities from both sectors. Scenarios for these combined activities could be a) diving expeditions to the aquaculture units as a new recreational attraction for divers, b) diving expeditions and use of special equipment (ROVs) from the diving centre to facilitate aquaculture operational activities in cases of emergency or for risky procedures
- Time management by sharing the infrastructure such as the existing platform for aquaculture, diving or third-party vessels
- Monitoring parameters such as water quality to track pollution threats to the marine area
- Facilitate touristic growth in the area in combination with social acceptance of aquaculture
- Aquaculture gains acceptance and continues to grow while producing higher quality food
- Important touristic attractions contribute to growth of local businesses
- Creation of new jobs for trained and certified offshore staff
- Increasing synergetic effects by sharing infrastructure

Expected output:

- Aquaculture unit will gain acceptance and continue developing and producing better quality food;
- Important touristic attractions in place that are merely exploited today, will now contribute to growth of the wider area and to local business expansion;
- Trained and certified offshore staff with permissions and insurance in place;
- Benefit from exploiting same marine space;
- Co-use of transportation;
- Co-use of offshore experience.

Following UNITED's overall five pillar structure, the studies at the German Greek pilot address the aspects technology, economy, environment, society, law and government of which the results will feed into the re-lated work packages WP2-6. The assessment thereof will take place through the application of the Assess-ment framework coordinated by WP8 in co-development with leads from each of the pillars:

<u>Technology</u>: Some important characteristics of the aquaculture site relevant to the equipment deployment:
Power: Photovoltaic panels reside on a raft.
Connection: Ethernet connection (24Mbps) is available on the shore. No 4G network is available.
Mooring systems: Rafts, ropes, piers are available. Special equipment for the installation of sensors and cameras will be considered.
Water Quality parameters: The water quality parameters of interest for the site include temperature, dissolved oxygen, and current measurements, while environmental parameters will also be considered to measure the environmental impact of the activities to the area.
Information that need to be considered:

- Cameras application
- Drones application
- Mooring systems utilization
- Site size and structure
- Depth
- Fish Behaviour monitoring needs (for tracking any stress levels from diving expeditions)
- Species, fish growth period of year (necessary for optimizing production and operations)

<u>Transmission methodology:</u>

- Gateway device, collecting data from sensors and cameras in the site and transmitting them to the local network
- 4G/NB-IoT if available
- WiFi if possible from the gateway device (which will be installed in the site) sending data from sensor measurements to the network infrastructure available
- LoRa (low-power wide-area network protocol) or other protocols

Economy: In sectors such as aquaculture which need moorings or solid foundations, water depth can appear as a strong technical limitation for site evaluation. This fact can limit the region of interest due to the high impact on technical viability and project costs. However, the societal acceptance and gaining popularity of the aquaculture site could significantly contribute to the sustainability of the business, that might no longer experience complaints and barriers from the local community and may need to consider in the future an extention of the aquaculture unit in the surrounding area.

Other sectors that are indirectly related to the multi-use could actually benefit from the multi-use activities. For instance, local restaurants, hotels, boat transfers could see a rise in their profits by the touristic attraction caused by the aquaculture-diving center synergy.

Environmental issues/conditions

Feeding caged fish introduces a large source of nutrients to coastal areas which can lead to eutrophication. This eventually leads to increased algae growth, including toxic species of algae, rendering the water less suitable for certain recreational activities. The disposal also of untreated sewage from vessels can affect aquaculture, especially shellfish beds. For the purposes of the project, sensors and cameras are planned to be installed in the aquaculture facility in order to monitor any environmental disturbance in the unit. For the purposes of accurately and timely monitor and manage properly the infrastructure and the environmental conditions, project UNITED will install sensor devices and cameras on site. The data will be collected and transmitted via the local network to a software platform that will be able to monitor the environmental parameters and send notices and alerts when necessary.

Water Quality parameters to be monitored: The water quality parameters of interest for the site include temperature, dissolved oxygen, and current measurements, while environmental parameters will also be considered to measure the environmental impact of the activities to the area.

Another important parameter for the aquaculture undisturbed operation is the need to make sure the stress levels of the fish in the aquaculture unite remain low. For the purposes of this, underwater cameras will be installed in the site to monitor fish behaviour.

Societal acceptance

Fish farms applying sea cages typically have large surface structures that impact on the aesthetics of seascapes viewed from the shore. Supporting facilities on land may also have an effect on the coastal landscape, especially if they are close to resorts or tourist beaches. The present feedback regarding pilot social acceptance fluctuates from negative to neutral. The aim of this project is to enhance the positive view of the local community in the pilot site so as for the aquaculture unit to continue undisturbed with its activities as well as for local residents to learn to enjoy the interesting activities that take place in the site.

Legal issues / pending licenses

All activities that will take place to the area close to the aquaculture unit should follow the rules of the according authorization that has been granted to the aquaculture site:

Ministerial Order by the Ministry of Environment, Spatial Planning and Energy, granted in the 28th of February, 2020, with the subject: "Approval of Environmental Terms, which concerns the expansion of an existing floating marine unit for fish farming, in the marine area to 29.76 acres (from 20 acres) and an annual capacity to 462.12 t (from 230 t / y), in the place "Kasidiara", sea area "Stenou Gaidouronisiou", Municipality of Saronikos, Regional Unit East Attica, Attica Region, with "KASTELLORIZO SA" as its body."

Regarding the scuba-diving tours, there are no known restrictions in legislation regarding swimming close to aquaculture units. Insurance issues should be investigated regarding the new multi-activity concept. Framework of this business model in potential commercial roll-out should also be examined if it is according to government law. Issues of marine responsibilities (accidents, search and rescue, spills, etc.) need to be defined between all users of marine space.

Table 5: Summary of barriers and benefits of multi-use activities for Greek pilot

Co-use related Parameters	Description
Available structural/monitoring/ communication/ management system capabilities	At the moment system's requirements are gathered, purchased and installed equipment. The collected information from the site, that will be useful for the installation and deployment are: **Power:** Photovoltaic panels reside on a raft. **Connection:** Ethernet connection (24Mbps) is available on the shore. No 4G network is available. **Mooring systems**: Rafts, ropes, piers are available. Special equipment for the installation of sensors and cameras will be considered. **Water Quality parameters:** The water quality parameters of interest for the site include temperature, dissolved oxygen, and current measurements, while environmental parameters will also be considered to measure the environmental impact of the activities to the area. Information that need to be considered: • Cameras usage • Drones usage • Mooring systems utilization • Site size and structure (provide diagram) • Depth • Behaviour monitoring needs • Species, fish growth period **Transmission methodology:** • 4G/NB-IoT if available • WiFi if possible from the device to the network infrastructure available • LoRa or other protocols
Legal challenges to be addressed (regulations, licences, insurance policies, other sectorial policies e.g. incentive systems)	• All activities that will take place to the area close to the aquaculture unit should follow the rules of the authorization that has been granted to the aquaculture site • No known restrictions in legislation regarding scuba-diving close to aquaculture units. • Insurance issues should be investigated regarding the new multi-activity concept. • Frame-work of this business model in potential commercial roll-out should also be examined if it is according to national law.

Social (acceptance)/socioeconomic aspects to be considered	The aim of this project is to enhance the positive view of the local community in the pilot site for the aquaculture unit
Environmental challenges to be addressed	Water Quality parameters to be monitored as well as fish stress levels
Economic (feasibility) challenges to be addressed	Costs should be brought down and yields should increase
Expected benefit from UNITED (spatial efficiency, functional synergies, sharing permitting investment and infrastructures to reduce operational and maintenance costs, etc.)	• Aquaculture unit will gain acceptance and continue developing and producing better quality food; • Important touristic attractions in place that are merely exploited today, will now contribute to growth of the wider area and to local business expansion; • Trained and certified offshore staff, correct permits and insurance in place; • Benefit from exploiting same marine space; • Co-use of transportation; • Co-use of offshore experience.

2.2 Mapping UNITED pilot cases with Multi-use solutions from projects from "The Oceans of tomorrow" and other relevant projects

The table below provides the overview of pilot cases and theoretical studies relevant for UNITED pilots. Main sources for this exercise were the international EU co-funded FP7: Oceans of tomorrow and Horizon 2020 Blue Growth projects, as well as some national projects.

Table 6: UNITED identified multi-use cases and projects that developed similar multi-use solutions

Pilot Name	Pilot cases	Similar multi-use solutions from other projects
German pilot	Blue mussel & seaweed- & wind energy production	**EDULIS:** Offshore wind and mussels (BE) **MERMAID:** offshore wind and aquaculture in the North Sea (seaweed, shellfish) and in the Baltic Sea (seaweed, fish) **ORECCA:** Offshore renewables and aquaculture (biomass, fish) **AquaLast** (Germany – Lead: AW)**:** offshore wind and aquaculture (loading on offshore support structures, such as wind turbine foundations, caused by mussel longlines) **Biological and technical feasibility study of marine aquaculture in the Thorthonbank area, Belgium: Co-use**

		of space with offshore wind farms (Belgium - University of Ghent, SINTEF Ocean): Offshore wind and aquaculture (blue mussels) **Flandres Queen Mussel (FIOV)** (Belgium - Stichting voor Duurzame Visserijontwikkeling -SDVO, ILVO): Offshore wind and Aquaculture (development of floating buoys with mussel ropes for spat collection) **Mosselkweek in Belgische windmolenparken** – Mussel production within Belgium Wind Farms (Belgium – Lead: University of Ghent): Offshore wind and aquaculture **MytiFit** (Germany – Lead: AWI): Offshore wind and Aquaculture (mussel fitness, infestation of parasites, and selection of hard substrates for multi-use) **NutriMat** (Germany – Lead: IMARE): Offshore wind and Aquaculture (Use of fouling organisms of offshore platforms for fish feed in land-based aquaculture) **Nysted Sea Wind Farm Mussels** (Belgium – DTU): Offshore wind and Aquaculture (investigation on the possibility to multi-use for longline mussel farming) **Offshore-Aquaculture** (Germany – Lead: AWI; Terramare): Offshore wind and Aquaculture (investigations of the settlement and growth of bivalves and macroalgae in the German Bight to test its feasibility for offshore multi-use) **Offshore Site Selection** (Germany – Lead: AWI; Thünen, University of Rostock, Kutterfisch, WindMW, Deutscher Fischereiverband, Skretting): Offshore wind and Aquaculture (offshore site selection for IMTA in co-use of offshore wind farms) **Roter Sand Project** (Germany – Lead: AWI): Offshore wind energy and Aquaculture (development of system design for the use of offshore environments for the cultivation of species for aquaculture and bio-extraction)

Dutch pilot	Solar energy & wind energy & seaweed production	SOMOS – Safe production Of Marine plants and use of Ocean Space (The Netherlands – Lead: Wageningen University; TNO): Offshore wind and seaweed ORECCA: Offshore renewables and aquaculture (biomass, fish) MERMAID: offshore wind and aquaculture in the North Sea (seaweed, shellfish) and in the Baltic Sea (seaweed, fish) WINSEAFUEL (France - French National Research Agency): Offshore wind and seaweed (seaweed mass production for bio-methane and bio-products in wind farms) MUSES: Offshore Wind Farm & Aquaculture
Belgian pilot	Wind energy & flat oyster & seaweed production & flat oyster restoration	ORECCA: Offshore renewables and aquaculture (biomass, fish) MERMAID: offshore wind and aquaculture in the North Sea (seaweed, shellfish) and in the Baltic Sea (seaweed, fish) EDULIS: Offshore wind and mussels (BE) SYMAPA: Synergy between mariculture & passive fsheries
Danish pilot	Tourism & wind energy production	MUSES: Tourism and offshore wind farm
Greek pilot	Aquaculture and tourism	MARIBE: tourism and aquaculture MUSES: tourism and aquaculture

2.2.1 German pilot mapping with relevant projects

The goal of the 'Ocean of Tomorrow- Joint Research Forces to Meet Challenges in Ocean Management" initiative is to support multidisciplinary approaches and cross-fertilisation between various scientific disciplines and economic sectors on key cross-cutting marine and maritime challenges. Overall, 31 projects have been selected under 'The Ocean of Tomorrow' program. The following funded research projects provide useful approaches in methods and solutions particular for the German Pilot:

- H2Ocean: Development of a wind-wave power open-sea platform equipped for hydrogen generation with support for multiple users of energy
- MERMAID: Innovative Multi-purpose offshore platforms: planning, Design and operation
- TROPOS: Modular Multi-Use Deep Water Offshore Platform Harnessing and Servicing Mediterranean, Subtropical and Tropical Marine and Maritime Resources
- SENSEOCEAN: Marine sensors for the 21st Century
- LEANWIND: Logistic efficiencies and naval architecture for wind Installations with novel developments.

H2Ocean

Although this project investigated new concepts for multi-use offshore platforms, its predominant focus was energy harvesting as a core activity. Individually proven technologies (renewable energy harvesting + hydrogen generation + aquaculture + environmental monitoring) were gathered to develop a proof-of-concept design for a fully integrated multi-component and multi-purpose platform to exploit far offshore ocean resources in a sustainable way and assess the impact at both, environmental and economic levels. The H2OCEAN platform harvested wind and wave power, using part of the energy on-site for multiple applications – including a multi-trophic aquaculture farm, and converted the excess energy on-site into hydrogen to be stored and shipped to shore as green energy carrier. Especially, the site selection for the test of the H2OCEAN design is similar to UNITED: North Atlantic Ocean, North Sea and Mediterranean Sea. An aerodynamic floating Vertical-axis wind turbine (VAWT) and WEC (Wave Energy Converter) represented the building blocks of an integrated WEC+VAWT hydrodynamic model. The aquaculture activities included the production of fish, shellfish and seaweed. Useful information from H2Ocean for the German pilot can be deduced from the following project findings:

- Full production programmes
- Transportation requirements of seaweed and mussels
- Operating scenarios of multiuse platforms
- Requirements specifications from technology
- Process flow diagrams.

MERMAID

The project exploited offshore wind and wave energy potential combined with the implementation of marine aquaculture. The aim was to develop theoretical concepts for the next generation of offshore platforms, which can be used for multiple purposes, including energy extraction, aquaculture and platform related transport. Similar to the UNITED approach, MERMAID does not envisage the building of new platforms, but rather examine multiuse concepts for including new structures at existing plants at different sites and conditions. Compared to MERMAID, however, UNITED implements new constructions to the identified single use plants in real life environment moving from TRL 5 towards TRL 7. During MERMAID these concept designs were simulated but never implemented at real life testing sites. Nonetheless, the drafted inception report and the QA (Quality assurance) plan, developed in MERMAID, hold valuable information for the construction plans and deployment of seaweed and mussel long line cultures for the German Pilot. Important information from MERMAID can be gathered from:

- The inventory on existing legislative framework and policies for offshore wind farms and aquaculture in EU
- Methodology for Integrated Socio-Economic Assessment (ISEA)
- Guidelines for project development, to facilitate a smooth and safe management and implementation of the multiuse Platforms (MUP) concept
- Analysis on accumulated effects of various large scale structures interaction with waves, currents or seabed as well as the mixing and dispersion processes
- The developed decision-support system for transport infrastructure (based on a detailed and innovative forecasting system of various relevant parameters such as wind, waves, water level, currents and three-dimensional numerical flow and wave models)
- Economic and environmental feasibility studies of multiuse offshore platforms.

TROPOS

The TROPOS project developed designs for floating modular multiuse offshore platforms integrating a broad range of specific production activities. The innovative platform was adapted to deep waters, which enables integrated exploitation of oceanic resources (including maritime transport, energy, aquaculture, and leisure), with a focus on tropical, subtropical and Mediterranean sites. Especially, the impacts of TROPOS on society, the scientific and engineering community, the industry, and stakeholders, users and operators of future multi-use offshore platforms provide valuable information about stakeholder engagement for the German pilot Furthermore, lessons learned regarding logistic requirements, economic potential and limitations, environmental and socioeconomic impact, identified gaps in regulations and obstacles are very useful for planning and implementing the multiuse scenario of the German pilot. Building on this existing knowledge will help to avoid problems and complications in designing and planning at early development stages, saving time, efforts and costs. Advancement of knowledge about multiuse offshore platforms for UNITED can particularly be gathered from:

- Logistical requirements, including safety, construction, efficient installation, operation, maintenance, monitoring, specialized transportation, supply chain management and decommissioning of MUCL systems.
- Economic feasibility and viability assessment of multi-use platforms as a novel way to deliver new sources of growth and sustainable jobs, including the comparison to non-multi-use platforms in the areas of interest.
- Viability strategy for the deployment and exploitation of multi-use marine platforms.
- Environmental impact methodology and assessment, including a comparison to non-multi-use platforms.
- Established integrative and synergistic relationships between different sectors of industries and the most suitable multiuse components to be integrated in a platform at a specific site.
- Geographical assessment of resources, constraints and preliminary market potential in different target regions.
- Report on recommended appropriate environmental monitoring strategies as integral part of ecologically sustainable offshore projects.
- Stakeholder network and operation report (e.g. strategies on how to address conflicting interests).

SenseOCEAN

SenseOCEAN developed a new highly integrated, multifunction, cost-effective and mass deployable in-situ marine biogeochemical sensor system. The project provided a solution for the quantification of difficult to measure biogeochemical parameters, which are crucial to the scientific understanding of the oceans, management of ocean resources, in-situ calibration / validation of satellite earth observation data, and supply of data for development of state of the art biogeochemical (process) models. State of the art sensor technologies (micro fabrication, lab-on-chip, micro and calibration free electrochemical sensors, multi parameter optodes and multispectral optical sensors) were combined in a modular and configurable system, which is easily usable across various ocean and environmental platforms. Valuable information about methods and solutions for the construction of a lander and the implementation of measurement devices at the German pilot are:

- The development of integrated systems with sensors for pH, carbon dioxide, carbon, alkalinity, oxygen, nutrients, and metals (iron and manganese) but also for coloured dissolved organic matter, chlorophylls, photo pigments, primary production, organic fluorophores, etc.
- Knowledge on optimised integrated systems for power consumption, chemical usage and waste production
- Overall sensor technology, including power and data management, development and testing of novel sensing technologies and bio-fouling approaches to facilitate long-term deployment in the marine environment.

LEANWIND

LEANWIND addressed industry challenges such as delivering innovative and cost-effective deployment, operations, maintenance and decommissioning of large-scale offshore wind farms and the associated transport, logistics and equipment needs. The project identified savings across the supply chain, focusing on areas requiring cost reductions to achieve 2020 targets. Results of LEANWIND, which provide useful information for UNITED and especially for the German pilot include knowledge on:

- Demand for purpose-built installation and servicing vessels and equipment.
- Optimisation of maintenance strategies and developing novel access systems and equipment.
- Developing remote presence and condition monitoring systems to reduce on-site maintenance.
- Optimisation of full supply-chain logistics including on-land transport links.
- Identification of industry specific safety procedures for installation and maintenance activities.

However, these aspects are more relevant for the renewable energy production (offshore wind) of the German pilot and are less crucial for the implementation of an aquaculture production site. Nonetheless, these findings present well researched aspects, which will be included in the overall technical and economic viability consideration of the German pilot.

Next to the "Ocean of Tomorrow" projects findings of other offshore aquaculture projects will be taken into consideration during the planning and implementation of seaweed and mussel long lines at the German pilot. Buck et

al. (2008) listed detailed results of innovative new approaches for sustainable use of offshore aquaculture sites, with special focus on the combination of extensive offshore shellfish and seaweed farming at exposed sites within the proposed offshore wind farm boundaries (Table 7). These studies provide a great baseline of information on biological factors that must be kept in mind, during the pre-operational and operational phase of the German Pilot.
When the biological feasibility of cultivating mussels, oysters and kelp within offshore wind farm sites was investigated, Buck et al. (2008) observed excellent growth of these species in offshore environments that differed depending on exposure sites, system designs, installation mode, and season. Settlement of young mussels on artificial collector substrates decreased with increasing distance from the shore (Walter et al., 2008). Results on the development of suitable offshore spat collecting techniques, detailed knowledge about (macro and micro) parasites, bacteria and virus infestations at different sites, implementation of biodiagnostic techniques for the health analysis of cultured mussels, and collection of all relevant data (e.g. shell stability and attachment strength of mussels), for the further processing of mussels as a product for human consumption, will greatly support the aquaculture process at the German pilot.

Table 7: UNITED identified multi-use cases and projects that developed similar multi-use solutions

Pilot Name	Pilot cases	Similar multi-use solutions in projects Oceans of Tomorrow and other
German pilot	Offshore wind and extractive aquaculture	• MERMAID • Edulis • MUSES • MARIBE
Dutch pilot	Seaweed cultivation, floating solar, mussels, nature and offshore wind	• MERMAID • Edulis • MUSES • MARIBE • SOMOS • Wier en Wind
Belgian pilot	Flat oyster production in wind farms	• MERMAID • Edulis • MUSES • Programma Rijke Noordzee
Danish pilot	Tourism and offshore wind farm	• MUSES
Greek pilot	Aquaculture and tourism	• MUSES • MARIBE

This table is based on a long-list of identified multi-use projects, both including multi-use platforms and multi-use of space. The long-list was prepared based on input gathered at the UNITED webinar (June 2020), supplemented with additional multi-use projects known of. A total of 22 projects were identified, including European funded projects and nationally funded project.

Among the projects funded under Oceans of Tomorrow, but not included in the table above, are H2OCEAN, TROPOS, Space@Sea and Leanwind. This projects have all three focussed on the development of a shared (floating of fixed) platform to accommodate other activities. None of the UNITED pilots make use of such a platform. Leanwind was mentioned as a relevant project but focusses on optimisation of offshore wind energy generation and does not include a multi-use component.

2.2.2. German pilot requirements for multiuse business models

Based on findings from literature the requirements for multiuse business scenarios are very diverse. The overall market situation looks well and is likely to expand for mussels, oysters as well as for brown and red algae in the future. Buck et al. (2008) stated, that red algae can be directly sold to the consumer as a healthy "green and clean" bio-food or be a valuable substance in industry for various purposes (e.g. emulsifiers, ingredients for food, medicine). Hence, the overall requirement of a strong market for offshore aquaculture products, produced at the German pilot, is given. The development of a commercial offshore aquaculture in combination with wind farms in the North Sea region depends on critical factors such as (Buck et al., 2004):

- Service life of infrastructure as well as the mussel yield obtained per meter long line.
- Shipping costs (which cannot significantly be reduced by developing an offshore servicing vessel that can jointly be used for wind farm and mariculture operations and maintenance).
- Market price and the annual settlement success of juvenile mussels, which are the main factors determining the breakeven point.

Overall, based on the results from offshore aquaculture projects in Table 8, it is advisable to identify measures to reduce investment costs for long lines used per culturing plot at offshore locations (Buck et al., 2008).

Table 8: Description of offshore aquaculture projects from 2000 until 2009 by Buck et al. (2008).

Project	Funding	Description
Feasibility Study	AWI	• Proof of concept for aquaculture operations in offshore wind farms • Review of worldwide offshore aquaculture experiences (biology, techniques, multi-use ideas) • Feasibility study for a combination of aquaculture in offshore wind farms in the North Sea • Preliminary market analysis
Roter Sand	AWI	• Development of offshore-technology and system-design • Technical aspects and biological feasibility at the offshore test site *Roter Sand* • Development of submersible long line systems and floating ring systems
Offshore-Aquaculture	The Senator for Environment, Construction, Transport and European Affairs (SUBVE); AWI	• Potential of blue mussel and sugar kelp culture at all planned offshore wind farm sites in the North Sea • Settlement success of mussel larvae • Growth rates of seaweed and mussels • Biological and physical site-selection-criteria
Coastal Futures	Federal Ministry for Education and Research (BMBF); AWI	• Assessment of multi-use issues of wind farm–mariculture interactions in offshore areas within an integrated coastal zone management approach • Aspects of co-management and cooperation between involved actor groups such as wind farmers, fishery groups and public authorities • Potential schemes for governance and management arrangements
MytiMoney	BMBF; AWI	• Assessment of economic potentials for offshore mussel cultivation

		• Calculation of the economic valuation of joint wind farm–mariculture use in offshore locations by taking into consideration market conditions, investment and operating costs • Development of a model in order to assess different scenarios
MytiFit	SUBVE; AWI	• Fitness, settlement success and overall health of offshore cultivated mussels • Test of different substrates for the offshore collection of mussel spat • Analysis of mussel infestations with macro- and micro parasites, bacteria and viruses • Assessment of health and energy situation of mussels via biodiagnostic techniques • Analysis of mussel growth and shell stability
AquaLast	SUBVE; AWI	• Use of offshore wind turbines as anchor points for open ocean long line aquaculture Modelling and calculation of possible loads by currents and wave action • Evaluation of the hydrological conditions and mechanical loads onto the foundation in a field experiment of Sylt • Development of a computer program to correctly predict loads for large scale offshore long lines
GIS German Bight	AWI	• GIS-based decision support tool for offshore aquaculture development • Mapping of all German mariculture sites • Determination of potential open ocean aquaculture installations in the German Bight
River Jade	SUBVE; AWI	• Settlement, fitness and health of near shore cultivated mussel • Near shore reference site (settlement, growth, mussel health and shell stability) for the *MytiFit* project
AquaInno	Federal Ministry of Economics and Technology (BMWI)	• Pond-in-Pond system for near shore environments • Floating recirculation system • New technology for juvenile fish after smoltification
Euro-Tour	IMARE; SUBVE; AWI	• Fitness and health status of *Mytilus* along the European Atlantic coast Site-Selection-Criteria for mussel cultivation in near shore/offshore areas from southern Portugal to northern Denmark along the Atlantic Coast

2.2.3 Dutch pilot mapping with relevant projects

The Dutch pilot, as mentioned in chapter 2.1.2, will attempt synergies between seaweed cultivation, floating solar power, mussels' cultivation and offshore wind farms. Some of the previous similar cases have been reported by European funded projects such as:

Table 9: Related projects with the Dutch pilot co-use activities

	Types of synergies	Related projects
Dutch Pilot	aquaculture: fish, seaweed, shellfish & wind farm & wave/tidal energy	• MERMAID • MUSES

MERMAID

MERMAID developed concepts for the next generation of offshore platforms which can be used for multiple purposes, including energy extraction, aquaculture and platform related transport. The project did not envisage building new platforms, but theoretically examined new concepts, such as combining structures and building new structures on representative sites under different conditions. The North Sea case-study is located north of the Wadden Sea, 55 km above the Wadden Sea Island called Schiermonnikoog, in an already licensed site to develop offshore wind farm, named Gemini. At this location, an offshore wind energy farm is being built and it is planned to be fully operational by 2017 onwards with a total capacity of 600 MW (www.geminiwindpark.nl). A yearly production of 2600 GWh is expected from a total of 150 wind turbines with a 4 MW capacity. The distance between Gemini and the nearest port Eemshaven is 85 km.

Insights coming from MERMAID project for the MU:

Impact on local stakeholders

A thorough examination of the current political and social conditions in the North Sea site revealed that in terms of final MU design, which includes mussels and seaweed production, the most vulnerable groups and those impacted more are fishermen, persons involved on activities related to tourism, recreational boating and shipping. With regards to wind power production, fishermen consider that there will be reduction in the area available for fishing. The energy sector concerns are dealing mostly with difficulties to reach agreements with the fishing communities since they often do not adhere to rules and regulations. With regards to aquaculture, the wind energy industry considers the introduction of such multi-uses as a barrier and additional risks. The introduction of multi-use may also make transport maritime services more complex, but on the other hand there are potential synergies. To counterbalance the negative impacts, fishermen were exploring the possibility of compensation fees for lost fishing ground and/or additional employment for their fishing vessels, e.g. through fishing with static gears and sailing with tourists in and around the farms. New fishing vessel designs have been drafted in the Masterplan Sustainable Fisheries projects taking into account adaptations for service and maintenance work in wind farms. Specific employment impacts of aquaculture are not available. With regards to wind-power production, it is expected that the Gemini wind-power park will create around 500 full time jobs during the construction and installation phase and another 120 full time jobs during the operational phase. Local tourist industry might also benefit from sightseeing trips to wind farms. The employment impacts of the transport maritime services are mainly concentrated on the redesign of fishing vessels towards multi-purpose vessels, which may give fishermen the opportunity to carry out maintenance works, logistic and transport activities. Main stakeholder groups in wind power production and transport maritime services include competent authorities, energy companies, construction companies, investment and development companies, consultancies, fisheries, shipping and NGOs. For the case study site, those stakeholders include Ministry of Economic Affairs, Ministry of Infrastructure and Environment, Province of Groningen, Energy Valley (authorities), NUON Vattenfall, ENECO (energy companies), Van Oord, Ballast-Nedam, Siemens (construction and development companies), Typhoon Offshore (investment and development company) Fair Wind (consultancy), Visafslag Lauwersoog, VisNed, Vissersbond (fisheries), Groningen Seaports (shipping), and The North Sea Foundation (NGO). For aquaculture, also aquaculture companies are main stakeholders. For the case study site, they include PO Mossel, Machinefabriek Bakker and, Hortimare.

Controversies, Uncertainty and Implementation Obstacles

Controversies about wind power production have arisen due to the lack of trust between offshore wind sector and the fishery community. For fishermen, any new fishing restriction because of offshore wind farms is a major issue. Also, controversies about aquaculture have arisen because the Integral Management Plan for the North Sea explicitly states that fish cultivation is unlikely to apply on open sea due to environmental constraints. It is rather questionable if the North Sea environment in the Dutch parts can allow for fish aquaculture.

As a result, till now there is no area designated for aquaculture in the spatial plans for the North Sea. The fact that the already awarded permits for the Gemini site are only for single use is a major obstacle for all types of potential multi-use is the fact that. An MUOP license for production is an important prerequisite for stakeholders, but this crucial issue has not been tackled till now. The issue of the MUOP license to produce applies also for the cases of the transport maritime services and the wave energy production. In general, the current practice for offshore wind parks is to forbid other vessels to enter the designated parks in order to avoid questions on risks and responsibilities. As a result, risks associated with third-party access cannot be assessed.

Monetization of Environmental Externalities

Due to the multidimensional character of the impacts (socio-economic and environmental of direct and indirect outcomes, i.e. at stakeholder, industry and community scale), a range of different information was needed in order to assess them. As a result, market data, secondary data for the performance of simulations, survey based primary data, data provided from literature review, consultation with experts and stakeholders and information coming from environmental impact assessments were important in the framework of integrated assessment. The North Sea offers a wide range of ecosystem services that provide several benefits to human society. Apart from negative environmental effects, MUOPs might have positive impacts on the provision of the ecosystem services such as:

a) the foundation and scour protection of wind turbines become an artificial reef on which invertebrates do well and the foundations can be quickly colonized and create entire communities of marine life;
b) production of healthy food in an environmentally sustainable way;
c) seaweed aquaculture is a non-feed culture and instead of releasing nutrients, seaweed captures nutrients and will lead to improved water quality;
d) high abundance of benthic filter-feeders such as mussels will increase transparency in the water-column and that will improve light conditions for benthic vegetation.

Moreover, there are possibilities for improving sea life and ecological conditions that need to be further explored. Finally, science and education can be improved, using the structures as examples of innovative engineering and aquaculture that provides food and energy to people.

MUSES

MUSES project defines the objectives of the particular multi-use of offshore wind and aquaculture as:

- Direct attachment of installations i.e. fish cages or mussel/seaweed long-lines to offshore wind turbine foundations or development of new infrastructural solutions, for instance in the form of fully integrated multi-purpose platforms;
- The co-location of aquaculture installations within the security zone of the OWF farm, for instance, seabed cultivation of mussels within the vicinity of the OWF.

Insights coming from MUSES project for the MU:

Drivers and Added Value

The combination of OWF and aquaculture has mainly been driven by the need to increase the aquaculture production, a key component of the Common Fishery Policy, Blue Growth Strategy and national policies.

The main challenge to enhancing production of aquaculture is the lack of available space in inshore sheltered areas (F. Franzén, et.al., 2017) and visual and environmental impacts. Moving aquaculture activities further offshore can potentially reduce negative impacts (water quality and visual impacts) in coastal areas. For example, in UK, further expansion of finfish aquaculture raises environmental concerns and, therefore, this MU is seen as an opportunity for moving aquaculture to 'further exposed sites' (European Commission, 2016a).

Given the large fixed costs associated with development and operation of aquaculture in offshore areas (DEFRA, 2011) aquaculture developers consider the combination with OWF as an opportunity to make this move feasible and profitable. Cost saving can potentially be derived through shared operations and maintenance (O&M) between the two sectors.

Moreover, use of renewable energy instead of diesel for aquaculture operations could potentially ensure green credentials and allow aquaculture produced seafood to be marketed as a premium product. In some cases, this MU is also seen as an opportunity for improving Corporate Social Responsibility (CSR), ensuring public support and local community approval for the OWF developments.

Barriers and negative Impacts

Wider application of this MU still faces many challenges, including:

- Technology readiness level, especially with regards to harsh environmental conditions in offshore areas, and compatibility of technologies used for different types of aquaculture (e.g. cage vs line) and OWF (e.g. floating vs jacket vs monopile);
- Unknown cumulative effects: there is particular concern with regards to combination with fish aquaculture (and bivalve farming to a certain extent);
- Unassessed risk, unclear permitting processes and insurance implications, and a lack of planning and financial incentives targeting specifically this MU. These are needed to enhance commercial drive for such concepts.

Although many past projects have analysed this MU, information is not readily available due to protection of intellectual property, or is scattered across different sources, with uncertain future availability (i.e. when the hosting license of project websites expires).

Although some national policy and regulatory documents support this MU, the power imbalance between the two sectors has been insufficiently addressed to date. As a general rule, OWF operators of the already licensed or operational OWFs, have priority over other maritime users (aquaculture, fisheries). Project finance and maritime permits and licences given for specific technical proposals, are acquired at a certain estimated risk level and generally cannot be amended past the project planning stage (B. H. Buck and R. Langan, 2017). For example, the German Federal Marine Facilities Ordinance allows for the development of aquaculture at already existing wind power installations, as long as the aquaculture site does not become an obstacle for general maintenance.

This gives the OWF operators a de-facto veto right against any development deemed hindering or detrimental to their activities in the area. The interest of investors to actually invest in the development of this MU seem to be limited to a few examples in the UK and Belgium. Apart from the UK, existing aquaculture farms in EU are operating on a very small scale, or in the pilot stage. This implies very limited investment and technical capacity of individual aquaculture developers whereas such MU developments would require considerable investments for the advanced technological solutions. Therefore, funding is more likely to come from joint ventures.

For investors, proof of the concept is needed before engaging more actively. Challenges in combination with seaweed include low financial capacity of the sector and low added financial benefit given the underdeveloped market and industry in Europe.

On the other hand, fish aquaculture has high maintenance requirements, increasing traffic around the site, while the impacts on the OWF installation (i.e. fouling) are still unknown. This also further increases high insurance premiums required by the OWF insurance companies, and the question remains how these costs are to be shared between the two developers.

Additional factors shaping the feasibility of this MU are:

- Distance to shore: for example, shellfish (mussels, oysters, scallops) usually require a 2-day window for distribution to the next step of the supply-chain; the distributor. For far offshore locations it is difficult to predict when harvesting and subsequent distribution can take place.
- Security of tenure: most OW is licensed for around 25 years, after which all infrastructure has to be completely removed. If the aquaculture farm is successful, this requires consideration of what will happen when OWF are to be decommissioned.

2.2.4 Dutch pilot requirements for multiuse business models

The main activities/functions related to co-use/multi-use, that need to be included in a unified business model designed for the Dutch pilot use case are the following:

- aquaculture: fish, seaweed, shellfish
- wind farm
- wave/tidal energy

Currently the Dutch pilot has not yet concluded on a final business plan for the multi-use, yet some initial thoughts derived from previous related projects (van den Burg, S. W. K., 2017) have been considered for the operational phase of the multi-use activities. Wind farms and aquaculture are likely to affect each other in multiuse arrangements - using ocean space for different purposes and activities (Buck, B. H., M. W., 2010). Both sectors face the same constraints in terms of operation costs, limited accessibility (weather windows), distance to farm site, available working days, and difficult logistics for operation and management (Buck, B. H., M. W., 2010).

In the MERMAID project, it was concluded that shared use of the physical infrastructure like, for example, the turbines' monopoles, is not desirable (Rockmann et al., 2015). The cost category with the greatest potential for reduction is the operation and management cost. Up to 50% of the charged maintenance labor costs are lost as waiting time: waiting for good weather conditions, certified personnel, transport, necessary tools and equipment (He et al., 2015). It is suggested that by combining wind energy and mussel aquaculture, these costs can be reduced. For example, when a multi-purpose vessel sails out to transport a maintenance crew to and from the wind turbines, its crew can inspect the aquafarm installations feed the fish and maybe harvest fish/mussels, while the maintenance crew is busy carrying out the maintenance work. When tasks are finished, the maintenance crew boards the vessel again and the crew and harvest are taken ashore. Based on expert consultation, Lagerveld et al. (2014) expect a 10% reduction in O&M (Operation & Maintenance) costs can be realized through this multiuse.

Economic and Political

The key economic and political risks identified relate to issues around market entry due to intense competition against established sectors such as fossil fuels and nuclear vs offshore wind and fisheries vs aquaculture shellfish. Climate change is a driver for national policies including renewables in energy mix; opportunity for market entry exists for a large number of competitors but this is not restrictive apart from the competition for grants during early stage technology development. Possibilities to get certified require early cooperation with private and public standard-setting agencies.

Insurance expenditure

The scalability of aquaculture activities may be severely limited in order to comply with insurance requirements due to the close proximity of the two industries. Due to lack of benchmark data insurance implications need to be studied early on in the design phase and insurance sector requirements to be fully understood. The proximity of the two different sector activities will need to be considered with scalability in mind, and ensure future expansion for either or both sectors.

Environment

The impacts on the environment can be amplified by the combination of activities due to cumulative and in-combination impacts. During construction and installation, operation and maintenance, impacts on the physical environment as a result of offshore projects (and associated activities) is combined with impacts from other marine activities or users in the sea. A detailed environmental impact study, including ecosystem effects needs to be undertaken to avoid these issues. Knowledge of the surrounding waters – through baselines surveys and monitoring – is needed to ensure enough reaction time is available for industries and other interested parties to respond to environmental changes.

Health & Safety

Multiple Health and Safety risks are identified. Injuries can be caused by incident with geological features, including injuries as a result of vessel interaction during installation, cable lay or access (e.g. vessel grounding or capsizing), caused during foundation installation caused by gas pockets or equipment failure during pile refusal caused by geological features and as a result of system interaction during installation (e.g. grounding or capsizing). Injury caused conflicting offshore operations and vessel interactions can be caused by vessel collision, by simultaneous operations (e.g. subsea and topsides) and by interference with other sea users. Dependent on the type of risk, mitigation strategies include conducting a full geological survey prior to installation, the development of adequate safety plans, targeting the prevention of simultaneous operations, and creation of a marine vessel exclusion zone in conjunction maritime authorities. Injury to divers during subsea operations include injury caused by entrapment, injury caused by falling objects, injury caused by decompression sickness and injury caused by use of tools underwater. Mitigating these risk requires divers to be fully certified, using a reputable dive company with an accident-free track record and ensuring that this company produces and complies with a high-level safety plan for the work being undertaken.

2.2.5 Belgian pilot mapping with relevant projects

An overview of matched multi-platform solutions developed according to literature review and proposed methods for developing these solutions.

Table 10: Related projects with the Belgian pilot co-use activities

	Types of synergies	Related projects
Belgian Pilot	Wind energy & flat oyster & seaweed production & flat oyster restoration	• Edulis • SYMAPA • Programma Rijke Noordzee • MERMAID • MUSES • ORECCA: Offshore renewables and aquaculture (biomass, fish)

Edulis

Edulis (2016 – end of 2019)**: offshore mussel culture in wind farms** has been a collaboration between Ghent University, the Institute for Agriculture, Fisheries and Food Research (ILVO), 5 private partners: Belwind (operated by Parkwind), Brevisco, C-Power, Colruyt Group and DEME Group, and a third research partner: RBINS. Edulis studied the feasibility of mussel culture in offshore wind farms, 30 to 50 km off the Belgian coast. This ambitious pilot project was largely financed by private funding and facilitated by Flemish and European funding.

In **May 2017** a first experimental mussel culture system was installed in the C-Power wind farm. At this location mussel seed capture and further mussel growth has been monitored. Regular mussel sampling results have been linked to the prevailing environmental factors to document mussel growth.

In **November 2017** a second mussel culture system was placed in the Belwind concession. The forces, exerted by the sea on the mussel longline, have been measured by means of integrated force gauges. By comparing these results to the prevailing currents and wave conditions, the minimum requirements for a mussel culture system could be determined and the system design could be optimized.

Goals were to gather info on:

- The biological feasibility of offshore mussel culture in the Belgian North Sea
- The technical feasibility and requirements for an offshore mussel culture system fit for heavy sea
- The possibilities for integration of mussel farming with the existing activities in wind farms
- The profitability of commercial offshore mussel culture
- The sustainability of offshore mussel culture and the impact on seawater quality

Moreover, in the framework of the EDULIS-project EDULIS project, a mathematical model was needed to simulate the behaviour of mussel line systems under the effect of environmental loads such as waves and currents. After a preliminary study, the Maritime Technology Division of UGent (MTD) developed an in-house code for this project. The starting point for the development of the new code was the open source software MoorDyn (Hall et al., 2015), originally developed to predict the dynamics of submerged moored systems. The open source nature of MoorDyn allowed MTD to customize the code according to the needs of the EDULIS project. Numerous modifications and improvements were made to the original software to enhance its capabilities (Pribadi et al., 2019). This model will be applied for the simulations of the behaviour of the oyster and seaweed longline in the Belgian pilot of UNITED.

Hence, the experience of the partners with the offshore longline systems and operational challenges in EDULIS, will be of utmost importance in the Belgian pilot of UNITED.

SYMAPA

The specific lines of research of SYMAPA (VLAIO project) are:
- Identification of efficient substrates for the capture of mussel and flat oyster spat and biodegradable substrates for habitat enrichment as well as an operational monitoring program to evaluate the effects of mariculture and passive fishing.
- Identification of efficient passive gears for the prevailing conditions in the Belgian part of the North Sea and finding efficient incentives to increase the fishing capacity of passive gears.
- Optimal plot design for a combination of aquaculture of mussel, flat oyster and seaweed, habitat enrichment and passive fishery.
- Evaluation of North Sea resistant and safe production and harvesting systems for clams and seaweed, including guidelines for ship design, development of monitoring practices, automation of harvesting, advanced adhesive for direct seeding of sporophytes, predictable maintenance and harvest times,….
- Sustainable multiple use and value chain creation of marine resources.

The research questions and experiments concerning flat oysters within SYMAPA and those within UNITED are complimentary to each other and will help each other in lessons learnt e.g. for the oyster spat capture devices.

De Rijke Noordzee

With "De Rijke Noordzee", Nature & Environment and the North Sea Foundation are committed to nature conservation as a permanent part of the construction of every wind farm. They are developing a blueprint for nature restoration in all offshore wind farms. This demonstration project can inspire the entire wind sector. And of course: increasing the enthusiasm of the wider public for the wonderful opportunities of offshore wind. Results and pros and cons could aid the restoration project of flat oyster within the Belgian pilot of UNITED.

<u>The approach: Building living reefs</u>

In close cooperation with the wind and hydraulic engineering sector and science, living reefs are built at five locations in Dutch offshore wind farms for oysters, tube worms and horse mussels (*Modiolus modiolus*), among others. Reefs are a shelter for many marine species and a source of food for other sea creatures. The reef structures, which are designed and tested in a lab, consist of hard materials to which various species can adhere.

MERMAID

The project exploited offshore wind and wave energy potential combined with the implementation of marine aquaculture. The aim was to develop theoretical concepts for the next generation of offshore platforms, which can be used for multiple purposes, including energy extraction, aquaculture and platform related transport. Similar to the UNITED approach, MERMAID does not envisage the building of new platforms, but rather examine multiuse concepts for including new structures at existing plants at different sites and conditions. Compared to MERMAID, however, UNITED implements new constructions to the identified single use plants in real-life environment moving from TRL 5 towards TRL 7. During MERMAID, these concept designs were simulated but never implemented at real-life testing sites. Nonetheless, the drafted inception report and the quality assurance plan, developed in MERMAID, hold valuable information for the construction plans and deployment of seaweed and oyster longline cultures for the Belgian Pilot. Important information from MERMAID can be gathered from:

- The inventory on existing legislative framework and policies for offshore wind farms and aquaculture in EU

- Methodology for integrated socio-economic assessment
- Guidelines for project development, to facilitate a smooth and safe management and implementation of the multi-use (platforms) concept
- Analysis on accumulated effects of various large-scale structures interaction with waves, currents or seabed as well as the mixing and dispersion processes
- The developed decision-support system for transport infrastructure (based on a detailed and innovative forecasting system of various relevant parameters such as wind, waves, water level, currents and three-dimensional numerical flow and wave models)
- Economic and environmental feasibility studies of multi-use offshore platforms.

MUSES

In MUSES, the multi-use combinations that involve tourism and aquaculture are divided into three forms:

- The first form is similar to pescatourism but differs in its operation, it mainly involves hosting customers on vessels to visit aquaculture sites and learn about aquaculture techniques and tradition.
- The second form involves diving/snorkeling or other active recreational activities which are practiced in proximity to, or within, aquaculture installations to observe the resident fauna.
- The third form includes sport fishing tourism (mainly angling) practiced next to aquaculture installations in marine spaces which normally function as attractive areas for a number of fish species.

As the Belgian pilot within UNITED expects to go from TRL5 to 7, next steps could be to develop tourism combined with aquaculture and then the results from the MUSES project could be very relevant and offer guidance.

ORECCA

The goals of the **ORECCA project** (Off-shore Renewable Energy Conversion platforms – Coordination Action) are to create a framework for knowledge sharing and to develop a roadmap for **research activities in the context of offshore renewable energy** that are a relatively new and challenging field of interest. In particular, the project will stimulate collaboration in **research activities leading towards innovative, cost efficient and environmentally benign offshore renewable energy conversion platforms for wind, wave and other ocean energy resources**, for their combined use as well as for the complementary use such as aquaculture e.g. biomass and fishes and monitoring of the sea environment e.g. marine mammals, fish and bird life. The objectives of the ORECCA project are to:

1. **improve the information exchange** and promotion of specific research cooperation in this field between academia and industry, public and private actors;
2. **create** an efficient and focused **framework for knowledge sharing**;
3. **involve and stimulate all the relevant stakeholder groups** in Europe to define the framework for future exploitation of renewable energy sources in the offshore;
4. **develop roadmap studies** for the research, deployment and regulatory activities in the field of offshore renewable energy.

The outcome and lessons learnt from ORECCA could benefit the Belgian pilot within UNITED.

2.2.6 Belgian pilot requirements for multi-use business models

The pilot is a scientific project, so the reference to the commercialization is meant for future upscaling in case of a successful pilot. No information is readily available. The study will take into account market value and market demand. Expected products for commercialization are flat oysters, sugar kelp and energy. Target markets are consumers of seafood and green energy, and users of ecosystem services. Research on oyster and seaweed production for the Belgian and potentially export market will be investigated. Oysters are a regional product in Belgium, the Netherlands, and France. For the commercialization of seaweed several potential markets exist, for example the food, feed additives, bioenergy, and bio refinement markets.

Based on findings from literature, the requirements for multi-use business scenarios are very diverse. The overall market situation looks well and is likely to expand for oysters as well as for brown and red algae in the future. Buck et al. (2008) stated that red algae can be directly sold to the consumer as a healthy "green and clean" bio-food or be a valuable substance in industry for various purposes (e.g. emulsifiers, ingredients for food, medicine). Hence, the overall requirement of a strong market for offshore aquaculture products, produced in the Belgian pilot, is given. The development of a commercial offshore aquaculture in combination with wind farms in the North Sea region depends on critical factors such as (Buck et al., 2008):

- Service life of infrastructure as well as the oyster yield obtained per meter long line.
- Shipping costs (which can significantly be reduced by developing an offshore servicing vessel that can jointly be used for wind farm and mariculture operations and maintenance).
- Market price and the annual settlement success of juvenile oyster, which are the main factors determining the breakeven point.

It is advisable to identify measures to reduce investment costs for longlines used per culturing plot at offshore locations (Buck et al., 2008).

2.2.7 Danish pilot mapping with relevant projects

Insights coming from MUSES project for the MU:

MUSES project has already developed a multi-use synergy of tourism and offshore wind farms (OWF) joint on and offshore infrastructure and operational activities.

In MUSES, this type of multi-use includes OWF sightseeing boat tours and shared onshore facilities such as OWF related information centres and museums. Other synergies between OWF and tourism can be developed in several ways, including:

- sightseeing boat tours, sometimes combined with angling;
- specially designed platforms around the turbines serving as a resting ground for
- seals, designated facilities for divers and offshore restaurants in the vicinity of OWF;
- unique wind farm design and layout can serve as a tourist attraction and regional
- landmark;
- on land visits to OWF information centres and museums, and platforms for observing
- the farms with telescopes;
- boat tour operators can be engaged in OWF related monitoring activities;
- helicopter flights around OWF.

MUSES has identified that there are plenty of available examples of this multi-use in the Baltic and North seas. More specifically, in the coastal areas of Denmark, Belgium, Sweden, Germany and the UK, OWFs are already being consciously integrated into regional tourism activities. In Belgium, there are boat tours to the first national OWF, Thorntonbank (owned by C-Power), situated 30 km from the coastline. For business groups, the tour operator collaborates with the visitor centre of C-Power in Ostend, where a delegate from the wind farm operator gives a presentation about the OWF. The tour boat does not cross the 500 m safety zone yet, despite the distance, visitors are able to experience good views of the wind farm.

In Germany (North Sea), in addition to boat tours (outside the 500 m safety zone) to one of the OWFs, there is also an on-land observation platform in Bremerhaven with an information board and multimedia terminal. In the UK, the safety distance is usually only 50 m, allowing vessels in close proximity to the turbines. Some examples can be found in Brighton, East Sussex in Southern England as well as to Ramsgate, Kent (visits to Thanet OWF) [48] and Great Yarmouth, Norfolk (visits to Scroby Sands OWF) in Eastern England; Llandudno, Wales in Irish Sea (visits to the Gwynt Y Mor OWF).

In Middelgrunden OWF in Denmark, which is the UNITED pilot site, MUSES states that tourists can even climb the 60 m tower of one of the turbines and open the nacelle (if the weather conditions are suitable). This OWF also provides a good example of an attractive OWF layout and the benefits of early engagement of local community in a co-design process. The wind farm layout follows a single curved line, continuing the Copenhagen city structure which has the shape of a super-ellipse, characterised by the old defence system west of Copenhagen (WWEC, 2017). This MU is also initiated on a temporary basis, usually as part of the OWF developer's corporate social responsibility (CSR) local outreach campaigns [51]. These are undertaken especially during the pre-planning stage when local acceptance needs to be secured for the OWF project to continue.

Regarding the drivers and the added value that this synergy can bring, tourism and offshore wind energy sectors often compete for the same space: shallow waters which are close to shore. Visual impact of OWFs on the natural landscape can negatively affect the acceptance of OWF project in the coastal areas. One of the main drivers for this MU is that it could potentially overcome issues related to OWF project acceptance and the "NIMBY" phenomenon (Not In My BackYard).

It increases local knowledge about the importance of green energy and provides an opportunity to derive long-term benefits for local communities by promoting innovation, entrepreneurship and job growth. Moreover, if the OWF has a unique design and layout, it can become a symbol for the local region and create a sense of pride among locals.

2.2.8 Danish pilot requirements for multiuse business models

However, some reports identify the interactions that these two types of activities might have when based in same marine space and to assess the risk to maritime operations.

As reported by Raza Ali Mehdi and Jens-Uwe Schröder-Hinrichs, (2016), the design of an offshore wind farm (OWF) can have a major impact on the safety of maritime operations in the vicinity. Factors such as the number of turbines, turbine spacing, and tower design can all have an effect the probability and consequences of various maritime accidents.

Risk assessment (Raza Ali Mehdi and Jens-Uwe Schröder-Hinrichs, (2016))

Perhaps more importantly, there is also an increased risk of accidents due to the increased maritime traffic as a result of activities related to OWFs. In addition to the increased traffic density, and reduced sea space, wind turbines may also cause problems with a ship's on-board navigation equipment. In fact, the potential accidents that maritime operations face due to offshore wind farms can be classified into five different categories.

- Navigational accidents involving passing vessels (Powered and Drifting)
- Navigational accidents involving wind farm support vessels
- Accidents during OWF installation and decommissioning operations
- Accidents during emergency maritime operations such as SAR
- Accidents in harbors and ports that deal with offshore activities

2.2.9 Greek pilot mapping with relevant projects

Table 11: Related projects with the Greek pilot co-use activities

	Types of synergies	Related projects
Greek Pilot	aquaculture: seabass and sea-bream	• MARIBE: tourism and aquaculture • MUSES: tourism and aquaculture

MUSES: One of the first multi-use marine space projects that match with the co-activities that are planned to take place in the Greek pilot are the MUSES project. In MUSES, the multi-use combinations that involve tourism and aquaculture are divided to three types of forms:

- The first form is similar to pescatourism but differs in its operation, it mainly involves hosting customers on vessels to visit aquaculture sites and learn about aquaculture techniques and tradition.
- The second form involves diving/snorkeling or other active recreational activities which are practiced in proximity to, or within, aquaculture installations to observe the resident fauna.
- The third form includes sport fishing tourism (mainly angling) practiced next to aquaculture installations in marine spaces which normally function as attractive areas for a number of fish species.

In this particular project, there were different pilots that combined the aforementioned forms of tourism and aquaculture in many parts of the world. There was a pilot in Italy, in the Veneto and Emilia Romagna regions. Active experience of this combination was identified at the Cavallino-Jesolo mussel plant in the northern Veneto region where sport-recreational fishing and guided tours take place within the aquaculture site. In Slovenia, touristic and educative activities are offered by aquaculture farmers in Piran Bay, a triplet multi-use combination (tourism, aquaculture and environmental protection), located in a protected fishing area and natural park. The farmers also participate in research projects concerning several environmental and biological issues. The combination of Aquaculture and Tourism has also been identified in areas of the French Atlantic including Charente-Maritime, Arcachon, the Sea of Iroise, the Gulf of Morbihan and the Bay of Brest. In the Spanish Atlantic, specifically the Ria de Arousa (Galicia), mussel aquaculture companies interact with tourism companies, contracting tourist vessels for various operations related to aquaculture activities. In Portugal, at least two different forms of this multi-use have been implemented: both the first form where tourists are taken onboard to view aquaculture activities (especially mussel aquaculture) and the second form whereby diving takes place next to the tuna farming installations set offshore. In Malta, another form of this multi-use exists involving organized diving in open sea Blue fin tuna farming cages located 1 mile offshore [39]. In Greece, this multi-use was previously operational in Rodos Island where an aquaculture developer accepted tourists into the site for educational purposes and potentially fishing from the cages.

The drivers identified by the MUSES for this particular multi-use seem to be aligned with the drivers of the UNITED project, regarding this multi-use use case. The main driver is related to:

- The economic benefits of combining both sectors.
- The availability of funds (EMFF) to diversify the aquaculture sector and the role of FLAGs in promoting this diversification into tourism across Europe.
- Increasing sustainable fish consumption,
- The growing interest in sustainable and locally-based tourism.

The barriers and negative impacts identified were:

- Restrictions in legislation or in its interpretation which regulate the possibility of hosting tourists on board aquaculture vessels, was identified as a major barrier. Only regional legislation in Emilia Romagna, Italy referred to and defined this multi-use.
- There is absence of adequate regulations related to insurance against accidents.
- Existing vessels used for aquaculture are not often suitable for touristic use.
- Lack of case studies and business models for this MU.
- Limited standards and guidelines to train fishers and aquaculture operators, coupled with their limited experience and skill in management, customer services and entrepreneurial skills also hinders this multi-use.
- Poor entrepreneurship and investment capacity of aquaculture operators is a key challenge which is informed by their spatial fragmentation.

- possible increase in touristic pressure in already overcrowded areas, with possible increases in coastal cumulative impacts.
- Environmental concerns also arise with the involvement of recreational fishing activity next to aquaculture plants. There is the possibility of fish stock overexploitation if multi-use activities involving fishing are not well monitored.

MUSES has another multi-use type that is related to the Greek pilot of UNITED, which involves Underwater Cultural Heritage (UCH), Tourism & Environmental Protection. This type of multi-use has been defined as the combination of touristic or recreational activities with the protection of underwater archaeology and its adjacent marine ecosystems.

The main driver for this multi-use combination is public demand for alternative tourism activities. Therefore, this makes UCH sites accessible to the public, encouraging their protection and appreciation of their value and significance. This brings about possible mutual opportunities and advantages amongst UCH authorities, diving centre and tour operators, touristic service providers, fishery institutions and associations (e.g. NGOs) involved in marine protection. The MU offers both ecological and economic benefits and opportunities.

According to stakeholders, in Greece, Malta and Cyprus, the most important drivers are environmental issues and policy goals of achieving 10% MPA9 while exploring multiple synergies between UCH and environmental protection. Other driving factors include the provision of new jobs due to new marine museums and information stands on land and the increase of local revenues related to tourist services as well as improved regulation and funding in place for UCH.

- The barriers identified form MUSES regarding this multi-use use case are described below:
- Limited public access to UCH sites
- Limited specialised skills restricts accessibility
- Limited, fragmented funding for tourism and environmental
- Strict regulations on the protection of UCH sites
- Limited knowledge about possible UCH sites
- Resistance of UCH authorities and NGO's due to risk of theft or damage to artefacts
- Heterogeneous actors and fragmented nature of UCH interests

MARIBE: Project MARIBE investigates cooperation opportunities (partnerships, joint ventures etc.) for companies that wish to develop their sectors and promote the multi-use of space in the offshore economy. The sectors are Marine Renewable Energy, Aquaculture, Marine Biotechnology and Seabed Mining. MARIBE links and cross-cuts with the Transatlantic Ocean Research Alliance and the Galway Statement by reviewing the three European basins (Atlantic, Mediterranean, and Baltic) as well as the Caribbean Basin.

In the field of Aquaculture and Tourism, MARIBE has identified a number of opportunities as well as barriers, first individually and then as a part of a co-existence and collaboration in the same marine space. The project has identified the great biodiversity of the Mediterranean Sea, as a potential market for the products of tourism and aquaculture as well as biotechnology. This basin in particular presents an important degree of seasonality in some activities (tourism, fisheries), which also needs to be considered, regarding the business model of co-use to be developed, while proposing the combination of aquaculture with wave energy or biotechnology to be ideally developed for the Mediterranean basin. What is more, a proper management of maritime space not only works to avoid conflicts, but it can also contribute to the identification of possible synergies between activities, ensuring at the same time both socio-economic development and the protection and sustainable use of marine resources.

For aquaculture individually, some of the challenges identified are:

- The development of sustainable aquaculture is dependent on clean, healthy and productive marine and fresh waters. Main criteria (and limitations) for aquaculture site selection are water temperature, chlorophyll-a concentration, depth and current speeds (FAO, 2013).

- For offshore sites, there are not adequate systems developed yet for the prevention of escapes from cages and protection from predatory wildlife.
- Submergible cages that allow aquaculture installations in sites with high waves and current speeds should be developed.
- Technological solutions are needed to make offshore aquaculture sustainable and economically viable. Industry is moving towards "integrated multi-trophic aquaculture" (IMTA, mixed farming), but it is currently at an early pilot stage.
- Long and complex processes for obtaining site licenses in the EU.
- Contamination by human activities like sewage treatment or other polluting activities. This crashes with the need of rigorous health rules for animal products.
- High development costs with insufficient incentives and support.
- Lack of long term view by industry and government for strategic plans, including R&D.
- Food quality concerns by society about final aquaculture products. Need to guarantee the quality and traceability of aquaculture products.
- Aquaculture sector presents a degraded industry image

For tourism accordingly:

- Tourism needs locations with some potential attraction to visitors. This issue could limit the development of the sector to some specific areas/zones.
- Selected sites for this sector must ensure several requirements:
    - Land proximity. This will ensure better Health and Safety for visitors and working staff. Long travel time to site the will be discouraging for tourists.
    - Shallow water, stable seabed & moderate met-ocean conditions.
    - Weather and conditions may often prove unattractive to visiting tourists. Areas on inshore may be preferable
- Leisure development also require some Health and Safety infrastructure:
    - Accidents during visitation activities or staff would require emergency transportation provisions (i.e. helicopter landing pad)
    - Fire safety would be an increased risk due to lack of outdoor space for people to get to. Other safety provision required (i.e. Safety boats)
    - Tourism expects entertainment, which implies either high levels of engagement or a diverse range of opportunities/activities; may increase the cost of investment substantially.
- The coastal tourism sector is not attracting or maintaining enough skilled personnel due to its seasonality and lack of long term career opportunities which can lead to problems in service quality and hamper competitiveness.

The challenges identified for the combination of the two sectors are:

Technical maturity: Some of the sectors analysed are in a very low TRL stage. This means that lot of research and development work must still be done. The aim to merge two sectors with very different stages can be problematic for the more advanced sector, limiting its development and even making it impossible. The obvious uncertainties existing in early steps of technology can contaminate.

Financial assessment: The sectors analysed nowadays are mainly under no full development. Due to this, it is difficult to perform realistic cost and benefit analyses just for one sector. Doing this type of analysis to assess the commercial and financial viability of the projects of two or more sectors combined will result even more difficult.

Social perception: There are some blue growth and blue economy sectors that can be seen as prejudicial by society.

Environmental limitations: Some sectors can produce a harmful impact on the environment. And some other sectors viability depends on the quality of this same environment. The co-existence of both can in this case result problematic.

2.2.10 Greek pilot requirements for multiuse business models

The coastal and maritime tourism sector is one of the five focus areas of the Blue Growth Strategy, and is thereby a top priority for European Union policy and projects. Coastal tourism accounted for 40% of the GVA, 61% of the jobs and 41% of the profits of the total EU blue economy in 2016 (European Commission, 2018); in the same year, around 2.127 million persons were directly employed in the sector (European Commission, 2018). Areas with high coastal and maritime tourism intensity have been recorded in Greece, Spain, Italy and France; in these countries the sector is also the strongest maritime employer (European Commission, 2019). Maritime and coastal tourism is a hugely diverse sector, ranging from nature-based tourism and low impact recreational activities on the coast to mass tourism. It is also a highly competitive sector, and there is sometimes strong pressure on coastal areas and resorts to remain attractive.

However, the combination of coastal and maritime tourism with aquaculture, has not yet been widely adopted, in order to have tracked a concrete business plan for such a multi-use case. Individual cases have been reported such as the one in Namibia, where the Deputy Minister of Fisheries and Marine Resources, Kilus Nguvauva, officially launched the Uis Fish Farm Eco Tourism Enterprise at Uis Village (The Fish Site, 2010). It is being undertaken with the assistance of a Japanese International Cooperation Agency volunteer, Mugiho Ataka, who prepared a business plan for the fish farm. The Japanese Government gave the Uis Fish Farming Eco-Tourism Enterprise a grant of $540 000. The grant was used for the purchase of four cages, fish feed, two boats with outboard motors, two chest freezers and other equipment necessary for the venture. Another relevant case is the one of swimming with caged tuna in Spain. In the Catalunia and Murcia regions in Spain, a unique and innovative system has been developed to farm blue fin tuna. This aquaculture operation is also being used as a tourist attraction, more specifically, to offer the opportunity to swim with the tuna in the open ocean cages (European MS Platform, 2019).

There are a number of topics that need to be considered for the creation of the multi-use business model. These topics should cover the value proposition from both sides of the co-use companies. Namely these are:

Types of supplies: Co-use companies need to determine the supplies components of the product/service or an entire product/service that will provide.

Market access: Co-use companies need to determine the types of communication channels as well as the access to existing markets or helps create new markets.

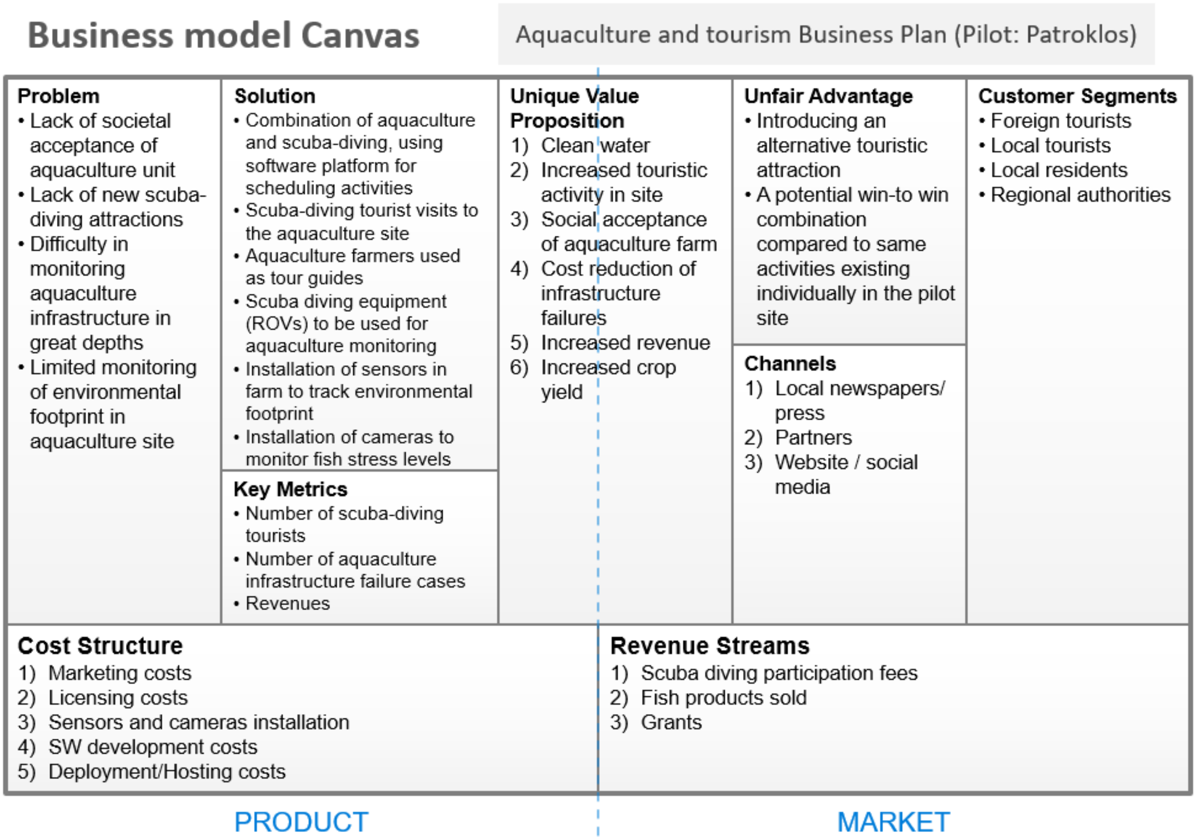
Funding: Co-use companies need to determine the types of funding for one or more activities in the business model.

Co-developing & research: Co-use companies need to determine to what extent they will be involved in (technology) development and research activities.

Knowledge & experience: Co-use companies should provide their knowledge and experience.

Combined use of space/resource: Co-use companies need to determine the grounds on sharing the same space or resource (because of geographical proximity).

The business model canvas for the particular pilot is depicted in figure below.



2.3 Parallel efforts in terms of types of activities and shared knowledge

From the overall five pilots that participate in UNITED project, there are a number of common multi-use activities that can be matched:

German Pilot: Offshore-FINO3

The scope of this pilot is to investigate the upscaling potential of multi-use colocation systems such as the production of offshore energy combined with aquaculture (mussel & seaweed), which is located close to several wind farms. The longline structures will be submerged 4 to 5m below the surface, reducing the wave action on the installation. The pilot's objective is to explore synergetic effects between offshore energy production and aquaculture as well as to reduce technological, financial, health and safety, as well as environmental risks for future multi use colocation systems.

Belgian pilot

The Belgian pilot aims to improve the design and deployment methods of offshore aquaculture (flat oyster and sugar kelp) activities and restoration (flat oyster) at offshore wind parks. The main objective is to optimize scheduling of these multi-use activities, identify and supply source biological materials, and identify optimal off-shore equipment (grow-out systems, longlines, scour material, seed collector, holding system, matrass). Moreover, water quality variables, oyster growth, changes and predation and biodiversity will be monitored using field-measurements and predictive models. The findings will be used to develop business cases and financial analysis of integrating the offshore wind and aquaculture and restoration activities.

Dutch pilot

Within UNITED, the **multi-use of seaweed production in offshore wind parks** is investigated. Moreover, research will be performed on remote monitoring, data collection and anchoring of the systems. Within NSIL there is another pilot that investigates the possibilities of **floating solar panels in an offshore windfarm**.

Danish pilot

The Danish pilot targets the expansion of **tourism activities (boat tours, leisure fishing and diving) related to offshore wind farms.** The pilot therefore serves as a demonstrator of the improved multi-use information technology (boat scheduling system) and physical technology (facilities for divers on platform). The pilot also aims to advise on the health and safety practices and on related regulations (safety zone measures, permission for fishing, and insurance with tour operator) of such multi-use activities.

Greek pilot

The Greek pilot investigates possibilities to expand **tourism activities (leisure scuba diving) at aquaculture sites.** Based on existing activities of aquaculture and tourism in the shared marine space, several actions will be taken to increase the TRL level of such multi-use solution. The pilot aims to increase aquaculture production efficiency, monitor technologies to synchronize activities, and demonstrate the use of Decision Support System for new development. In addition, the pilot will investigate challenges in terms of insurance issues, profitability, risk/health impact, economic sustainability, while minimizing pollution prospects and facilitating touristic growth and social acceptance of aquaculture activities.

Table 12: UNITED demonstration Pilots and their multi-use activities.

Pilot	Sea Basin	Multi-use activity
German Pilot	North Sea	Offshore wind energy research, cultivation of blue mussels and seaweed
Dutch Pilot	North Sea	Floating solar and seaweed cultivation
Belgian Pilot	North Sea	Offshore wind farm, cultivation of flat oysters and seaweed, and restoration of oyster ecosystems
Danish Pilot	Baltic Sea	Offshore wind farm and visits to wind turbines (tourists, technicians from the sectors, etc.)
Greek Pilot	Mediterranean Sea	Aquaculture (fisheries) and leisure scuba diving

3. UNITED PILOTS REVIEW OF EXISTING TECHNOLOGICAL SOLUTIONS

3.1 Analysis of pilot cases and multi – use cases requirements

3.1.1 Technical Readiness Level of pilots

Economic theory views that a decision should always be the outcome of a productive activity whose inputs include intellectual efforts of an individual or a group of individuals, computing hardware and software, volumes of data, etc. (Bonczek et al., 1981). All decision-making processes underlie a continuum ranging from highly structured to highly unstructured. While structured decision making refers to a repetitive routine, the latter means a descriptive of a situation where there is no "cut-and-dried" method for handling a new problem, because it has not arisen before, or because it is to elusive and complex for a custom-tailored solution (Bonczek et al., 1981). As UNITED, and the construction design of pilots in particular, address the dilemma of unstructured decision making processes, it is crucial to follow a unified strategy along the project process, once novel problems arise, which do not allow for a habitual pattern of specialized solutions. Hence, within UNITED, the approach for general problem solving includes usage of analogies from similar industries and sectors, clear definitions of problems and the usage of already applied specialised strategies from the past.

Translating the existing pilot solutions from the development state (TRL5) to demonstration in an operational environment (TRL7), presents a great challenge as various bottlenecks and uncertainties at technological, regulatory, financial, environmental, and socio-economic levels have to be considered. The ability to predict how changes in resources and infrastructure might affect value generation is incomplete in most cases due to complex relationships between inputs (natural resources, infrastructure), outputs (e.g., ecosystem services) and the value of those outputs. Thus, planning tools, models for optimal set-ups and improvements as well as strategic decision support systems (DSS) will be used in the process. Especially, DSS are considered to attack semi-structured organizational problems, which often occur at the strategic planning level (Courtney, 2001). For this reason a thorough review of already applied solutions within the pilots is given, to define, which strategies are required to reach the final steps towards TRL7.

Pilot	Current TRL	Planned TRL
German Pilot	5	7
Dutch Pilot	5-6	7-8
Belgian Pilot	5	7
Danish Pilot	6	8
Greek Pilot	5	7

Figure 3: Current and Planned TRLs of UNITED pilots

3.1.2 Existing planning Tools, Solutions and Strategies

Already existing tools, solutions, strategies are available for UNITED:

- Experienced and well-trained personnel in the field of offshore engineering that owns/has access to necessary equipment/measurement devices and tools
- Long-time environmental data (hydrographic) series of the locations
- Complex technological and logistic infrastructure at all Pilots (*see details below*)
- AQUACROSS assessment framework that contributes to environmental assessment regarding human activities, within aquatic ecosystems
- EDULIS approach of a prototype mussel system and farm lay-out suitable for the North Sea conditions that allows modelling for predictive mussel growth and calculate drag forces
- IMPAQT decision making process for processing data from multiple sources. An advanced IMTA model yields spatially explicit data on how the different farm components interact with the environment on the scale of an ecosystem that can be used for planning decisions
- EuroGOOS – Global Ocean Observing System, that provides operational oceanographic services

- CATARACT – Tool offering an innovative water management, which identifies critical events, self-adaptation of measurement, transmission profiles and energy management
- SOMOS- Technical Standards for Safe Production of Food and Feed from marine plants and Safe Use of Ocean Space. A contribution to resilient marine resources for tomorrow

German pilot, Technological Solutions

The research platform FINO3 in the North Sea is well equipped and has a self-sufficient power supply, which provides all technical devices with 230V and 400V mains voltages. To bridge the transitions between the units an uninterruptible power supply guarantees the supply of the scientific calculators for about 5 min. Three independent satellite connections for data transmission and VoIP telephony are available on the platform. A redundant data acquisition takes place and the data is mirrored daily to a server on land, so scientists can access the data. Moreover the infrastructure of FINO3 has:

- An airfield for helicopters up to 14 meters in length and 5.3 tons
- A container for setting up measuring devices with free 19'' racks
- An energy container
- A tank container
- A magazine/storage container
- A workshop container
- A 1.0t crane
- A 300l seawater tank and a 2000l freshwater tank
- A submersible pump with hose, to pump seawater onto the platform
- A tripod for loads in/out of pillar interior
- Lamps and emitters to illuminate the deck and the jetty
- Three berths and two camp beds in two containers for overnight stays of crew

FINO3 consists of the following main components:

- lightning rod
- three-sided lattice tower with booms between 30 and 105 m high
- helicopter deck
- bridge for oceanographic measurements
- work deck
- transition piece with jetty design
- six diagonal supports for the platform corners and the base points of the mast
- monopile (foundation pipe) with an anchoring depth of approx. 30 m and a total length of 55 m

Technical specifications:

Total height of structure	172 m
Height of platform deck	22 m
Water depth	22 m
Anchoring depth in seabed	30 m
Diameter of monopile	3.0 – 4.7m
Edge length of mast	1.8 – 6 m
Boom length	3.1 – 8.8 m
Area of platform deck	13 m x 13 m
Diameter of helicopter deck	14 m
Total mass	600 t

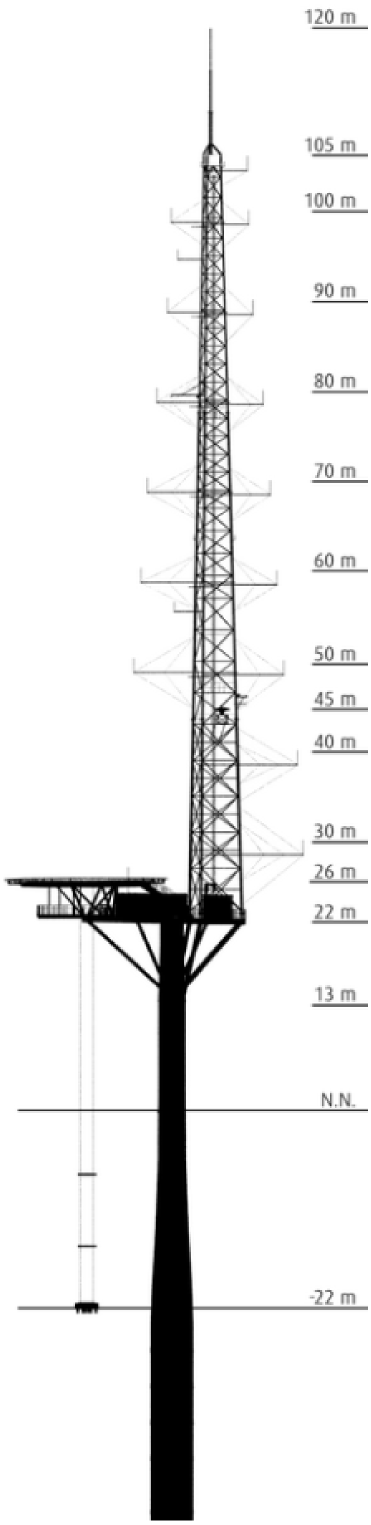


Figure 4: Design and construction details of FINO3.

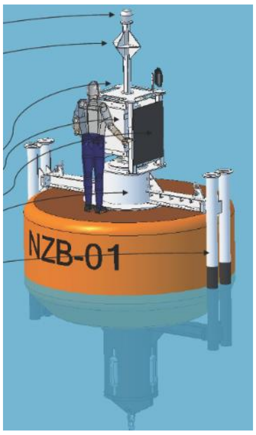
Dutch pilot, Technological Solutions

The North Sea Innovation Lab (NSIL) is an offshore lab of 6 square kilometres, with 6 research plots, 12 kilometres from the coast of The Hague, with the following technical specifications:

- 600ha/ 6km2
- 12 km offshore (harbour Scheveningen)
- Water depth approx. 18-20m
- Officially demarcated (cardinal buoys & registered in hydro-graphic cards)

This pilot is equipped with a sensor set up in order to gather information on temperature, light, nitrate, phosphate and ammonium, conductivity, salinity, chlorophyll-A, turbidity and horizontal as well as vertical flows (ADCP Nortek Aquadopp profiler). Additional equipment includes:

- Radar reflector
- DAS module: LoraWan gateway
- AIS (Automatic Identification System)
- GPS sensor
- Compact Weather Station
- Stainless steel box for electronics
- Space for solar panels
- Tube with manhole with battery
- Tubes for sensors



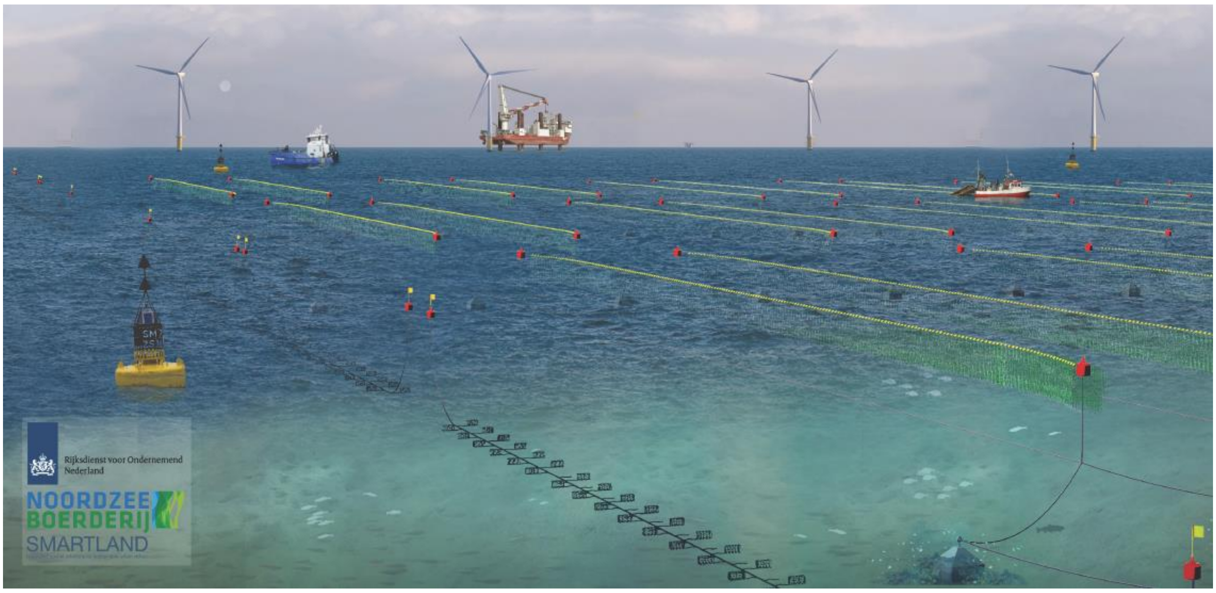


Figure 5 : Infrastructure of the North Sea Innovation Lab.

Belgian pilot, Technological Solutions

The project will be carried out in two locations offshore in the wind parks of Belwind and Northwestern 2, both belonging to the group of Parkwind at 50 km from the coast (average depth 25-30m). The vast experience of the Parkwind team builds on the success of the wind farms Belwind (55 wind turbines), Nobelwind (50 wind turbines) and Northwind (72 wind turbines).

UGent also has an analytical lab for seaweed, mussel and oyster sample analysis as well as a wet lab for marine aquaculture (shellfish, fish).

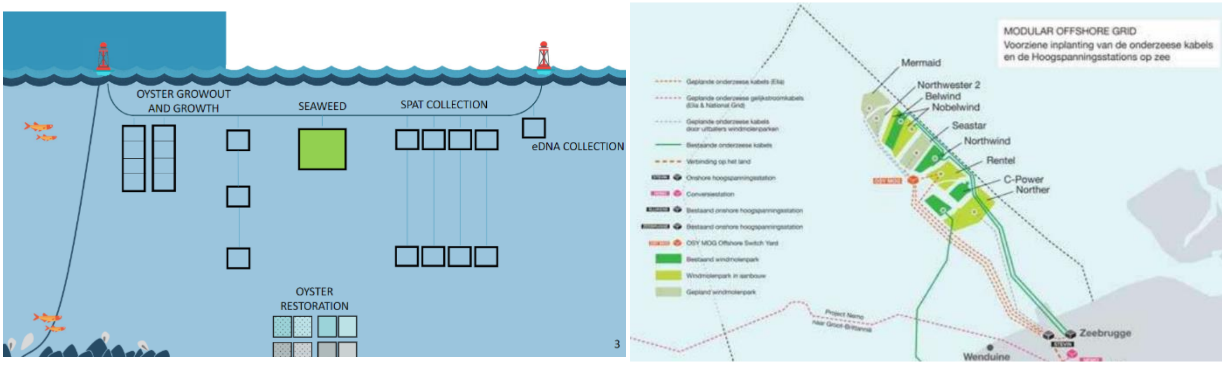


Figure 6 : Infrastructure of BelWind.

Danish pilot, Technological Solutions

A new visitor Centre Approach for the 40 MW offshore wind project Middelgrunden Wind is established of the coast of Copenhagen, Denmark. SPOK has specialised in social, planning and environmental impact of offshore wind and ocean energy including job creation and communication with stakeholders. They are professionals in organizing visiting programs for Middelgrunden Wind Farm, which includes OWF sightseeing boat tours and shared onshore facilities such as OWF related information centres and museums.

Facts on the Middelgrunden Offshore Wind farm:

- Power 40 MW
- Hub height 64 metres
- Rotor diameter 76 metres
- Total height 102 metres
- Foundation depth 4 to 8 metres
- Foundation weight (dry) 1,800 tonnes
- Wind speed at 50-m height 7.2 m/s
- Estimated power output 89 GWh
- Park efficiency 93 %

Technical data:

- Foundation depth: 4 to 8 metres
- Foundation height (total): 8 to 11.3 metres
- Foundation weight (dry): 1,800 tonnes
- Material: Reinforced concrete
- Shape: Circular with ice cone at the upper part

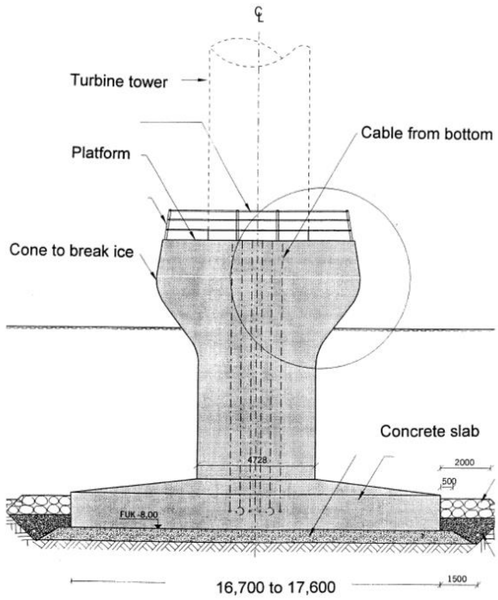
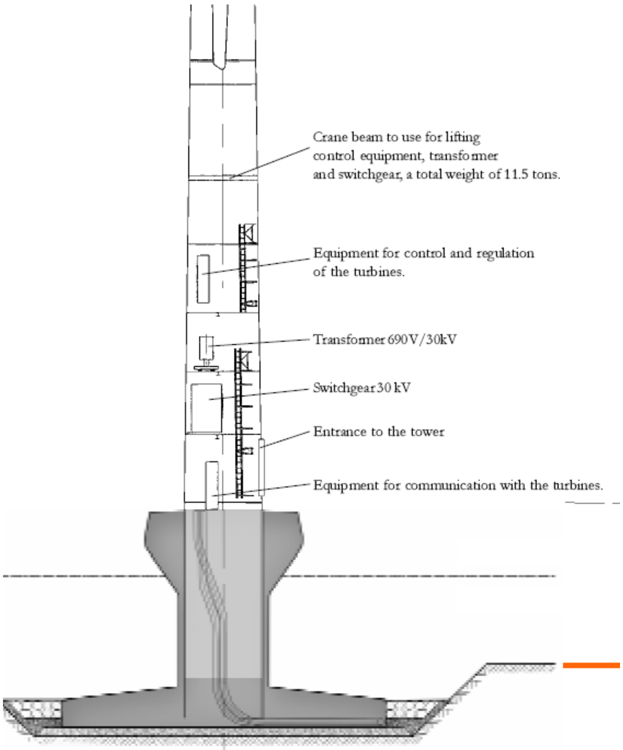


Figure 7: Design of concrete gravity foundation. The height of the total foundation is between 11.3 and 8m.

The turbines are repaired form maintainance twice a year, whereas the electrical system (30kV) is only inspected once a year and maintained every second year. Daily maintenance is carried out by the administration and includes:

- Checking the access ladder used by minor boats for damages, which are caused by ice or collision with the larger service boats

- Service and maintenance of the drainage system for water condensed in the moist control equipment
- Repair of cracks in the foundation rails
- Repair of joints between tower and foundation
- Checking the rescue equipment and the warning lights on top of the turbines



Wind Parameters at Middelgrunden:

- Wind speed at 50-m height: 7.2 m/s
- Weibull scale parameter at 50-m height: 8.1 m/s
- Weibull shape parameter at 50-m height: 2.3
- Energy density at 50-m height: 380 W/m2
- Turbulence intensity at 50-m height: 0.12

Central connection:
The central turbine is connected by two 20 MVA cables to the power plant. The other turbines are connected to the central turbine in series connection. This solution is the least flexible. If the cable between two turbines breaks down, some turbines will be cut off from the main cable. The third solution was chosen, as the estimated production loss in the last solution was smaller than the extra costs for establishing two separate cables.

- Switchgear: 30kV
- Transformer: 690V/30 kV dry transformer
- Cables: 20 MVA, three-core XLPE submarine cables

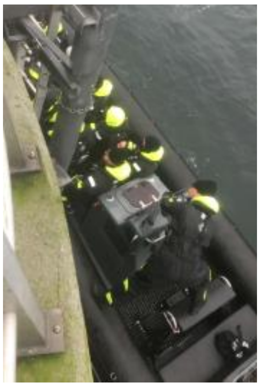


Figure 8: Windpark Middelgrunden (left), zodiac to access the turbines (right) and design construction of turbine (top).

Greek pilot, Technological Solutions

KASTELLORIZO operates a fish-farming unit, on floating facilities in the marine area near islet "PATROKOS" (the islet is located near the coast, 850 meters away). The aquaculture total annual production of marine Mediterranean fish in that area is 230 tones. There is great touristic interest in the area, as many tourists visit the coasts of PATROKLOS islet mostly with private boats on the summer. Many tourists visit the coasts of PATROKLOS islet mostly with private boats, while in the summer a boat provides the service of transferring tourists to the island.

The islet is private property; thus it is allowed to visit PATROKLOS beaches to swim. Near the aquaculture area, scuba diving activities take place, to explore the area's exceptional natural beauty. Other interesting underwater sites that exist in the area, is an underwater car cemetery next to the aquaculture site, as well as a shipwreck on the opposite side. Another significant attraction are the many shipwrecks that have taken place in that area as well as ancient artefacts, making Scuba-diving activities quite popular in that area.
Some important characteristics of the aquaculture site relevant to the equipment deployment:

Power: Photovoltaic panels reside on a raft.

Connection: Ethernet connection (24Mbps) is available on the shore. No 4G network is available.

Mooring systems: Rafts, ropes, piers are available. Special equipment for the installation of sensors and cameras will be considered.

Water Quality parameters: The water quality parameters of interest for the site include temperature, dissolved oxygen, and current measurements, while environmental parameters will also be considered to measure the environmental impact of the activities to the area.

Information that need to be considered:

- Cameras application
- Drones application
- Mooring systems utilization
- Site size and structure
- Depth
- Fish Behaviour monitoring needs (for tracking any stress levels from diving expeditions)
- Species, fish growth period of year (necessary for optimizing production and operations)

<u>Transmission methodology:</u>

- Gateway device, collecting data from sensors and cameras in the site and transmitting them to the local network
- 4G/NB-IoT if available
- WiFi if possible from the gateway device (which will be installed in the site) sending data from sensor measurements to the network infrastructure available
- LoRa (low-power wide-area network protocol) or other protocols

Technology setup

Architecture

As a pilot lead, WINGS and technical manager of the pilot, WINGS plans to install different types of sensors for measuring water quality parameters, in the fish pens of the aquaculture. Off-water and underwater cameras could also be installed in site to monitor fish behaviour and for disease prevention as well as to facilitate in measuring the food waste that remains in the cages. WINGS smart gateway, a device produced by WINGS that will be installed in the aquaculture site as well, will be responsible for transferring the data coming from sensors and cameras to the cloud (via the available network). In the cloud platform of WINGS, advanced algorithms based on Artificial Intelligence will produce Advanced Analytics through the data measurements that will facilitate the understanding of the overall production to the aquaculture owner. The WINGS platform also will provide a Decision Support System that will facilitate in the operational procedures and in the optimization of the production. The Dashboard will be used for the data visualization to present the results of the algorithms developed in the platform.To sum up:

Smart Gateway:

- collecting data from sensors, cameras
- sends to cloud through Network transmission

Cloud platform:

- Production management

- Decision Support System
- Advanced Analytics

Dashboard:
- Management and monitoring
- Data visualization
- Business decision support
- Ecological Footprint

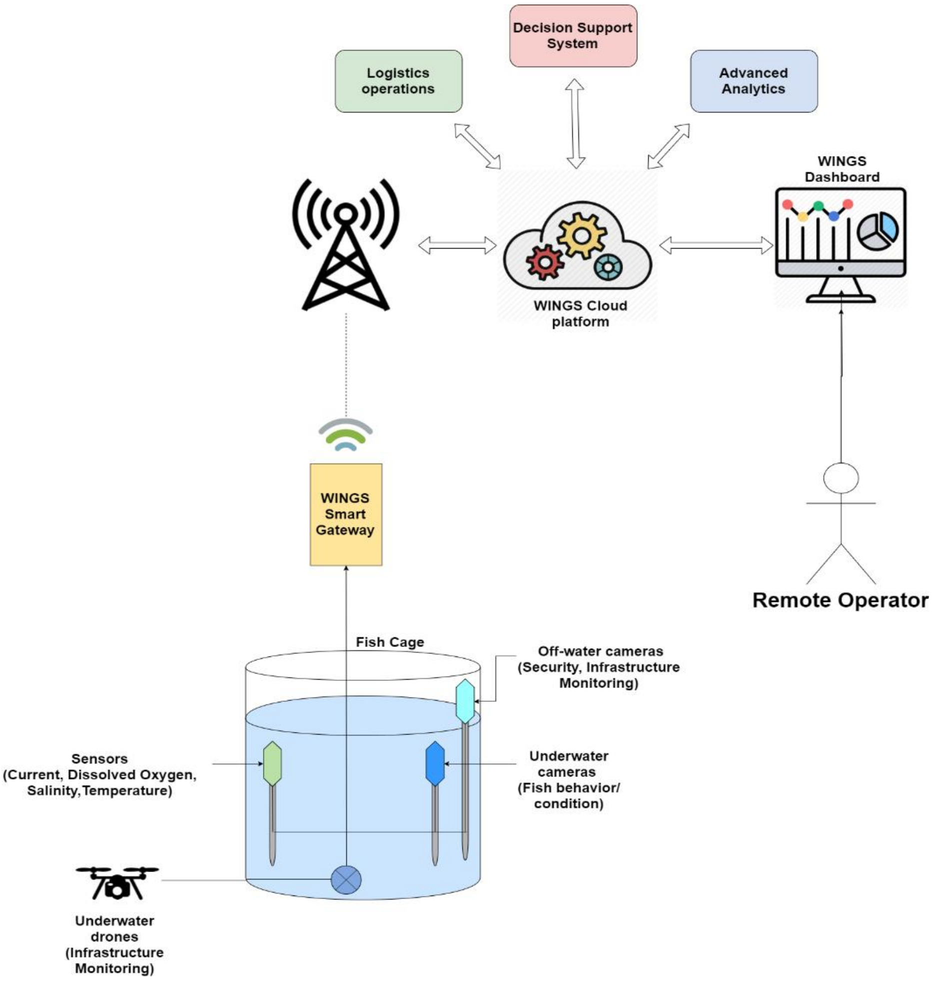


Figure 9: Greek pilot site architecture

Transmission methodology:
- 4G/NB-IoT if available
- WiFi if possible from the device to the network infrastructure available
- LoRa or other protocols

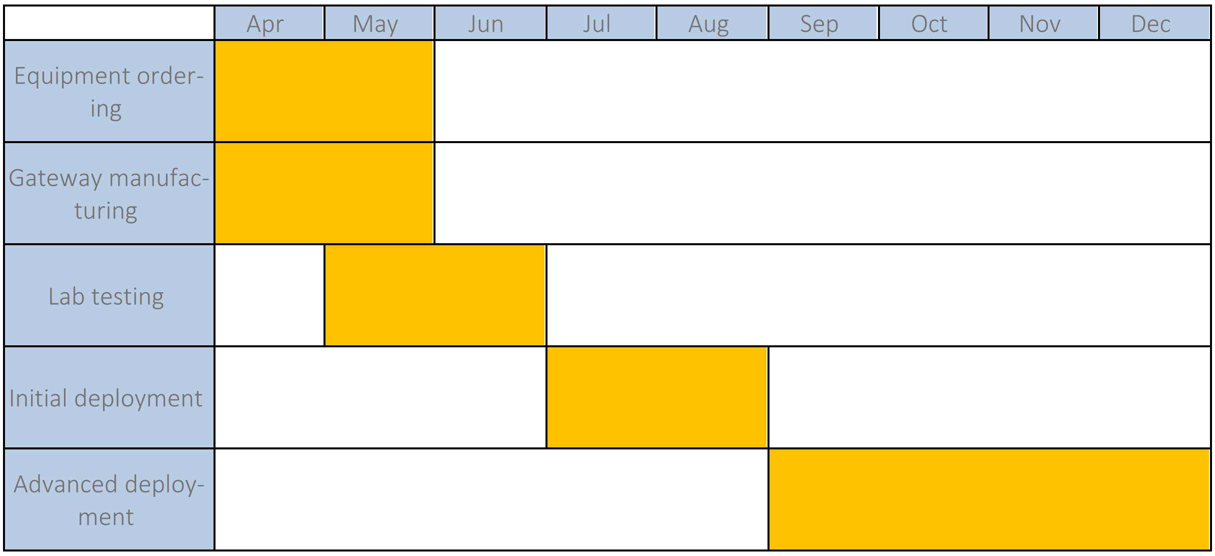
Implementation

The deployment of the pilot will take place in a series of steps that are described as follows:
- Equipment order for testing: i) Two underwater cameras, 1 for lab testing and one to be deployed on the field. ii) One multi-parameter unit sensing water quality parameters such as temperature, dissolved oxygen,

salinity, turbidity, chlorophyll-a, pH etc. iii) One current meter is also considered for monitoring the water currents at the site.

- Transmission devices manufacturing: The gateways that are going to handle the transmission of the data from the site to the cloud platform are going to be manufactured satisfying the requirements of the sensors and cameras.
- Lab testing: The aforementioned equipment and transmission gateways are going to be excessively tested at a lab environment before moving to the actual aquaculture environment.
- Deployment: The actual deployment of the multi-parameter sensor and the underwater camera is going to take place.
- Additional deployments: Additional equipment like the current meter, more water quality sensors or an underwater drone that may be considered necessary at a later stage of the project will be ordered and deployed alongside the rest of the equipment.

Below, a GANTT chart for year 2020, shows also the timeframe of the aforementioned steps:



Below, the choices of sensors considered for the site are displayed:

Dissolved Oxygen and temperature

Model	Company	Price (EUR)	Notes	url
InPro Optical	Mettler Toledo	NA*	Asked for quote. No reply	click
DO profile probe	OxyGuard	2840	Asked for quote. Price is from partners' list	click
Oxygen probe	OxyGuard	540.2	With anti-fouling cap, galvanic	click
Optical DO	YSI	NA*	Proprietary device	click
Optical DO	Aanderaa	1460	+395 for 10m cable	In folder
Galvanic DO	Sensorex	NA	Asked for quote. No reply	click
Hamilton VisiFerm	Yokogawa	NA*	Asked for quote	click
Hamilton visiTrace	Yokogawa	NA*	Asked for quote	click
Lumin-S optical DO	Sensorex	1165.88	316 steel (also comes with titanium encasing)	click
DO6400	Sensorex	498.46	Galvanic	click
AnaCont LED	Nivelco	NA*	Transmitter for surface waters, offer by TCB ?	click

Turbidity

Type	Company	Price (EUR)	Notes	url

Turbidity	Mettler toledo	NA*		click
Turbidity	Real tech	NA*		click
Turbidity	Chelsea Technologies	NA*	RS232, 0-5V, SDI-12 and 4-20mA	click
Turbidity	Intermountain Environmental Inc	NA*	SDI-12 output	click
OBS501 Turbidity	Campbell scientific	NA*	SDI-12, RS232 and 0-5V	click
Turbidity	Aanderaa	NA*		click

Chlorophyll, Nitrates and ammonia

Type	Company	Price (EUR)	Notes	url
cphyll	Eureka water probes	NA*	fluorometer	click
Vlux miniSOnde	Chelsea Technologies	NA	Multi-parameter (includes PAH, BTEX, cphyl a and b, etc)	click
UviLux	Chelsea Technologies	NA*	PAH, Tryptophan, BTEX, NDSA, PTSA	click
UniLux	Chelsea echnologies	NA*	Cphyll a, cyanobacteria, rhodamine, fluorescein	click
Ion PRO probe sensor	Libelium	NA*	Ammonium and NO3 included	click
ammonium	ECDI	NA*		click
Nitrate	ECDI	NA*		click

Multi-parameter sensors

Mutli-parameter sonde	Compnay	url
AP2000/5000/7000	Aquaread	click
Aqua TROLL 400/500/600		click
EXO 1, 2 ,3	YSI	click

According to the budget submitted to the proposal, KASTELORIZO can provide a budget for equipment of 14K each (sensors + cameras + transmission gateways + other equipment) with WINGS also assisting in buying the proper equipment.
As for the camera, the model that is going to be initially tested and used is the BARLUS UW-S5-4CS.

*NA: Not Available

Software platform: A software platform that will facilitate the aquaculture site and the multi-use activities in four ways:

1. For added value services, based on Artificial Intelligence that will help improve the operational management of the aquaculture unit.
2. To monitor environmental conditions of the pilot site
3. To monitor fish behaviour, in order to track any disturbance to fish of the aquaculture unit from touristic and marine activities
4. To schedule the multi-use activities between the aquaculture unit, the touristic expeditions (and all the linked activities and scenarios between the two)

More specifically, the software platform can provide:

Monitoring and management

- Production monitoring: Production parameters such as stock density, FCR, stock size and more information are all visualized at the homepage of the site as well as in each specific structure's dedicated information page.
- Environmental monitoring: Environmental parameters can be monitored at all times via the dashboard. Important values are always displayed on the dashboard, while the user can always access each individual sensor and check the evolution of their parameters' time series in dedicated charts. Additionally, the water quality analytics that are executed on the background are visualized and indicate trends for specific parameters, as well as identified outlier values or threshold violations that were observed.
- Behaviour monitoring: Behaviour monitoring is available through a dedicated page where the user can select one of the installed cameras (if any) to live stream its output.
- Remote sensing monitoring: Satellite footage is daily recorded in the pilots. Satellite images can be displayed for the user to inspect at any time.
- User data input: Operational data such as manual observations or husbandry operations can be regularly reported through a series of input forms.
- Task management: The management of the maintenance, operational and husbandry tasks is one of the features that is also offered by the dashboard.
- Configuration: A settings page allows the operator to declare their preferences in terms of parameters, protocols and other options. Additionally, the configuration of the site can be modified here, editing the structures, the species residing on site and other characteristics of the farm.

Decision Support System

A Decision Support System (DSS) to drive the business logic of the system and assist the operator to make decisions regarding different aspects of the operation. Algorithms will be developed based on the aquaculture farm's business requirements and exploit the available data collected to answer specific questions for the user or provide an overview of the status to facilitate decision making.

Scheduling of the MU activities

A number of mult-use activity scenarios are planned to take place during the operational phase. These scenarios need to be co-ordinated by the software platform that will schedule the events and create requests for a particular activity from either the aquaculture unit or the diving center. Such events/scenarios namely could be:

- Mapping of underwater landscape of aquaculture site with the use of ROV (owned by Planet Blue)
- Diving expeditions to the aquaculture site (unique wetland for divers to see)
- Diving expeditions for cleaning aquaculture area from waste
- Inspection with the use of (Remote Operating Vehicle) ROV of the aquaculture diver while repairing the infrastructure
- Inspection with the use of ROV of the aquaculture infrastructure that are placed in great depths (anchors)

3.2 Definition of technical multi – use cases requirements

The following requirements for tools and solutions have been formulated, which shall be developed within UNITED, in order to facilitate up scaling of MUCL systems and contribute to reach demonstrators in an operational environment (TRL7).

Technological (support) systems and tools

- Planning tool (software), to organize logistics (optimal maintenance windows/ harvest/ installation) and detect the optimal point in time to save resources (minimize labour input), to minimize economic losses (due to harvest/product quality losses) (D2.5)
- Design a boat scheduling system to organize tourism activities (diving, fishing, boat tours) (D2.5)

- Develop new technological concept to enhance the connection between offshore and coast for data transmission and remote monitoring of pilots (use loRA gateway and in-between node in case of inadequate connectivity) (D2.6)
- Using wave buoys and developing numerical models to quantify the wave dampening effect of floating solar arrays using wave buoys and numerical modelling (e.g. SWAN), creating an environmental monitoring plan to monitor the ecological impacts of aquaculture and solar power activities in a co-use setup (D4.4)
- Optimise off-shore equipment (oyster/mussel grow-out systems, long lines, scour material, seed collector, holding system) (D8.1)
- Developing reliable predictive mathematical models for the evaluation of field-measurement data (e.g. water quality variables, oyster growth, predation, biodiversity etc.) (D8.3)
- Develop an intelligent management system (IMS) and a decision support system (DSS) (D2.5)

A potential decision support system could follow the approach of Figure 10.

1) Problem identification
2) Problem analysis
3) Developing and evaluating potential solutions
4) Selection of best solution
5) Transferring solutions into actions
6) Following up on the actions and validation of outcome

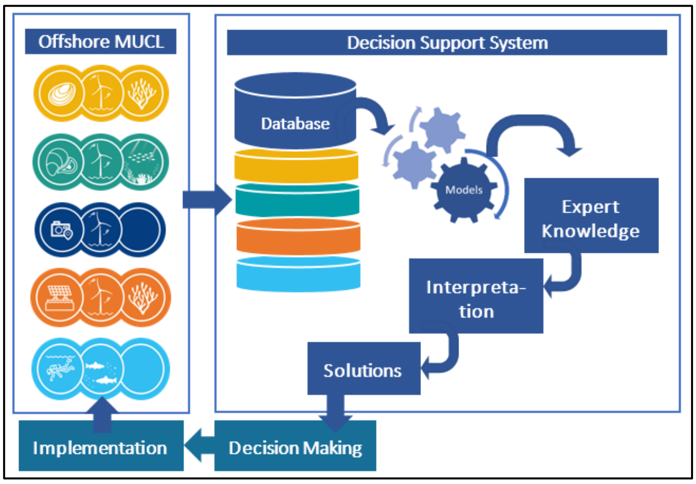


Figure 10: Process of a decision making support system

Organizational guidelines supporting decision making

- Collection of standardized implementation guidelines as solutions for all aspects of MUCL (social, environmental, technological, law, administrational) (D4.4, D5.5, D6.4, D7.2)
- Administrative guidance tool for political and administrative workers to facilitate the future implementation of MUCL systems (D5.3, D6.4)
- Standardized conceptual design description and test protocol guidelines for the implementation and maintenance processes of MUCL plants, callibration standards for complex measurement tools, as well as defined technological requirements with regard to Pilot site infrastructure (identification of infrastructure limits), such as network load (due to multiple sensors/cameras), power supply, network bandwidth to support multi equipment transmission (D7.2)

Based on the questionnaire that was addressed to the pilot leaders during Task 1.1:

German pilot technological aspects regarding technological requirements of multi-use:

1. <u>Type of information /tool/ equipment that would help to make upscaling off German pilot's multi-use activities possible:</u>
   - Broad data bases on biotic/abiotic factors and reliable models; software for analysis
   - Experienced/well trained staff and standardized procedures; training offshore facilities, experts in the field of offshore engineering

- Planning tool to organize logistics (optimal maintenance windows/ harvest/ installation) and find optimal point in time to save resources (minimize labour input), to minimize economic losses (due to harvest/product quality losses), e.g.: "seasonal variability, where the highest yields of laminanarin and mannitol coincided with the lowest yields in ash, protein, moisture and polyphenols. Clearly, the harvest strategy must be adjusted to the product the kelp shall be converted to (human consumption, biochemicals, biomass).
- Administrative guidance tool: to bring all relevant political and administrative workers together and create a guideline or a single contact person (contact office for future permissions)

2. Processes/ parameters to be monitored in addition or instead of what the German pilot already has been monitoring so far:

A lander will be installed, that will record the following additional data to the already recorded hydrological and meteorological data.

Sensor - detected parameters:

- Combined CTD and O2-Sensor Conductivity, Temperature, depth, O2, salinity
- PH-Sensor to measure the PH-Value
- Fluor Sensor to measure Chlorophyll and Algea-Values
- Echosonder to measure Water contents (concentration of faeces)
- Pan- and tilt-device echosonder to ensure wide angels (movement of longline)
- Electronic and transponder echosonder that are necessary for function
- ADCP to measure local current velocity
- Light sensors to measure daylight intensity
- Turbidity sensor to measure turbidity
- Cameras to get photos (mussels, fish, antifouling)
- LED Lights next to cameras
- NO3 Sensor NO3 and UV Light
- Biofouling Sensor to measure biofouling

Dutch pilot technological aspects regarding technological requirements of multi-use:

1. Type of information /tool/ equipment that would help to make upscaling off Dutch pilot's multi-use activities possible:

Not possible to answer yet

2. Processes/ parameters to be monitored in addition or instead of what the Dutch pilot already has been monitoring so far:

To be defined with the partners. Oceans of Energy will probably measure wave height to be able to get insight in the wave demping possibilities of floating solar energy/panel structures

Belgian pilot technological aspects regarding technological requirements of multi-use:

1. Type of information /tool/ equipment that would help to make upscaling off Belgian pilot's multi-use activities possible:

- Broad data bases on biotic/abiotic factors and reliable models; software for analysis
- Governmental support to develop the whole value chain
- New tools for monitoring offshore

- New technology to enhance connection between offshore and coast (reduction of travel time, independent from
- wheather conditions,etc.)

2. Processes/ parameters to be monitored in addition or instead of what the Belgian pilot already has been monitoring so far:

- Presence of parasites (Bonamia and Marteilia), which has never before been done for the Belgian part of the North Sea
- Oyster spat fall
- Oyster growth
- Oyster restoration on the structures set out at sea
- Kelp growth
- If possible cameras or with AUV monitoring of settlement and restoration of material set at sea
- Lander would have been interesting but is unfortunately no longer available

Danish pilot technological aspects regarding technological requirements of multi-use:

1. Type of information /tool/ equipment that would help to make upscaling off Danish pilot's multi-use activities possible:

Not relevant

2. Processes/ parameters to be monitored in addition or instead of what the Danish pilot already has been monitoring so far:

Missed opportunities for visit caused by lack of infrastructure

Greek pilot technological aspects regarding technological requirements of multi-use:

1. Type of information /tool/ equipment that would help to make upscaling off Greek pilot's multi-use activities possible:

Increase of the network bandwidth, to support multi equipment transmission, install extra solar panels to cover the power needs

2. Processes/ parameters to be monitored in addition or instead of what the Greek pilot already has been monitoring so far:

Processes to be monitored will be:

- For aquaculture site:
  - Feeding procedures,
  - Repairing infrastructure (nets, anchors),
  - Maintenance on technological equipment installed (sensors, cameras),
  - Waste management processes,
  - Behaviour monitoring , disease diagnosis for the fish.

Regarding the Scuba Diving center:

  - Timetable of scheduled expeditions to site,
  - Equipment used for expeditions.

Parameters to be monitored: Water quality parameters, such as Dissolved oxygen, temperature, chlorophyll, nitrate

3.3 Parallel solutions in terms of technology and pilot installations

All pilots will carry out some common activities to facilitate their synergies and co-use of marine space including:

- An overview of the foreseen operational activities
- Measurements (remote/on-site)
- On-site inspections
- Tests/demonstrations
- Sample collection
- Visitors
- Trainings
- Frequency of the foreseen activities
- Setup, procedure for the activities
- Type of vessels used
- Type of crew/ people required

Each pilot though has tailored its activities based on the TRL, the specifications of their co-activities, the site's geographical location particularities and many other parameters. Below a summary of the parallel activities that will take place in each pilot during the pre-operational phase (these activities are likely to keep taking place in other phases as well):

German pilot

The work and installations for the German pilot will mostly aim on the development of remote control/operation practices of plant (monitoring devices have to be automated) with high durability, as well as the development of Data Acquisition and Control System (DACS) as well as a communication system.

Nearshore - Kiel Marine Farm (Baltic Sea)

Longlines have been installed in April 2020 to test and adjust automation and monitoring equipment before operating offshore. The line is anchored to the bottom with drill anchors and weights. The Kiel Marine Farm operates a harvesting and supply boat from the close harbour and has some on-land storage facilities, power supply and an office to support the pilot.

Offshore- FINO3

Seaweed and mussels will be cultivated within a 500m radius from the research plant FINO3 (operated by FUE). The wind farms as well as the area (500m radius) around the monopile are marked as safety zone in the nautical maps and prohibit any trespassing or entering. The longline structures will be submerged 4 to 5m below the surface, reducing the wave action on the installation. Via remote monitoring data on biomass growth (mussel, seaweed), as well as biotic and abiotic environmental parameters are collected to assess the environmental suitability of the offshore site for aquaculture production and evaluate potential impacts of the longlines on marine flora and fauna. For this, a benthic lander will be positioned below the mussel and algae cultivation site while additional sensors are attached directly to the longlines. The collected data will be transmitted to FINO3 via a sea cable from the lander to the platform, from where it is sent via an independent satellite connection onshore.

Dutch pilot

The NSIL will install a net construction for the culture of seaweed in the North Sea. The first phase of this pilot will focus on the current questions that have not been answered yet regarding offshore seaweed systems, whilst successfully harvest seaweed. These questions relate to the measurement of data, remote monitoring and anchoring. The first year is focused on retrieving knowledge on the behaviour of the net system, where the second year will be on optimising the net system if needed.

The Dutch pilot is building upon the latest technology available in the marketplace: The AtSeaNova & SMAC3.0 system. The Dutch pilot is developing the SMAC4.0 system that will be an improvement on the SMAC3.0 system. The improvements will include adding multiple substrates in one single system as well as verification of the best orientation of the system. It will be useful if mooring force measurements as well as remote monitoring systems could be employed.

Belgian pilot

In the pre-operational phase, different aquaculture systems will be tested nearshore at the site of Westdiep (Figure 1) at 5km off the coast in front of Nieuwpoort (average depth 15m). The nearshore site of Westdiep has several longlines since April 2017, being part of the Belgian projects "Value@Sea" and "Symapa" and is managed by UNITED partner Brevisco. The lines are currently used for test productions of flat oyster (Ostrea edulis), blue mussel (Mytilus edulis) and seaweed. In UNITED, the nearshore site will be used for testing different types of growing equipment for flat oyster, nature-inclusive scour protection and for sugar kelp (Sac-charina latissima) growth. The best performing set-up will be selected and applied in the operational phase at the offshore site.

Greek pilot

During the pre-operational phase, this pilot will install hardware which will monitor and collect data in the aquaculture farm. There is a lacking network at the aquaculture site. There is no 4G network available at that point. Therefore, the pilot is installing connectivity equipment, which is connected to the shore, where telecom network is available. The pilot will also install a physical platform in the water where any necessary equipment can be stored.

As a pilot lead, WINGS and technical manager of the pilot, WINGS plans to install different types of sensors for measuring water quality parameters, in the fish pens of the aquaculture. Off-water and underwater cameras could also be installed in site to monitor fish behaviour and for disease prevention as well as to facilitate in measuring the food waste that remains in the cages. WINGS smart gateway, a device produced by WINGS that will be installed in the aquaculture site as well, will be responsible for transferring the data coming from sensors and cameras to the cloud (via the available network). In the cloud platform of WINGS, advanced algorithms based on Artificial Intelligence will produce Advanced Analytics through the data measurements that will facilitate the understanding of the overall production to the aquaculture owner. The WINGS platform also will provide a Decision Support System that will facilitate in the operational procedures and in the optimization of the production. The Dashboard will be used for the data visualization to present the results of the algorithms developed in the platform.

4. ANALYSIS OF THE CHALLENGES IDENTIFIED FOR SUCCESS IN EACH PILOT

4.1 Identified challenges per pilot

Multiple challenges, which all Pilots face, are identified in deliverables D1.1 (technological-, economic-, environmental-, social-, legal barriers) and D5.1 (stakeholder assessment).

4.1.1 German Pilot

Challenges for offshore mussel and seaweed long line cultivation

As the German Pilot is located in a high energetic environment (50-year wave of approximately 18m), it is not accessible during severe weather conditions during the fall and winter months, which emphasizes the need for automated data collection and remote monitoring through robust technology (long lifetime and service intervals). Vessels can only access the plant at a swell below 1m wave. The plant can be reached via helicopter until wind speeds of 50 knots, however in case of thunderstorms, neither flying to the platform nor working is possible. In order to install a sea cable by divers, wave heights must remain below 1m, which only occurs during summer months. These intense offshore situations also require resistant mooring and anchoring solutions to prevent the mussel and algae long lines from tearing and breaking away. Cost-intensive and time consuming Pilot visits via vessel have to be minimized (service/maintenance and recovery of different materials/ measuring devices should be combined within one work stage), thus maintenance of algae and mussel long lines can only be conducted twice a year (during the project). However, in the future, these technical and logistical problems may be solved by special harvesting and processing ships, which withstand intense weather conditions, or by automated treatment and transport procedures. Further identified challenges of the German pilot are:

- Reduced availability of skilled labour (offshore experience)
- General insufficient knowledge of and information on biological data for offshore location, e.g. time and scale of spat fall, growth rates of mussels and seaweed
- Limited knowledge about mooring prerequisites for mussel and algae long lines at site
- Damage risks of mechanical loads, collisions with vessels/ships/fishing boats
- Drifting aquaculture construction strikes the turbine foundation and possibly damages the foundation? Extra drag force of drifting aquaculture construction gets stuck around the turbine foundation, increasing its surface area
- Equipment and material has to be resistant to: antifouling, high forces acting on installation (waves, tides, current, storms, high salinity, corrosion)
- Sufficient database of biotic/abiotic factors (fields of: meteorology, physical oceanography, marine chemistry, biology, geology, geography) is needed to run realistic models during the planning/conception phase (simulation and calculation are based on long-term data recordings)
- Long administrative process to get permits from the government
- To make future growth profitable and hence economical feasible, up scaling is crucial with regard to economies of scale
- Quick response and fast track food and fodder quality tests have not yet been established within the EU, the existing fast track test in Ireland is not validated/established in EU

Challenges during the construction of the monopile

During the construction of FINO3, the monopile was planted 30m deep into the seabed, applying a hydraulic hammer. Complications, which need to be kept in mind during the general ramming process of monopiles, may arise from stones and scour. Another challenge, during the monopile construction, is the noise emission, which negatively affects marine mammals (e.g. harbour porpoise). During the construction of FINO3, a sound-absorbing veil of air bubbles was applied for the first time in an offshore foundation around the construction site. Further risks lie in the production, transport and assembly of material on land and at sea as well as obtaining special spare parts.

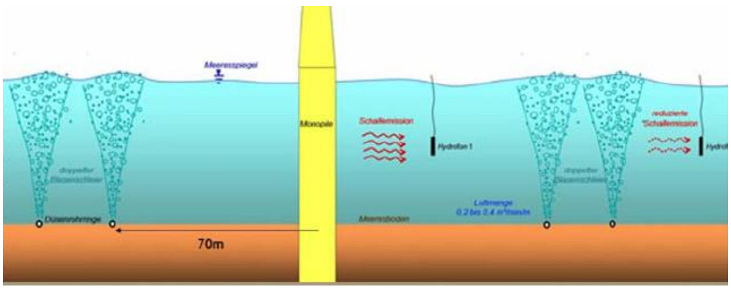


Figure 11 : Application of sound-absorbing veil of air bubbles during ramming of monopile for FINO3, to protect marine mammals from acoustic noise emission.

4.1.2 Dutch pilot

Regarding the Dutch pilot, the **main obstacles** to overcome are:

- the safe deployment of the different operational activities (seeding, growing, harvesting and processing)
- the elimination of risk of damage to the wind infrastructure

Bottlenecks to be addressed are the technology of large scale harvesting of the seaweed and the alignment of peak activities (boat movements, heavy equipment) during the harvesting. The results of this work will help TSC and wind park owners enormously in the development of large-scale offshore seaweed farms in existing wind parks and for offshore wind farms that are to be planned (offering integrated wind/aquaculture activities in tender-phase) in the North Sea, and synonymous areas.

Combining solar power production and aquaculture in an offshore environment could potentially have significant positive impact. Specifically, for the aquaculture, as it is generally difficult to monitor the "health" of the aquaculture production system that is located far offshore. Therefore, sensors (e.g. temperature, light, turbidity, algae, nutrients etc.) that are able to transfer their measurements to an onshore monitoring station are required for remote operation of these production facilities. The first task is to develop a suitable operations & maintenance (O&M) concept that is able to realize the synergy of aquaculture and solar co-use. This will identify all the boundary conditions for this form of co-use. Based on this a suitable connection between the solar and aquaculture production system will be engineered, built and tested (demonstrated). This connection should demonstrate that it is possible to transfer power between an aquaculture and solar production system in an offshore environment. Due to the large distance between the aquaculture & solar systems in the pilot, the aquaculture production system will be simulated by means of a reference buoy that will be placed close to the solar system. This will reduce cost significantly still be fully representative of this use case.

4.1.3 Danish Pilot

In the case of Middelgrunden Wind Farm, the constraints and problems that affect all aspects connected to offshore activities are related to the tourism activities around the wind farm.

Middelgrunden wind farm was established in year 2000. And during its construction the challenges and barriers associated with the engineering, ecology, legislation, society, economy, and health and safety of personnel, were dealt with.

No big constraints or problems are foreseen with the expansion of tourism activities at the site, or with the inclusion of other target groups in the tourism activities such as the association of divers. The health and safety of personnel is a key issue. It is now dealt with both during the boat tour and while accessing the turbines foundations. Specific instructions to the visitors are given.

4.1.4 Belgian Pilot

Multiple challenges, which all Pilots face, have extensively been identified in deliverables D1.1 (technological-, economic-, environmental-, social-, legal barriers) and D5.1 (stakeholder assessment).

Regarding the Belgian pilot:

Challenges for offshore flat oyster and seaweed longline cultivation and restoration of flat oyster

As the Belgian Pilot is located in a high energetic environment, it is not accessible during severe weather conditions, which are often apparent during the fall and winter months. This emphasizes the need for automated data collection and remote monitoring through robust technology (long lifetime and service intervals). Vessels can only access the plant at a swell below 1m wave. These intense offshore situations also require resistant mooring and anchoring solutions to prevent the oyster and algae long lines from tearing and breaking away. Cost-intensive and time-consuming pilot visits via vessels need to be minimized (service/maintenance and recovery of different materials/ measuring devices should be combined within one work stage), thus maintenance of algae and oyster longlines can only be conducted at limited frequency. Further identified challenges in the Belgian pilot are amongst others:

- Distance from the coast: 50 km
- Exposed North Sea conditions: single wave height of 12m is to be expected
- Disease management (e.g. *Bonamia* and *Marteilia*)
- Timing of the project
- Mooring prerequisites for oyster and algae longline at site
- Damage risks of mechanical loads, collisions with vessels/ships/fishing boats
- Loss of an anchor

- Equipment and material has to be resistant to: fouling, high forces acting on installation (waves, tides, current, storms, high salinity, corrosion)
- General insufficient knowledge of and information on relevant biological data for offshore location, e.g. time and scale of spat fall, growth rates of oyster and seaweed offshore
- Sufficient database of biotic/abiotic factors (fields of: meteorology, physical oceanography, marine chemistry, biology, geology, geography) is needed to run realistic models during the planning/conception phase (simulation and calculation are based on long-term data recordings)
- To make future growth profitable and hence economically feasible, up scaling is crucial with regard to economies of scale
- Quick response and fast track food and fodder quality tests have not yet been established within the EU, the existing fast track test in Ireland is not validated/established in EU

4.1.5 Greek Pilot

Identified barriers by the pilot

Ancient artefacts and private property:

One issue that should be taken into consideration, is that island PATROKLOS is a private property that has also been characterized as an archaeological area and placed in a zone of absolute protection which prohibits any kind of construction. Strict protection measures and resistance from authorities protecting ancient artefacts, usually restrict tourist access to UCH sites due to risk of damage and theft. Licenses and legal issues should be investigated in order to proceed to any intervention in the marine space around that islet.

Other possible barriers to realizing multi-use include economic concerns (opportunity costs, disruption of farming operations and balancing value and expectations with costs), societal concerns (disapproval of the aquaculture operation by the local community) and environmental issues (risk of excessive feeding of fish, impact on stress levels of fish).

Economics challenges:

Other possible barriers to realizing multi-use include economic concerns (opportunity costs, disruption of farming operations and balancing value and expectations with costs). Better understanding of the economic performance of marine aquaculture production systems in combination with tourism is needed to stimulate investment. Economic and financial analysis is needed, including estimation of capital requirements and production costs, return on investment, and internal rate of return. The models should also include a comprehensive risk analysis, reducing risk and maximizing economic performance. Maintenance costs including those of sensors, ROVs and diving gear should also be taken into account.

Societal barriers:

Aquaculture itself in the pilot site has already triggered environmental and social concerns, which have influenced the way the public might perceive the multi-use. The image of aquaculture is frequently negative across countries and regions, and very often based on the negative impacts of very few commodity species [1]. To face and improve the negative image of the multi-use, there must be a proactive as well as reactive communication with society. Removal of negative perceptions takes time, and a paramount premise is transparency and the avoidance of environmental and food safety scandals. The ultimate challenge is to tackle this negative image by clarifying responsibilities with public and political stakeholders, and to make aquaculture a prioritized activity in most coastal nations.

Environmental barriers:

The effect of the multi-use on the environment (tourists overcrowding the area, waste dismissed in the water or the coastal area) is a challenge that needs to be effectively tackled. What is more, waste management of the aquaculture site (feeding waste left not consumed by the fish in the pens, as well as dead fish and fish emissions), that is currently manually monitored and handled by sampling, needs to be enhanced with the use of a smart system that will be installed in the site, that will consist of sensors collecting measurements sent to a cloud platform to produce timely alerts to the fish farmers to take action, as well as produce analytics insights to farm managers to be aware of the progress of the environmental conditions in the farm.

Technical barriers:

Sensors:

The measurement needs for the multi-use activities can be divided into two overlapping categories. In one category are measurement needs to advance aquaculture production. These measurement needs require the development or application of sophisticated and advanced scientific and engineering tools and techniques. Advances in health diagnostics, stress and digestive physiology will require development and application of these new tools (FAO, 2010).

In another category are the measurement needs for the operation and management of commercial facilities, particularly as part of monitoring and control systems. Measurement tools for commercial facilities must be robust and cost-effective. Sensors have been widely used in aquaculture, particularly in monitoring water quality. Ideal sensors in aquaculture would be low-cost, robust, resistant to biofouling, self-calibrating, permit remote operation, and provide measurements in real time.

The value of sensors increases with connection to control equipment that manages life-support systems or automates husbandry operations. Sensors are available to measure temperature, salinity, dissolved oxygen, and water currents, although wider use of some sensors is constrained by high cost and uncertain reliability. Sensors to measure or estimate phytoplankton and microbial biomass and activity need improvement. Sensors (e.g., video, sonar) and image analysis can be used for biomass estimation, inventory control, equipment inspection, environmental observation, and farm security. These sensors can be used as components of feeding systems in cage culture. In some cases, sensors exist, but cost reduction is needed for routine application.

Connectivity:

Connectivity issues should be investigated and carefully planned for the pilot, as sensors and cameras might be demanding in terms of speed, bandwidth, latency, and data load.

Legal and insurance barriers:

Concerning any multi-use legislation, this has not been considered yet, though aquaculture operations and activities should be carried out under very specific rules. These rules should be followed to any other operations that are going to take place in the aquaculture premises. Accordingly, for diving expeditions near aquaculture sites, no related regulation has yet been established. What needs to be considered is the safety regulations and the different types of insurance needed for: a) the aquaculture staff that will be involved, b) the diving tourists and the diving instructors, c) any accidental damage to the aquaculture infrastructure and the diving gear.

4.2 Mapping with identified challenges risks and barriers from literature review

4.2.1 German Pilot

In the following chapter, challenges, risks and barriers from literature and their relevance for the German pilot are presented. Generally, constraints and problems affect all aspects connected to offshore activities, such as engineering, ecology, legislation, society, economy, as well as health and safety of personnel. Due to the increased complexity of offshore structures only major aspects are addressed and thus, the list does not lay any claim to completeness.

Technical and logistic challenges

La Riviere et al. (2015) pointed out the extensive logistics, required for the installation and maintenance of offshore wind farms. These observations can be confirmed with long term experience of operating FINO3, where equipment and trained personnel at the right place and at the right time play important key factors. However, even more crucial are meteo- and hydrodynamic conditions. Particularly, weather windows - during which marine operations are permissible regarding wind, wave, water level or current conditions – determine the critical path in an offshore project. Hence, unexpected bad weather conditions may lead to a delay of offshore operations, resulting into high costs, as well as risks of safety and damage to equipment (La Riviere et al., 2015). Christensen et al. (2015) predicted, that investment cost of offshore equipment (cages, anchoring, long lines) can easily be doubled compared to coastal aquaculture, making it difficult to attract investors. Although, meteo- and hydrodynamic forecasts can be obtained from various public and commercial sources, their quality often lacks good in-situ measurements. La Riviere et al. (2015) stated, that especially for installation or maintenance of high-tech structures, such as offshore wind turbines in shallow-water regions (say <30m), the present hydrodynamic forecasts are considered to be inadequate. They assume, that present forecast modelling systems are often calibrated against storm conditions and not specifically for mild weather conditions with wave heights of up to 1.5m, during which wind farm installations and maintenance typically take place (La Riviere et al., 2015). The challenges of such high energetic environments are not new to the (service-) team of the German pilot and over time, extensive experience was gained in scheduling operations and trips to the plant. Nonetheless, it is important to account for unforeseen weather related complications and react appropriately regarding planning. In the MERMAID project, a major difficulty presented the grid connection of the MUCL system, due to the costs induced by the long distance to the shore (27 km from the closest harbour) and the environmental impacts of the cables on the soft bottom (Christensen et al., 2015). This, will not be an issue for the German pilot, as only a short sea cable has to be installed (~100m) from the lander, positioned underneath the long lines, to FINO3, which is powered by its self-sufficient energy supply on the platform via three generators. Regarding geotechnical challenges (Claus et al., 2014) affecting the overall structure and foundation of the German pilot due to the effects of waves, currents, seismic loads, or a combination of all, can be neglected, as these matters were addressed during the construction of FINO3. Overall, offshore environment poses particular constraints, barriers and challenges to the technical infrastructure (Losada et al., 2013), regarding the:

- Plant and its installation (e.g. load out complexity), operation and maintenance (e.g. grid outage) and decommissioning (e.g. removal of marine structures may result in pollution and disturbance of established habitats on the structures; specifically, removal of moorings and fixed foundations may present a higher risk; polluting fluids or materials)
- Equipment: mooring line system, foundation, anchors, corrosion, scour, fouling, fatigue (of transition piece), component failure
- Logistics: vessels, ships, personnel, transportation of equipment, collision risk of vessels, container ships and fishing boats

Ecological challenges

During the Mermaid project various ecological issues were noted, such as potential negative environmental impacts on marine ecosystems due to converters, structures and foundations of wind turbines. Aside from multiple environmental impacts (detailed description in deliverable D4.1: "Current Environmental Assessment Status of Pilots"), challenges in marine seascape conservation remain for all UNITED pilots, when combining ecological principles with the design of marine infrastructures (Claus et al., 2014). Hence, mitigation measures and eco-compatible design solutions need to be identified and the selection of construction materials and maintenance processes are carefully examined (Pirlet et al., 2014) and instructions of relevant directives such as MSFD (GES -Good Environmental Status, implemented in all EU member countries) are followed, particularly sections referring to energy introduction (i.e. noise production limits) to the sea environment (Van den Burg et al., 2017).
Challenges may also arise, in food quality of seaweed and mussels products. Unforeseen contaminations due to algae bloom presents a risk, as environmental conditions cannot be controlled (La Riviere et al., 2015). Furthermore, it was pointed out that the "organic farming" brand name could be compromised due to combination of aquaculture-shellfish with a wind park on "industrial" production setting, which could ultimately result in higher costs and/or lower revenue generated (Van den Burg et al., 2017). Furthermore, uncertainty about climate change and its consequences on aquaculture and energy production remain, which are impossible to predict (La Riviere et al., 2015).

Legislative challenges

One of the main challenges to aquaculture is the difficulty in getting permissions to exploit the ocean space for aquaculture production due to regulatory/institutional restrictions. Although, European policy-makers are strongly interest in co-production of energy and food, permitting procedures for upcoming industries, such off-shore aquaculture, and co-production are lagging behind (Christensen et al., 2015). Moreover, the lack of the definition of standards and standard procedures (e.g. assessment of (environmental) impacts, selection of the MUCL scheme suited to a given site) complicates a unified procedure for permissions and leads to unclear and lengthy licensing procedures. In order to find investors, the license procedure needs to be faster than today and uncertainties need to be minimised. Most EU countries face legal uncertainties with respect to property rights to production sites, balancing the access for the different activities (i.e. energy extraction and aquaculture), and un-certainty with respect to insurance and liability issues at multiuse sites (Christensen et al., 2015). Although, these constraints are not relevant for the installation of the German pilot, as all licences and official approvals were already obtained, do they present a serious barrier for future up scaling of commercial MUCL systems.

Social challenges

Cooperation between industries (e.g. aquaculture and energy) requires a positive attitude of the parties involved, which is not always easy, as company cultures may differ (Christensen et al., 2015). Often, the EU public perceives negative effects of marine aquaculture without accounting for positive effects - such as the potential relaxation of the exploitation of benthic fish stocks and habitats. The MERMAID project classified persistent opponents to ma-rine aquaculture into 1) coastal residents who fear impairment of waterfront views and waste accumulation on beaches, and 2) environmentalists in a broad sense, who are concerned about pollution, impact on the ecosystem. Due to these reasons, the UNITED consortium has planned many different stakeholder engagement activities to connect people from different (industrial) backgrounds and lay the basis for harmonious collaboration in the fu-ture. These engagements will also include other external stakeholder groups, which may also be subject to con-flicting user needs (harbours with commercial and tourist maritime routes, fisheries, oil and gas platforms, natural habitats, restricted conservation areas (Christensen et al., 2015).

Economic and financial challenges

Due to higher risks resulting from offshore environment, economic feasibility is negatively affected. One of the biggest challenge for offshore sites is to find solutions that are profitable for all stakeholders. This includes analysis of risks and (extra) insurance costs. A successful co-production requires a site suitable for both energy and food production. This is not self-evident and there might be a lack of suitable ocean space (Christensen et al., 2015). Financial support related constraints could develop due to lack of (or removal of) investment, triggered by a num-ber of possible causes (Van den Burg et al., 2017):

- Wait-and-see investors, who do not invest due to the risk of losing development costs and due to little benchmark data
- Finance instruments related problems
- Poor lending appetite from banks resulting from low economic climate
- Lender fail to comply with financial legislation/regulation (Basel III, Solvency II)
- Price fluctuations of products

Most encountered insurance issues can be explained by perceived increased complexity and unproven nature of technology (see *technical challenges*) resulting in an over-cautious approach that could severely limit the scale of the aquaculture deployment. Over-cautiousness on the potential impact from each industry to the other may result in prohibitively high insurance quotations, entailing increased costs, delays and even a failure of the overall project (Christensen et al., 2015).

Health and safety challenges

Van den Burg et al. (2017) identified potential risks, which could lead to accidents and injuries of personnel and workers at the German pilot as well:

- Ergonomics:
    - difficult to construct design
    - moving around system: slips, trips and falls
    - restricted movement: lack of space to access components

  - lifting: hoisting parts and tools into position
- Ports and mobilisation:
  - vessel movements: collision
  - port operations: material handling, refuelling, waste disposal
  - unsuitable facilities: quayside loading limits, Subsea Operations (entrapment, falling objects, decompression sickness, use of tools, underwater
- Working at height (falls, dropped objects)

In order to prevent accidents from happening during UNITED, rigorous safety plans according to Van den Burg et al. (2017) for fabrication, construction and maintenance (including preliminary safety plan) of offshore equipment and infrastructure will be followed.

- Fully resourced, site specific construction safety plan including programme for the works
- Independent onsite safety team with marine safety experience
- Regular independent equipment inspections
- Minor requirement for divers to be met using fully certified, reputable dive company with accident free track record are used (ensure this company complies with high level safety plan for the work being undertaken)
- Working at Height:
  - All workers undergo certified working at height training
  - Fall arrest systems (harness etc.) is employed in all risk areas.

4.2.2 Dutch pilot

Regarding the combination of tidal energy with aquaculture, the technical and logistic challenges of the pilot are mapping with already mentioned challenges as the German pilot in 4.2.1. Namely, some of them are:

- The extensive logistics, required for the installation and maintenance of offshore wind farms. (La Riviere et al., 2015)
- Unexpected bad weather conditions and lack of reliable meteo and hydrodynamic forecasts may lead to a delay of offshore operations, resulting into high costs, as well as risks of safety and damage to equipment (La Riviere et al., 2015).
- Extra costs induced by the long distance to the shore of the grid connection of the MUCL system (MERMAID project)
- Geotechnical challenges (Claus et al., 2014) affecting the overall structure and foundation of the pilot, due to the effects of waves, currents, seismic loads, or a combination of all
- Overall, offshore environment poses particular constraints, barriers and challenges to the technical infrastructure (Losada et al., 2013), regarding the:
  - Plant and its installation (e.g. load out complexity), operation and maintenance (e.g. grid outage) and decommissioning (e.g. removal of marine structures may result in pollution and disturbance of established habitats on the structures; specifically, removal of moorings and fixed foundations may present a higher risk; polluting fluids or materials)
  - Equipment: mooring line system, foundation, anchors, corrosion, scour, fouling, fatigue (of transition piece), component failure
  - Logistics: vessels, ships, personnel, transportation of equipment, collision risk of vessels, container ships and fishing boats

Societal and environmental challenges match with German and Belgian pilot. Regarding one of the main obstacles that the Dutch pilot has mentioned in 4.1.2. which is eliminating the risk of damage in wind farm infrastructure, according to "*Review on risk assessment on transit and co-use of offshore wind farms in Dutch coastal Water"* (https://zoek.officielebekendmakingen.nl/blg-842692.pdf) performed by ARCADIS, commissioned by the Dutch Ministry of Economic Affairs and Climate policy:
*T*he information available on co-use of wind farm areas, by means of static fishing, aquaculture or tidal energy installations, it is difficult to perform the assessment. In the dossier used in the development of the proposed

policy, these groups are mentioned, though not covered in deep detail. Techniques and methods vary and pose technical demands on the wind farm infrastructure in some cases, which are very case sensitive and(yet)unclear. To get a complete overview of these techniques, additional research on specific techniques would be necessary. Therefore, these risks are assessed as uncontrolled. The proposed risk control measures do not act on the possible hazards related to these co-use techniques. Before any of those techniques can be used, it is required to understand, quantify and control the risks. Concerning Search and Rescue (SAR) operation, two SAR exercises were dedicated to operations within wind farms. Based on these exercises it is concluded that SAR-operations in wind farms can be performed safely. Even though helicopter support is limited due to hinder of turbines, KNRM vessels can act effectively. Deployment of a helicopter inside the wind farm is possible, only with clear visibility (daytime) and when the pilot considers the operation to be within acceptable safety limits.

Regarding legislation issues, identified by the Dutch pilot on long term concession for commercial exploitation, most activities at the Dutch EEZ are subject to licensing procedures, in order to protect nature and environment, and to guarantee safety at sea. Aquaculture activities are not subject to a formal Environmental Impact Assessment based on Directive 2014/52/EU, but culture sites, whether experimental or commercial, are subject to licences based on the Fisheries Act. In 2011, temporary licences for experimental mussel culture in the North Sea were provided by the Dutch government (Henrice M. Jansen et.al., 2016). The size of such an experimental site should not exceed three hectares, and licences were provided for a period of 3 years with possibilities for a 5-year extension. Even though permits were issued, culture trials were not started. Industrial and investors participation in new activities are generally based on a long-term strategy for the development of sites and technologies to enable a return on investment. This requires the support of long-term investment potential, and long-term licensing and policies. The policy context for combinations of maritime functions is developing. Despite the interest in combining functions in policy documents (MIE, 2014), laws and regulations do not foresee in such combinations. Until recently, the concessions granted to offshore wind park operators made co-use illegal. Since 2015—following a parliamentary notion—it is now under discussion whether wind park operators should be obliged to study the possibilities for co-use (Henrice M. Jansen et.al., 2016).

4.2.3 Belgian pilot

In the following chapter, challenges, risks and barriers from literature and their relevance for the Belgian pilot are presented. Generally, constraints and problems affect all aspects connected to offshore activities, such as engineering, ecology, legislation, society, economy, as well as health and safety of personnel. Due to the increased complexity of offshore structures only major aspects are addressed and thus, the list does not lay any claim to completeness. As no data are available for multi-use projects offshore with *Ostrea edulis* in the Belgian part of the North Sea, literature research was based on experiences of multi-use with *Ostrea edulis* in the German part of the North Sea.

Logistic challenges

La Riviere et al. (2015) pointed out the extensive logistics, required for the installation and maintenance of offshore wind farms. As important, if not even more crucial are meteo- and hydrodynamic conditions. Particularly, weather windows - during which marine operations are permissible regarding wind, wave, water level or current conditions – determine the critical path in an offshore project. Hence, unexpected bad weather conditions may lead to a delay of offshore operations, resulting into high costs, as well as risks of safety and damage to equipment (La Riviere et al., 2015). Christensen et al. (2015) predicted that investment cost of offshore equipment (cages, anchoring, longlines) can easily be doubled compared to coastal aquaculture, making it difficult to attract investors. Although, meteo- and hydrodynamic forecasts can be obtained from various public and commercial sources, their quality often lacks good in-situ measurements. La Riviere et al. (2015) stated, that especially for installation or maintenance of high-tech structures, such as offshore wind turbines in shallow-water regions (say <30m), the present hydrodynamic forecasts are considered to be inadequate. They assume that present forecast modelling systems are often calibrated against storm conditions and not specifically for mild weather conditions with wave heights of up to 1.5m, during which wind farm installations and maintenance typically take place (La Riviere et al., 2015). Overall, offshore environment poses particular constraints, barriers and challenges to the technical infrastructure (Losada et al., 2013), regarding the:

- Plant and its installation (e.g. load out complexity), operation and maintenance and decommissioning (e.g. removal of marine structures may result in pollution and disturbance of established habitats on the structures; specifically, removal of moorings and fixed foundations may present a higher risk; polluting fluids or materials)
- Equipment: mooring line system, foundation, anchors, corrosion, scour, fouling, fatigue (of transition piece), component failure
- Logistics: vessels, ships, personnel, transportation of equipment, collision risk of vessels, container ships and fishing boats

Biological challenges

Aquaculture species chosen for multi-use in the Belgian pilot, namely the flat oyster *Ostrea edulis* and sugar kelp *Saccharina latissima* have both been assessed as promising candidates of different trophic levels for offshore cultivation in the German Part of the North Sea (German Bight).

Sugar kelp: the family Laminariaceae, commonly referred to as "kelp" is one of the most important macroalgal families in temperate coastal rocky ecosystems, especially in the northern hemisphere. As ecosystem engineers they provide habitat and nursery grounds for a wide range of organisms, including commercially exploited species (Smale et al. 2013, Bertocci et al. 2015). The importance of kelp is, amongst other things, reflected by its high species number, its considerable overall biomass, its dominance, and its economic significance (Bartsch *et al.* 2008). The utilisation of algal products plays an essential role in many fields of modern everyday life. Laminariaceae offer a variety of goods used in human and animal consumption, in industrial products or for bioremediation (Bartsch *et al*. 2008). For aquaculture production, Laminariaceae plants are "seeded" on ropes, which are subsequently fixed to various suspended or floating culture devices. Detaching *S. latissima* blade portions from the meristem induces them to become sporogenous far ahead of their natural reproductive season, making mature sporophytes available all year round (Buchholz and Lüning 1999; Lüning *et al*. 2000; Pang and Lüning 2004). Adapted to strong currents as young individuals, Laminariaceae species will grow well and produce large amounts of biomass at exposed sites of the German Bight (Buck and Buchholz 2005).

Flat oyster: Following mainly biological and technical requirements, but also a regulatory and economic framework, *Ostrea edulis* was identified as a potentially successful candidate for offshore cultivation in the German Bight (Buck *et al*. 2006) and grows successfully under exposed conditions in offshore environments (Buck 2007; Brenner *et al.* 2012; Pogoda *et al.* 2011, 2013). It is an extractive species, consuming phytoplankton, and thereby indirectly reducing nutrient emissions of higher trophic species. Additionally, oyster require low maintenance as they do not require additional food (Pogoda *et al*., 2011).

The biological performance of European oysters was investigated at three different offshore sites in the German Bight during the first multi-use aquaculture project "Open Ocean Aquaculture" as well as in the project "Offshore Oyster Physiology" (OysterPhys). Research focused on growth performance, condition and survival rates in these high-energy environments. For a higher resolution of overall condition, elemental and biochemical compositions as well as macroparasitic burden were analysed. Offshore cultivated flat oysters showed:

- Positive growth rates (shell length and dry mass) (Pogoda *et al*. 2011).
- Aesthetic shell (Matthiessen 2001, Newkirk *et al.* 1995, Pogoda *et al.* 2011) depending on the site selection – hence crucial
- Bigger size class of introduced spat resulted in higher survival (Matthiessen 2001, Newkirk *et al.* 1995, Pogoda et al. 2011) and higher condition index (Pogoda *et al.* 2011).
- Condition index is the ratio of flesh mass to shell mass and the most common index to evaluate the surrounding environment on the organisms (Walne and Mann 1975; Davenport and Chen 1987). It is an adequate parameter to describe the commercial quality, physiological state and health of bivalve molluscs (Buck et al., 2017). Condition index values for European oysters indicated excellent conditions

(Pogoda *et al*. 2011). The combination of successful growth performance and obviously excellent overall condition of offshore-cultivated oysters resulted in insignificant mortalities. In contrast to commercial oyster production in nearshore environments, which often suffer from high mortalities, offshore survival rates were high (96-99% in lantern nets) and encourage open ocean cultivation (Pogoda *et al.* 2011).

- Parasite infestation: Studies on the macroparasite burden of offshore-cultivated European oysters reported a zero infestation at offshore locations in the North Sea. In general, parasites can affect condition and health of host animals. Pogoda *et al.* (2012) showed that offshore grown oysters were free of macroparasites and that infestation rates increased with proximity of the sites to shore. The debate over the effects of parasites on the energy status and overall health of the host is still open as robust data to elucidate these issues is still lacking (Buck *et al*., 2017). All known micro- and macroparasites found in European coastal waters are harmless to consumers, but may have negative condition effects (macroparasites) and cause higher mortalities (microparasites) in infested hosts (Brenner *et al.* 2012). Beside the potential harmful effect, some macroparasites cause aesthetic risks, since they are visible due to their colour (*Mytilicola intestinalis*). Oysters are commonly eaten raw and consumers would not accept this abnormal appearance. As oysters and mussels represent high-value seafood products, an aesthetic appearance of the shell—especially on the oyster half-shell market—and meat is rather important. From an economic point of view the absence of macroparasites in shellfish products is certainly favourable.
- Restoration and ecosystem services: Oyster stocks are now in the focus of European conservation efforts due to their high ecological value. In the context of cooperation within the Oslo-Paris Commission (OSPAR), the native oyster was identified as a severely endangered habitat creating species and its protection in its area of distribution was concluded (Buck *et al*., 2017). According to the *Habitats Directive* for the protected habitat type "reef", a favourable conservation status has to be preserved or restored, hence restoration of flat oyster reefs is one of the goals in the Belgian pilot. Challenges to its restoration are the availability of clean settling substrate and the presence of sufficient numbers of oyster larvae.

Technical challenges

Main research efforts in an international perspective were placed in the provision of study offshore technology, which resist the extreme environmental conditions and warrants safe utilisation of the installation. So far however, little operational implementation of the results of extensive research has been undertaken. The Belgian pilot will install a longline construction for the cultivation of seaweed and oysters with submersible ropes, which is one of the advised techniques for offshore multi-use application. The advantage of submersible culture constructions is the avoidance of the impact of harsh weather conditions and strong wave mechanics (Buck *et al*., 2017). The final design however is pending and the design of the longline for the oysters and seaweed will be done applying the MoorDyn-UGent tool. Furthermore, the following parameters and challenges need to be taken into account (adapted from Buck *et al*., 2017):

Design oysters:

- Anchor types/mooring devices
- Material and functionality of the longlines
- Materials and mesh size of collectors
- Distance below the surface to avoid destructive effects of surface waves.
- Weight: taking into account fouling

Design seaweed:

- All the above under « Design oysters »

- Longlines: need to reduce mechanical abrasion. As this can be difficult, longline systems are considered unsuitable for macroalgal culture under offshore conditions in the German Part of the North Sea. Hence the possibility of other structures attached to the longlines, e.g. nets, are considered for the Belgian pilot.
- Logistic and cost problems of efficient transfer of sporelings from the laboratory to the grow-out location as well as appropriate tending of the carrier system under the prevailing rough weather conditions.
- Fixing the carrier constructions => takes enormous labour requirements enormous and time management
- Fairly exposed sites with rough conditions are suitable for seaweed, however, only if the carrying support structure is sufficiently rigid to withstand the rough to extreme conditions encountered

Ecological challenges

Aside from multiple environmental impacts (detailed description in deliverable D4.1: "Current Environmental Assessment Status of Pilots"), challenges in marine seascape conservation remain for all UNITED pilots, when combining ecological principles with the design of marine infrastructures (Claus *et al*., 2014). Hence, mitigation measures and eco-compatible design solutions need to be identified and the selection of construction materials and maintenance processes are carefully examined (Pirlet *et al*., 2014) and instructions of relevant directives such as the Marine Strategy Framework Directive (MSFD) (GES -Good Environmental Status, implemented in all EU member countries) are followed.
Challenges may also arise, in food quality of seaweed and oyster products. Unforeseen contaminations due to algae bloom presents a risk, as environmental conditions cannot be controlled (La Riviere *et al*., 2015). Furthermore, uncertainty about climate change and its consequences on aquaculture and energy production remain, which are impossible to predict (La Riviere *et al*., 2015).

Legislative challenges

One of the main challenges to aquaculture is the difficulty in getting permissions to exploit the ocean space for aquaculture production due to regulatory/institutional restrictions. Although European policy-makers are strongly interested in co-production of energy and food, permitting procedures for upcoming industries, such offshore aquaculture, and co-production are lagging behind (Christensen *et al*., 2015). Moreover, the lack of the definition of standards and standard procedures (e.g. assessment of (environmental) impacts, selection of the multi-use scheme (suited to a given site) complicates a unified procedure for permissions and leads to unclear and lengthy licensing procedures. In order to find investors, the license procedure needs to be faster than today and uncertainties need to be minimised. Most EU countries face legal uncertainties with respect to property rights to production sites, balancing the access for the different activities (i.e. energy extraction and aquaculture), and uncertainty with respect to insurance and liability issues at multi-use sites (Christensen *et al*., 2015). Although these constraints are not relevant for the installation of the Belgian pilot since it is a research pilot, they can be important for commercial exploitation in the future.

Social challenges

Recent international studies point to a generally supportive attitude of the majority of stakeholders towards spatial and/or operational integration of marine aquaculture and offshore wind energy (Wever *et al*. 2015; Michler-Cieluch and Kodeih 2008; Vollstedt 2011). Many stakeholders that were consulted believe that the combination of a limited number of sustainable marine uses — such as offshore wind energy and fish farming – appears as an attractive solution to increasing, and competing demands for limited ocean space. Of overriding concern to many of the stakeholders (environmental agencies and organisations and researchers) are potentially harmful impacts of offshore aquaculture systems to the marine environment (Buck *et al*. 2012, Pogoda *et al.* 2015).

Turning to the potentially most involved actor groups — the offshore wind farm developers and operators, and the fisheries sector — a critical attitude is prevailing when consulting international references. Michler-Cieluch *et* *al*. (2009a) identified a number of potential synergies and benefits related to functional aspects such as joint use of transportation infrastructure, and organizational features such as the prospect to combine offshore working pattern, both of which hold the potential to reduce costs (e.g. for security systems or by vessel sharing) for both participating parties.Table 13 compiles potentials and restrictions related to interrelated operation and maintenance activities of offshore wind farms and aquaculture installations. However, a reliable estimation of financial benefits and overall economic viability needs to be done on a case-to-case basis (Buck *et al*., 2017). Even though the offshore wind energy sector is a highly innovative and dynamic sector that has been described as willing to take risks (Byzio *et al*. 2005), technical, legal, actuarial and operational concerns still appear to prevail (Michler-Cieluch and Kodeih 2008; Michler-Cieluch and Krause 2008).

Table 13: Compilation of the strengths, weaknesses, opportunities, and threats (SWOT-analysis), which identify and assemble internal and external favouring or inhibitory factors (potentialities and restrictions) of interrelated O&M activities of offshore wind fa

	Potentialities	Restrictions
Internal	*Strength*	*Weaknesses*
	• Development of a flexible, collective transportation scheme	• Little to no interest in joint planning process
	• Sharing of high-priced facilities	• Little willingness to engage into new fields of activity
	• Rationalization of operating processes	• Ambiguous assignment of rights and duties
	• Shortening of adaptive learning process for any offshore works by making use of available experience and knowledge	• Problems of interfering operations • Lack of motivating force due to doubtful mutual cost benefit
External	*Opportunities*	*Threats*
	• Available working days coincide	• Unfavourable accessibility of wind farm location inhibits joint O&M
	• Transportation and lifting devices are indispensable	• Lack of regulatory framework supporting co-management arrangements
	• Availability of a wide range of expertise (hard and soft skills)	• No access rights within wind farm area for second party
	• Lack of legislation in EEZ favours implementation of innovative concepts	• Unsolvable problems of liability • Dissimilar lease tenures

Health and safety challenges

Van den Burg *et al.* (2017) identified potential risks, which could lead to accidents and injuries of personnel and workers at the Belgian pilot as well:

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

In order to prevent accidents from happening during UNITED, rigorous safety plans according to Van den Burg *et al.* (2017) for fabrication, construction and maintenance (including preliminary safety plan) of offshore equipment and infrastructure will be followed.

- Safety course for working in offshore wind farms
- Independent onsite safety team with marine safety experience
- Minor requirement for divers to be met using fully certified, reputable dive team

Economic and financial challenges

The most relevant parameters that have an impact on potential commercial exploitation, an investment appraisal, an enterprise budget analysis, a break-even analysis, and a sensitivity analysis of various scenarios to evaluate economic profitability of bivalve and seaweed cultivation offshore are (adapted from Buck *et al*., 2010, Buck 2004, Buck *et al*., 2008a and b):

- Distance to shore
- Salinity
- Depth
- Condition of the sea bottom
- Turbidity and light
- Wave climate
- Current velocity
- Significant wave heights
- Nutrients
- Water temperature
- Wind velocities
- Distance between turbines
- Minimum spacing between turbines and any aquaculture co-use
- Size of aquaculture area
- Total length of the collector harness per longline
- Biomass of oysters and seaweed per meter of collector

Economic analyses found in literature consist of an investment appraisal by calculating the following: (1) net present values (NPV), (2) the internal rate of return (IRR), (3) an enterprise budget analysis, (4) a break-even analysis, (5) and a sensitivity analysis of changes of the most important parameters (Buck *et al*., 2017). Different scenarios have been developed. For mussels (and this might be extrapolated to e.g. flat oyster production from the Belgian pilot) assuming a baseline production of 2380 tons of consumption mussels per year (2 plots) the results of the economic study show that the base scenario is clearly beyond the break-even point. Varying parameter values, such as investment costs concerning longlines, new vessels or retrofitting, operating costs like wages and fuel, biomass yield, market price, total cost increases, and different discount rates, show different levels of feasibility. Offshore mussel production for consumption is profitable, but profits are less with a new vessel and a new land facility and higher in the scenarios without a new vessel and a new land facility, respectively. The NPV and IRR are large enough that this business can be recommended as long as there are existing capacities. Of course, all businesses can become profitable and respectively more profitable if costs can be reduced and revenues increased. The lack of practical experience of culturing mussels (and oysters) in exposed environments precludes estimating effects of economic risks.

4.2.4 Danish Pilot

Various drivers of conflict between wind farms and tourism

Offshore wind farming is expanding in response to renewable energy objectives and the attractiveness of the industry in terms of technological development and jobs. The location of offshore wind farms is mostly driven by cost: Locations with low depths, short cable routes and high winds are usually preferred. Technological advances and cost reductions enable wind farms to operate at profit, leading to more and larger wind farms being constructed. Turbines are also increasingly erected in deeper water further offshore, which may be helpful for addressing conflicts related to the visibility of turbines.

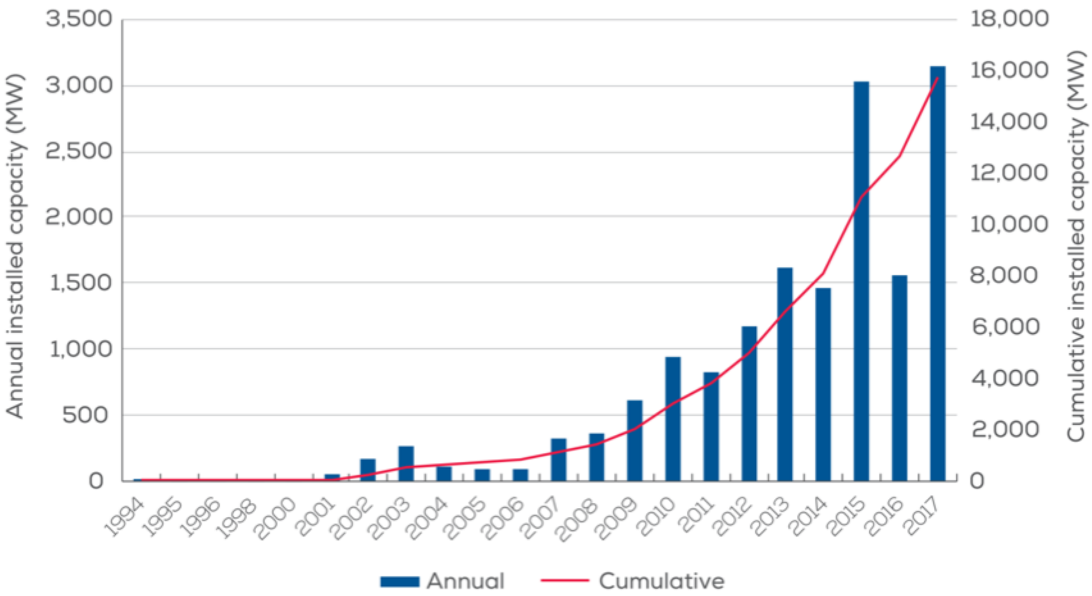


Figure 12: Annual and cumulative offshore Wind installation in Europe. Source : Wind Europe (2017)

The EU's Blue Growth strategy identifies coastal and maritime tourism as an area with special potential to foster a smart, sustainable and inclusive Europe. It is the biggest maritime sector in terms of gross value added and employment and is expected to grow by 2-3% by 2020 (Wind Europe, 2017).

The challenge for MSP authorities is to balance benefits for the national economy with advantages and disadvantages for local coastal communities. Coastal tourism is a very important economic sector locally and in some EU countries also of vital importance for the national economy, so achieving the right balance can be a difficult task (European Commission, 2019b).

Economic challenges

When developing offshore wind farms, planners and developers look for ways of reducing costs. Sea depth and distance from the shore are important factors in the costs of offshore turbines. Foundations are particularly expensive at sea. For a conventional onshore turbine, the foundations' share of the total cost is normally around 5-9 per cent, while the average for offshore turbines might be close to 21 per cent (IRENA 2012). Low depth zones are often closer to the shore and thereby more affordable for developing OWF, although shallow banks further offshore are also increasingly attractive (European Commission, 2019b).

It has also been reported that maintenance and insurance costs, especially if frequency of damage has risen due to damages caused by touristic vessels, might be of significant importance and needs to be carefully considered.

Legal and Insurance challenges

An important cost factor is the distance to a grid connection point on land (Offshore Wind Programme Board, 2016). Cables are made of expensive material, so the longer the route, the higher the costs. Longer cables also have a greater chance of being damaged, for example by vessels. The pilot should make sure that proper insurance is in place in case such damage occurs (R.Williams, 2013).

Societal challenges

As identified by European Commission (2019b), conflicts mostly arise over the attachment people have to a particular landscape (fears of the visual impacts of wind turbines) and access to sea areas. Stakeholders related to beach and coastal tourism are often concerned that the visibility of offshore wind farms from the coast reduces the attractiveness of the place. This could negatively influence the number of visitors and with this the local economy. Local property owners (residents and second home owners) can be concerned that offshore wind farms might decrease the value of their house, although there is no evidence for such a decrease. Offshore wind farms can block potential sailing routes, or restrict the available space for other recreational activities, such as windsurfing or diving.

The visual impact of offshore wind farms – whether real or expected – can give rise to emotional discussions. People can be very attached to a particular place and may strongly resent the visual intrusion caused by an offshore wind farm. Although the conflict over a wind farm may appear small, it can quickly escalate if these concerns are not taken seriously (European Commission, 2019b).

4.2.5 Greek pilot

Various drivers of conflict between aquaculture and tourism

Policy development for tourism is usually delegated to the regional and local level and rarely carried out at the national level, leading to several differentiations between different regions. An important driver of conflict is the diversity of the sector and the variety of needs associated with different types of tourism. The sector is largely driven by the contextually tourism economic power and changing tastes of tourists. Trends may shift quickly, requiring the sector to adapt. Presently, there is a tendency towards diversification, meaning more sustainable forms tourism are emerging (European Commission, 2019a). Experience-based tourism, that mostly focuses on scenic, cultural and environmental assets and local traditions usually attracts more affluent and discerning types of tourists. Nevertheless, mass tourism and "summer and sun" type vacations in coastal resorts are also still very popular.

Aquaculture is also one of the Blue Growth sectors predicted to keep growing in the future. The growing gap (estimated at 8 million tonnes) between the level of consumption of seafood in the EU and the volume of captures from fisheries (European Commission, 2013a) is partly expected to be filled by environmentally, socially and economically sustainable EU aquaculture (European Commission, 2016). The European Commission intends to boost the aquaculture sector through the Common Fisheries Policy reform, and in 2013 published Strategic Guidelines (European Commission 2013b) presenting common priorities and general objectives at EU level. The European Commission and EU countries are collaborating to help increase the sector's production and competitiveness. EU countries have also developed Multiannual National Aquaculture Plans to promote aquaculture (European Commission, 2016). On a more local level, aquaculture can be a major employer in coastal communities especially in more remote coastal regions; many such regions and communities therefore actively seek investment in the aquaculture industry.

In most countries throughout Europe, coastal tourism is an economic force many times greater than aquaculture (Dempster & Sanchez-Jerez, 2007), leading to unequal power relations between the sectors. Sea bream and sea bass farmers along the south-western Mediterranean coast of Spain, for example, state that interaction with tourism-oriented local authorities is the greatest barrier to development of aquaculture in their region and their greatest concern for continuing existing operations in coastal areas. Recreational fishing interests have also prevented aquaculture installations from being approved in Norway.

In the case of this particular conflict, space is an important driver. Water-based tourism and aquaculture often require similar areas, most prominently sheltered inshore locations protected from extreme weather. Fish and shellfish farms need to be close enough to the shore to ensure servicing costs are kept to a minimum; logistics also need to make financial sense. Shelter and clean water are particularly important for shellfish cultivation and smaller, less robust species of fish. In some countries, synergies have been found with tourism (e.g. "Aquiturismo" in Italy or "Sea Garden" concepts in Denmark; in areas where "sustainable" forms of aquaculture are practised, these can provide good-quality seafood to tourists, improving the area's attraction (Lukic et al., 2018). However, in places where aquaculture is not a traditional sector or has been intensifying throughout the years, conflicts with tourism are likely to become more eminent.

Identified challenges divided by category:

Legislation and insurance:

Restrictions in legislation or in its interpretation, which regulate the possibility of hosting tourists on board aquaculture vessels, was identified as a major barrier. Only regional legislation in Emilia Romagna, Italy referred to and defined this MU. There is absence of adequate regulations related to insurance against accidents. The development of the combination is also hampered by the fact that existing vessels used for aquaculture are not often suitable for touristic use (Vergílio M. et al., 2018).

Another conflict issue, as reported by the European Commission (2019a), indirectly addressing the insurance challenges as well as the health and safety issues that may occur, in the case of multi-use between aquaculture and tourism activities, is a potential accidental damage to boats and aquaculture installations. Underwater obstructions can be a hazard to craft that would otherwise be able to pass between a fish farm and the shore. A collision not only affects the tourists, but also damages the fish farm, with all possible consequences to both sides.

Mapping with pilot identified barrier:

This challenge is mapped with the legislation barriers identified in chapter 4.1.5 by the Greek pilot. The issue with the lack of insurance regarding transferring tourists through vessels has already been considered by the aquaculture business owners and the dive centre. It has been determined that even though the aquaculture owners are not covered legally to use vessels for tourism, vessels for transferring divers is covered with proper insurance by the diving company and this must be the way to be provided to diving-tourists. Regarding health and safety and insurance in case of accidents, this still needs to be investigated.

Societal challenges:

Visual impact of aquaculture sites. Sea-cage fish farms or mussel rafts typically have large surface structures that impact on the aesthetics of seascapes viewed from the shore. Supporting facilities on land may also have an effect on the coastal landscape, especially if they are close to resorts or tourist beaches. Spatial restrictions for recreational fishing and boating. Spatial restrictions are usually in place around fish farms and cages, amounting to much larger non-anchoring areas than the farms themselves European Commission (2019a). These challenges can affect the local community's as well as the tourists' view regarding the aquaculture farm in the pilot site, regardless of the touristic activities offered by the multi-use.

Mapping with pilot identified barrier:

The pilot has also identified the societal acceptance impact to the reception of the multi-use in the site. It has actually been highlighted as one of the most significant challenges that this particular pilot faces, as the local community till now, has showed a neutral to negative view towards the aquaculture activities taking place in the site. It is therefore of great importance to improve the social view with

Economic challenges:

The main challenge for planners is the lack of case studies and business models for this Multi-Use (MU). Limited standards and guidelines to train fishers and aquaculture operators, coupled with their limited experience and skill in management, customer services and entrepreneurial skills also hinders this MU. Poor entrepreneurship and investment muses report capacity of aquaculture operators are a key challenge which is informed by their spatial fragmentation (Vergílio M. et al., 2018).

Mapping with pilot identified barrier:

The great necessity to develop a concrete business model for the multi-use has also been identified by the Greek pilot. Other possible barriers are also economic concerns (opportunity costs, disruption of farming operations and balancing value and expectations with costs). Risk analysis is also very important for the multi-use, but very few insights are there, from past projects and case studies. Maintenance costs including those of sensors, ROVs and diving gear should also be taken into account.

Environmental challenges:

A common concern in promoting this MU is the possible increase in touristic pressure in already overcrowded areas, with possible increases in coastal cumulative impacts. Certain environmental concerns also arise with the involvement of recreational fishing activity next to aquaculture plants. There is the possibility of fish stock overexploitation if MU activities involving fishing are not well monitored (Vergílio M. et al., 2018).

Another similar challenge, (identified by the European Commission 2019a), is the potential impact of aquaculture and tourism activities on water quality. In the case of aquaculture: Feeding caged fish introduces a large source of nutrients to coastal areas which can lead to eutrophication. This eventually leads to increased algae growth, including toxic species of algae, rendering the water less suitable for certain recreational activities. In the case of tourism: Impact of waste on aquaculture. The disposal of untreated sewage from vessels can affect aquaculture, especially shellfish beds.

Mapping with pilot identified barrier:

These types of challenges have already been considered by the pilot site. For these purposes, sensors will be installed in the aquaculture farm site, connected with a cloud platform that will closely monitor the water quality at all times in order to track any significant deviations and produce timely alerts for aquaculture stuff to react.

5. SOCIETAL PROFILE OF THE UNITED PILOTS

5.1 Scope of interview with pilot stakeholders

One of the tasks carried out during the Task 1.2 period of time, was to gather some information regarding the current societal profile of the pilots, with the aim to predict the reaction of the local community in the case of multi-use. By local community, this is namely translated to residents of the area, local business owners, not directly involved with the multi-use activities, investors, local tourists and visitors of the site as well as the local authorities. WINGS and ACTEON with the help of SUBMARINER created a sample questionnaire for each pilot lead to address to a key pilot stakeholder. Key stakeholders in the UNITED pilots are considered the business owners of one of the key multi-use activities of the pilot site. This choice in the type of stakeholder was made based on:

- The level of close interaction with local community
- The number of years this interaction takes place

- The level of involvement with one of the multi-use activities

We need to clarify here, that the interview's attempt is to help us get a better perspective regarding the current societal view of the community, through the opinions and possibly some facts coming from a closely involved key person of the site. This would facilitate an initial gathering of some feedback regarding the status of the societal view that currently exists in the pilots, to create a first societal profile of the local community and predict reactions, in order to elicit the potential effects a multi-use platform may have on its local community. Below, the questionnaire that was created by WINGS in collaboration with ACTEON and SUBMARINER:

a) What do you perceive as local community in your site (local residents/inhabitants, local businesses, local authority, a type of interest group)?
b) What is the current local community view towards the active types of business in the site?
c) Have there been any complaints regarding the active types of business in the site? What particular group or type of stakeholder complained?
d) Please describe to what topics were these complaints about.
e) Has the local community view benefited the activities till now? If yes, explain how.
f) Has the local community made difficult the activities till now? If yes, explain how.
g) Is the pilot site currently attractive to local community? Please explain in what way (e.g. Visiting site, use it for business activities)
h) Is the pilot site currently attractive to non-locals or visitors?
i) Are there any touristic business activities in the site? Give a brief description of them
j) Do the local business owners think that relations with local community should get better?
k) Do the local business owners in the site think that relations with local community should stay as is?
l) Do the business activities that are involved in the UNITED project in the pilot site benefit in any way the local economy? If yes, please explain in what way.
m) Have the local business activities led to direct or indirect creation of jobs?
n) Does the local community think that existing activities in site (yes/no):
    a. benefit wildlife
    b. make the scenery interesting
    c. attract tourism
    d. restrict adjacent land uses
    e. exclude recreational fishing
    f. restrict public access
    g. enhance recreational fishing
    h. Identity of place
    i. change personal attachment to the area
    j. cause local community to use other areas for my recreation
    k. cause fewer people to visit the area
    l. cause fewer people to visit the area
o) In your opinion, do you think that the multi-use solution that UNITED project will develop would bring added benefits to local communities? Would such solution be accepted? What may be the main challenges related to its acceptance? Who may have an issue? Please, explain why?
p) Do you have any more comments regarding this topic?

The interviewer could use the above questionnaire as a roadmap on how to extract the information needed by the interviewee. The questionnaire creators of this task, have chosen to leave this first attempt to gain knowledge regarding the societal view on the current uses in a free format (interview format and not web based questionnaire with multiple answer options) in order to not constrain the answer options and to allow the possibility of gaining wider knowledge on the particular topic.

5.2 Results of the interviews

5.2.1 German pilot

The German pilot leads decided not to interview the particular pilot business orders at that time, as they have already communicated with them before and FUE has already formed a good view regarding the societal acceptance topic with FUE to have answered the related questions in a clear and explanatory manner, giving references where needed.

Regarding the current local community view towards the active business operations in the site:

Since the federal government decided to set up a research platform in the North Sea, close to planned and requested larger offshore wind farms in January 2002, the local perception has been rather positive. FINO3 is used to obtain meteorological, oceanographic and ecological data and forms the basis of a large number of research projects. With the help of measuring data and ecological insights, offshore construction projects such as wind turbines and substations are being optimized. The results help to clarify remaining uncertainties regarding the technical design of wind turbines and provide a database of environmental parameters in this area.

Thus, indispensable results and reliable monitoring data is gathered. Sponsors of the platform are the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the state of Schleswig-Holstein with state and EU funds, and the Federal Ministry for Economic Affairs and Energy (BMWi). Hence, a diverse group stakeholders (reaching from environmentally associated NGOs to economic political interests) greatly benefits from FINO3.

In addition, the platform offers small and medium-sized companies the opportunity to build up references and demonstrate their performance under realistic conditions. Due to the multiple benefits, which can be derived from FINO3, the overall public perception is positive. Moreover, FINO3 is located far from the shore and hardly noticeable when approaching, as it is surrounded by hundreds of wind turbines. Thus, there is no (visual) obstruction (or any other kind of negative aspect) for people, living at the sea side.

General Stakeholder perceptions on multiuse systems according to the findings of Wever et al. (2015)

During the OOMU project in 2005 and 2011, stakeholder workshops were conducted, in order to draw a clear picture of stakeholder views regarding multiuse in the German North Sea. Semi-structured interviews revealed a generally high acceptance of an integration of marine aquaculture and offshore wind energy among most stakeholders in the German North Sea context (Wever et al., 2015). However, depending on the field of expertise and the point of view of stakeholders, various concerns regarding social, legal, economic, environmental or technical issues were raised. Some stakeholders pointed out that large, possibly foreign investors would operate multiuse farms without generating any or only marginal benefits for the coastal region and local workforce. Particularly, NGOs were sceptical towards multiuse with regard to potential environmental threats. They stressed the importance of addressing environmental concerns early in the technology development process. A rather negative opinion towards multiuse was cast by representatives from fisheries associations that revealed a low acceptance of marine aquaculture in general. The proposed alternative uses in offshore wind farms – including aquaculture – seem to be perceived by some fisheries representatives as lip service to appease those that lost their fishing grounds (Wever et al., 2015). Overall, Wever et al. (2015) concluded that there were stakeholders on both the “winning” and the “losing” side. Although, the majority of participants (and interviewees) supported in principle the multiple use approach as a pragmatic solution to ever increasing demands for ocean space, the intensification of ocean use in itself was a cause of concern to many (Wever et al., 2015).

Results of a stakeholder survey on the feasibility of an offshore aquaculture facility in the North Sea at FINO3 by Geisler et al. (2018).

The results of the survey have shown that there is a great reluctance among potential stakeholders to invest in offshore aquaculture due to the lack of technical solutions. However, some stakeholders are interested in becoming active in this aquaculture sector.

1) In total, 67 stakeholders from various fields of expertise (aquaculture production companies : mussel/fish/algae; research institutes: (micro/macro) algae/mussel/IMTA/fish/equipment e.g. cages; supplier industry of offshore aquaculture: measurement equipment (sensors)/cages; consulting enterprise) were interviewed regarding their opinion on offshore MUCL systems. Overall, two general feedbacks were given: The interviewed stakeholders were interested in contributing and sharing their knowledge and experience in new offshore MUCL projects, while others
2) Were interested in conducting such a project and contributing with resources and experience from previous works. However, they have great concerns regarding the site of FINO3 and its unpredictable impact on potential aquaculture production.

Regarding any reports of complaints on the active types of business in the site

At the moment, there is no multiuse activity going on at FINO3, thus there have not been any complaints regarding seaweed or mussel cultures. No complaints are known due to the remote location. However, there were concerns of environmentalists at the beginning of the construction of FINO3, but so far, no negative long-term effects of FINO3 on the environment have been detected.

Researchers stated negative impacts of offshore wind parks (not FINO3!) on birds.

The platform is part of a bird monitoring program to evaluate these impacts.

The effects on resting and migratory birds have been monitored for some time and according to the Institute of Bird Research in Wilhelmshaven two main negative aspects were identified regarding wind farms (not FINO3, because just a pole, no actual turbine!) 1) the loss of habitat and 2) the danger of collision (Karberg & Nestler, 2015). Sensitive species, such as red-throated divers or common scoters in particular, avoid these structures, which limits their habitat. Also less nervous birds, such as terns or gulls are negatively affected by the wind turbines. Especially at foggy days with poor visibility, they often fail to notice the rotor blades in time and collide with them (Grüling, 2013).

Types of concerns from stakeholders that have risen through the years

Concerns regarded negative economic -, social- and environmental impacts as well as a challenging legal, logistic, technical complex situation when running a multiuse offshore system consisting of wind energy- and aquaculture production :

There have been no complaints for the existing use at the German pilot but there are some known barriers, risks for offshore activities in Germany.

The following points have been raised at a stakeholder workshop (Wever et al. 2015) and a stakeholder survey (Geisler et al. 2018) :

- Expected negative <u>economic</u> impacts on fishermen due to restricted areas (but this is rather due to wind farms not to FINO3.) and fear of international investors that won't create new jobs. Offshore multiuse aquaculture requires high investments, which is not attractive for individual fishermen (Wever et al., 2015). Further information about predicted costs, economic return and break-even points are lacking (Wever et al., 2015).
- From a <u>social</u> point of view, older fishermen are not interested in changing their profession from fishing to operating offshore aquaculture plants. Moreover, what are the overall benefits for coastal communities (e.g. alternative incomes) (Wever et al., 2015)?
- Expected negative <u>environmental</u> impacts on sea- and migrating birds, mammals, marine benthos (flora and fauna) due to rotor blades, construction noise, interference and restrictions of habitats by regular operating vessel traffic. According to the results of the stakeholder workshop conducted by Wever et al. (2015), local specific nutrient budgeting (lab&field research), carrying capacity analyses, prediction of impacts on surrounding marine environment (benthic environment, pelagic fauna) is necessary.
- Unclear <u>licencing</u> procedures (no standards) for offshore farms together with unpredictable risks and legal uncertainties regarding property rights in the EEZ (Wever et al., 2015).

- Unresolved technical challenges in terms of implementation, operation and maintenance in high energy environments (e.g. high temperature variation, strong currents). Safety concerns for workers as well as possibly impaired smoothness of operations of wind energy facility (Wever et al., 2015).

The overall local community benefit from current the activities

Overall, public opinion as well as political will is a strong motivator for breaking new grounds in industrial/commercial developments. Thus, if multiuse offshore co-location (MUCL) becomes accepted and politically "wanted"– marine aquaculture might turn out to be an additional selling point for wind farm operators (Wever et al., 2015). Regarding the survey, conducted during the feasibility study of FINO3, it became apparent, that stakeholders (research institutes, fish/ mussel/seaweed farms, supplying industries) had a general interest in expanding this economic branch, but were critical regarding the feasibility (Geisler et al., 2018).

Literature reviews have shown, that usually multiple many-sided views exist on such innovations, which means that there will always be beneficiaries, hence supporters, as well as interest groups that feel left out, hence opponents (Wever et al., 2015). Depending on who you ask people may appreciate or rather refuse the idea of MUCL, depending on the way an individual understands the systems and how he/she has been exposed to the subject of concern (e.g. the role of mental mind-models in ecosystem management) (Wever et al., 2015).

Overall, the policy (in Schleswig-Holstein (involved Federal State), in Germany and within the EU), has clearly demonstrated their commitment to the Blue Growth strategy. This view is reflected in the funding of diverse regional, national and major EU projects such as MERMAID, TROPOS and H2OCEAN of the 2011 EU "Ocean of Tomorrow" call.

There are many stakeholders (environmentalists: data and research on bird migration, porpoise population, benthic communities; SME: can test their products in real life environment, Wind farm operators: receive technological solutions from research at FINO regarding offshore constructions/logistics etc.) benefitting from the research platform FINO3, which is why these parties do not disapprove of FINO3.

Possible barriers that the local community has created to the business activities

Some stakeholders may be affected or concerned, but that may not only include locals but international stakeholders as well.

Offshore Multi-use is a relative new field for the local communities. So, there is a high demand for information and tests and there are no clear uniform rules or approaches yet. Planning and implementing a project is demanding but no clear difficulties there were no clear difficulties at that time. Tanker ships may be affected from offshore wind farms, as Data from Denmark and the Netherlands have shown that oil tankers chose different routes through the German Exclusive Economic Zone than the rest of the shipping industry (dpa, 2020https://www.sueddeutsche.de/wirtschaft/schifffahrt-hamburg-bundesamt-prueft-offshore-ausbau-dpa.urn-newsml-dpa-com-20090101-200129-99-686808).

Moreover, environmentalists from NGOs (Dolphin Rescue Society, Society for the Conservation of Marine Mammals, Nature conservation association of the federal state of Schleswig-Holstein) were concerned about the ramming of the monopile into the seabed of FINO3. They demanded effective sound insulation for all sound-intensive work at sea. They prefer gravity foundations for offshore plants in order to avoid noise emission, as explosions, pile planting, sonar and seismic analysis would endanger the native harbour porpoises and grey seals. They argue that marine mammals would be driven out of their habitat and could suffer from serious hearing impairment (Dolphin Rescue Society, 2008).

A new technical method was successfully developed by FUE to minimize or avoid these negative impacts (FUE 2008).

Regarding the active business activities (wind energy) level of attraction to local community

According to Ursula Prall, chair of the offshore wind power industry, there were no public protests against offshore wind farms, after all, the steel giants are far out on the water, away from municipalities. Ten years ago, the first German offshore wind farms were installed and now, there are more than 20 – with around 1500 wind turbines - in German waters, most of them in the North Sea. The profitability of wind turbines at sea has increased ever since, which enables the state to gradually withdraw from subsidies (Herberlein, 2020), marking the offshore wind power as a truly successful industry (Ursula Prall).

There is a strong interest of the local community in northern Germany to expand offshore activities. MUCL is a new topic for the local communities and further experience and information are needed (especially with increasing distance from the shore). Nonetheless, this might change and MUCL systems may become more interesting for local communities and municipalities, once they get a refund of energy costs. The minister of economics, Peter Altmaier, planned to reduce electricity rates for residents and communities of (on-) shore wind farms, in order to avoid local resistance and protests against new wind farms. Peter Altmaier proposes a levy on the municipalities, according to a key issue paper of the Federal Ministry of Economics (available to the ARD-Hauptstadtstudio). According to the paper, the payment of the wind farm operators to the municipalities is obligatory (Tagesschau, 2020). If the paradigm of reduced energy costs for municipalities will also be applied for offshore wind farms, local communities might become more interested in the overall activities of offshore wind farms and potential MUCL systems. Within the next 10 years, there is great potential for the development of modern energy production and multiuse offshore concepts (Tagesschau, 2020).

Although, Munich cannot be considered as part of the local community of FINO3 and the neighbouring wind farms, it highly profits from the green energy, produced by the offshore wind farm Dan Tysk. The energy group Vattenfall and the public utility company of Munich (public utility company of Munich has a 49% share of the wind farm) invested into Dan Tysk (in close proximity to FINO3), due to their ambition to cover the energy demand of 800,000 Munich households with green energy from wind parks. The electricity, generated by 80 wind turbine, will be enough to supply around 250,000 households in the Bavarian metropolis. Together with other projects in the North Sea, the Dan Tysk wind farm is one of the first targets of the Munich-based company's renewable energy expansion campaign (Kieser, 2010).

Especially, municipal utility companies and small electricity producers benefited from the installation of new wind farms and the redistribution of the German energy market due to the shutdown of nuclear power plants. In close cooperation with other municipal utilities, they often built and operated wind farms, to rely on their own renewable power generation. However, with the lifetime extension of nuclear power plants, between 8 and 14 years, invoked by the governing coalition in 2010, severely affected the plans of municipal utilities and small electricity producers. Consequently, local communities could benefit from offshore wind energy farms, next to small scale energy producers and municipal utility companies, as long as the government encourages and implements the energy system transformation.

Touristic business activities in the site

There are no touristic activities going on around the FINO3 site or close to the wind farms Butendiek, DanTysk and Sandbank as it is prohibited to enter the safety zones of the wind farms and FINO3.

Tourism is the main economic factor in northern Germany. About 20 million overnight and day visitors visit the region every year. Near shore touristic activities at the North Sea (but not at FINO3 and wind farms because not accessible) include sailing, (kite-) surfing, diving, mudflat walking, fishing, etc.

Regarding local business owners' view on whether relations with local community should get better

Yes, there is a strong need to have common reliable regulations for planning future activities and to attract investors

Regarding the positive impact of the current business (wind farm) to local economy

Small scale energy producers and municipal utility companies benefit from wind farms, as they have an opportunity to fill the "energy" gap resulting from the shutdown of nuclear as well as coal-fired power plants.
(Potentially) reduced energy costs for locals: Also, the local public might benefit from reduced energy costs, once it becomes effective (!), due to the obligatory payment of wind farm operators to the municipalities (Tagesschau, 2020).
Creation of Jobs: In July, 2017, Siemens Gamesa opened the world's most modern wind turbine factory in Cuxhaven, a central production site directly on the coast. An offshore nacelle factory in close proximity to the edge of one of Germany's North Sea ports, allows direct transportation of large and heavy wind turbine components by ship from the factory to wind power plants at sea. It supplies large offshore projects in the North Sea, together with the rotor blade plant in Hull, UK and the Esbjerg site in Denmark. While 850 people are directly employed in the factory, the city expects more jobs to be created in the craft trades and service industries as well as in the catering sector. In 2017, 2500 people have moved to Cuxhaven, several apartments and houses are built. Thus, the local business of lower Saxony benefited greatly from the wind farm industry. Overall, around 20,000 people are currently working in the wind industry of the German coasts (Preuß, 2018).

Regarding the positive impact of the current business (wind farm) to job creation

Regarding *wind industry*, new jobs were created (as mentioned in previous paragraph).

Regarding a *potential aquaculture* production industry (which does not exist at exposed offshore sites yet!): Evaluations have shown, that every percentage of EU-wide consumption of marine products, produced by aquaculture in the EU, creates 3000 to 4000 full-time jobs, contributing tremendously to employment in coastal and inland areas (European Commission 2013). Thus, jobs in the field of aquaculture production have successfully been established in a variety of sectors, such as fishing, supply industry, research, and services.

Yes/No Questionnaire

Does the local community think that existing activities at the site (yes/no):

a. **benefit wildlife**

Yes. The Local biodiversity establishes better than in other parts of the North Sea due to marine biologist Jennifer Dannheim from the Alfred Wegener Institute for Polar and Marine Research. She and her colleagues have observed this on the FINO research platforms in the North and Baltic Sea and in the alpha ventus wind farm consortium. Two factors are mainly responsible for the growth: new substrate and restricted maritime traffic. In addition, wind farms are inaccessible to shipping and fishing so that marine flora and fauna can develop undisturbed in these protected areas (Grüling, 2013).

and No. Environmental NGOs have concerns about the wildlife and negative impacts of wind farms especially on marine mammals and birds.

b. **make the scenery interesting**

No, the pilot site is out of sight due to its location 80km away from the next coast.

c. **attract tourism**

No, because no touristic activity is going on (prohibited) at wind farm or FINO3, so no one would visit the North Sea because of these sites.

d. **exclude recreational fishing**

No, because recreational fishing is not taking place offshore. However, it affects fishermen, as they are not allowed to enter the safety areas, which once belonged to their fishing grounds (Reccius, 2018).

e. restrict public access

Yes. Partly, as public access of the safety zone of wind farms and FINO3 is prohibited, so no fishing boats or cruises are allowed to enter. However, at this exposed site, far away from the coast there is a very limited or no demand to enter this area.

f. enhance recreational fishing

No, because, no fishing is taking place at the site anyway.

g. Identity of place

No. There is a very limited interest of the identity of this place. (Long distance from shore)

h. change personal attachment to the area

No. See above **h.**

i. cause local community to use other areas for their recreation

No, because the site is located far offshore, so it is neither visible from the shore nor accessible.

j. cause fewer people to visit the area

No. In fact, there might be even more people visiting due to increased cultural offers, as more people move to these regions because of new jobs.

Pernsonal thoughts of the interviewee, on whether the multi-use solution that UNITED project will develop would bring added benefits to local communities

Positive aspects of MUCL (wind + aquaculture):

- Yes, the knowledge and experience gained at UNITED will fill the demand of local communities for improved information. So a harmonized approach for regulations will be more likely.
- Wind farm operators have strong concerns regarding multi-use operations in Germany. UNITED could help to develop a better assessment of risks and enable future commercial operations.
- Creation of **new jobs** for locals in wind/aquaculture industry
- **Improvement of infrastructure** (gastronomy, cultural offerings, services) due to more people moving to a certain area (e.g. Cuxhaven, Helgoland)
- **Financial wealth** to municipality (e.g. Helgoland): "Before the offshore boom, poor Helgoland received up to five million euros per year from the municipal financial equalisation scheme. Now, it transfers two thirds of the trade tax revenue, around 40 million euros, to Kiel." (Reccius, 2018)
- Potentially reduced energy costs for locals (in case the law becomes effective)
- Investment opportunities for locals
- Energy demand of entire cities can be met via renewable wind energy (e.g. Munich), including new hydrogen storage technologies.
- Concerns of NGOs will be investigated by UNITED. Therefore UNITED will develop a scientific basis for future discussions and improved acceptance.

Negative aspects of MUCL (wind + aquaculture):

- Negative impact on marine flora and fauna (NGOs have serious concerns) but these issues will be investigated (see answer 18)
- Reduced fishing grounds (and decreasing job opportunities) for fishermen but these issues will be investigated (extensive monitoring progam)

Personal thoughts of the interviewee, on whether the MUCL will be accepted by the local community and the possible challenges faced

It is likely to accept the solution, once commercial MUCL is politically wanted and wind park owners have to oblige to MUCL concepts.

Wind park operators have to agree as well as environmental NGOs. Aquaculture has still a very poor acceptance in Germany due to major mistakes in the beginning of aquaculture in Europe several decades ago. One aim of the German pilot or UNITED is to improve this acceptance with a dissemination of new information of well-managed aquaculture farms these days.

Stakeholders that might have any issue :

- Wind park operators: increased risk of damage to turbines.
- Environmental NGOs: marine flora and fauna might be negatively affected by aquaculture → entanglement, disturbance of feeding grounds of mammals/birds and secluded retreats of fish.
- Fishermen: have to give up their traditional jobs, because their fishing grounds decrease or they cannot compete with aquaculture products from MUCL (→ most likely concerning mussel fishermen).

Personal thoughts of the interviewee.

It is difficult to summarize and reflect the views on offshore wind energy and aquaculture production of all potential stakeholders, as they range from positive to negative, depending on who is interviewed and affected in which way by MUCL.

5.2.2 Dutch pilot

For the Dutch pilot, the pilot leader NSF, who is also the business owner in the site, has answered the questionnaire.

Interviewee's personal definition of the local community in the pilot site

a. Local and regional businesses
b. Harbour area
c. Regional stakeholders such as :
    1. Fisheries
    2. Recreational
    3. Residents in the harbour area
    4. Nature
    5. Ship traffic

Regarding the current local community view towards the active business operations in the site:

Very positive, in 2016 an elaborate stakeholder consultation was performed where most stakeholders expressed themselves as very positive towards development of new economy of the coast of The Hagua.

Regarding any reports of complaints on the active types of business in the site

Not really. In the early days there were some concerns from small professional fishers but as soon as they realised it was a small operation in the scheme of things, they were not longer concerned. This was back in 2016.

Types of concerns from stakeholders that have risen through the years

We applied for the location permit in 2016 and at that stage they expressed concern about taking away fishing grounds. However, it was not so much towards our initiative but more an expression of general concern that new activities are claiming their original fishing grounds. Individual fishers are actually very interested about the possibilities of seaweed cultivation.

The overall local community benefit from current the activities

The local community has indeed benefited over the years. As indicated above, almost all stakeholders were very positive and that has really helped to get support from the municipality and in general just hands on support in the harbour.

Regarding the level of attraction that the pilot site causes to local community

The site is relatively far offshore, 12km and not suitable for visits by members of the local community because of safety concerns of visitors and installations. Furthermore, floating buoys in the sea is not all that exciting. We may change this in the future. There are plenty touristic activities though in the harbour where we operate from. Namely, these activities are :

- Fishing
- Boat trips
- Sailing
- Surfing

Regarding local business owners' view on whether relations with local community should get better

This is not really relevant here as the business owners are to a large extent local community.

Regarding the positive impact of the current active business to local economy

Yes, the pilot will be operated from the Scheveningen harbour and for this local businesses are involved.

Regarding the positive impact of the current active business to job creation

For this the pilot, activities are still too small. Hopefully this will change in the future

Yes/No Questionnaire

Does the local community think that existing activities at the site :

a. **benefit wildlife:** yes
b. **make the scenery interesting:** no
c. **attract tourism:** perhaps
d. **restrict adjacent land uses:** no
e. **exclude recreational fishing:** yes
f. **restrict public access:** no
g. **enhance recreational fishing:** perhaps
h. **Identity of place:** perhaps
i. **change personal attachment to the area**: not really
j. **cause local community to use other areas for my recreation:** no
k. **cause fewer people to visit the area:** no

Personal thoughts of the interviewee, on whether the multi-use solution that UNITED project will develop would bring added benefits to local communities

Yes. There is a large wind farm planned that does not immediately benefit the community. Making multi-use possible in those wind farms and in the pilot may be able to change that.

Personal thoughts of the interviewee, on whether the MUCL will be accepted by the local community and the possible challenges faced

Yes, more commercial activities for the harbour is really welcomed by the community and no possible challenges coming from them are foreseen.

Do you have any more comments regarding this topic?

Personal thoughts of the interviewee.

The multi-use functions such as food production and nature development inside wind farms create a real opportunity for local communities at various education levels to benefit from the presence of wind farms in their region. This is a very important benefit of multi-use as it may lead to more acceptance for climate driven innovations (such as large wind farms) in the marine space.

5.2.3 Belgian pilot

For the Belgian pilot, the questions were answered by our UNITED partner Parkwind, which is a business owner of the Belgian pilot site.

Regarding the current local community view towards the active business operations in the site:

The current localisation of the activity will be in the existing offshore windpark on the South-East side of the Bligh Bank (windpark Nobelwind), approximative 50 km offshore and not visible from the coastline. In general, the local community is very positive to the actual activity of the offshore wind energy. Since the new MSP (Marine Spatial Planning of the BE – EEZ zone), the offshore windpark zones are protected and secured zones and not accessible for third parties. But new activities, in agreement with the windpark owners, are now possible and the local community is very pleased that integrated multiple activities are possible in the limited zone of the BE EEZ zone (energy production – aquaculture).

Regarding any reports of complaints on the active types of business in the site

There are no complaints regarding the active types of business in the actual site. Due to the limited zone in the Belgian waters, the complaints came mainly from the fishery.

During the first years of exploitation of the windparks (2009 – 2014) we saw a lot of intrusions from the fishermen (mainly Dutch fishermen) into the secured zone, but now we see that this is normalized, and intrusions is now more from pleasure crafts that cut corners in these zone.

The overall local community benefit from current the activities

Renewable energy is the main benefit that the local community has gained. Offshore wind energy will produce approximative 10 % of the BE total energy consumption.

Possible barriers that the local community has created to the business activities

No difficulties were expired from the local community.

Regarding the active business activities (wind energy) level of attraction to local community

The pilot site is currently not attractive to the local community due to the distance to shore and the accessibility of the site.

Touristic business activities in the site

At the location of the Bligh Bank, no touristic activities are ongoing (distance and vicinity of the shipping lane). A touristic visit to the offshore wind industry is possible from Ostend, but not so far as the Bligh Bank.

Regarding local business owners' view on whether relations with local community should get better

Relations are already positive, so it will be good to maintain this.

Regarding the positive impact of the current business (wind farm) to local economy

Windenergy has an important spill-over to the local economy. Parkwind employs more than 95 people (develo ment, construction, operation and maintenance) and supports indirectly about 100 jobs (during the exploitation phase) per windpark in supplying sectors like engineering companies, shipping companies, maintenance companies. Local hotels and other facilities take advantages from our activities.

Regarding the positive impact of the current business (wind farm) to job creation

Parkwind employs currently 95 people.

Yes/No Questionnaire

Does the local community think that existing activities in site :

a. benefit wildlife : Yes

b. make the scenery interesting : Yes

c. attract tourism : Yes

d. restrict adjacent land uses : Yes

e. exclude recreational fishing : Yes

f. restrict public access : Yes

g. enhance recreational fishing : Yes

h. Identity of place : Yes

i. change personal attachment to the area : No

j. cause local community to use other areas for my recreation : No

k. cause fewer people to visit the area : No

5.2.4 Danish pilot

For the Danish pilot, the interviewee was the business owner of one of the business activities in the site, the one related to the touristic vessel activities.

Interviewee's personal definition of the local community in the pilot site

All with interest in business related to the offshore wind farm

Regarding the current local community view towards the active business operations in the site

Positive; it creates business and jobs

Regarding any reports of complaints on the active types of business in the site

No

Types of concerns from stakeholders that have risen through the years

No

The overall local community benefit from current the activities

Business, jobs

Possible barriers that the local community has created to the business activities

None

Regarding the active business activities level of attraction to local community

Yes

Touristic business activities in the site

Yes, 30-40 groups/year visiting the wind farm; some of them climb the turbine.

Regarding local business owners' view on whether relations with local community should get better

Yes – if possible as we have no problems todays

Regarding the positive impact of the current business to local economy and to job creation

Yes, Business, jobs

Yes/No Questionnaire

Does the local community think that existing activities at the site :

a. **benefit wildlife :** Not relevant
b. **make the scenery interesting :** Yes
c. **attract tourism :** Yes
d. **restrict adjacent land uses :** No
e. **exclude recreational fishing :** No
f. Restrict public access : No; the public has access to the water around the turbines, but not access to the foundation.
g. enhance recreational fishing : Maybe
h. **Identity of place :** Yes
i. change personal attachment to the area : Yes
j. cause local community to use other areas for their recreation : No
k. cause fewer people to visit the area : No

Personal thoughts of the interviewee, on whether the multi-use solution that UNITED project will develop would bring added benefits to local communities

Yes, caused by the business and jobs

5.2.5 Greek pilot

For the Greek pilot, the interviewee, was the a UNITED partner that is also the main responsible for one activities already existing in the pilot site, which is the aquaculture.

Interviewee's personal definition of the local community in the pilot site

As local community in the pilot site, I define this to be the local residents in the of the area covering Lavreotiki – Saronikos – Palaia Fokaia and the local authorities.

Regarding the current local community view towards the active business operations in the site

Residents of Palaia Fokaia are totally negative towards the aquaculture unit. This is because of negative rumours spread by the local authority due to particular conflicts of interest. The view of citizens of Lavreotiki can be characterized as a combination of positivity and neutrality.

Regarding any reports of complaints on the active types of business in the site

No formal reports of complaints have occurred through the years. There was just a general dissatisfaction on the aquaculture infrastructure, claiming that it is ruining the landscape.

The overall local community benefit from current the activities

Local community has benefited by the active business in the pilot through the years, via the opening of many job opportunities such as technical jobs for the aquaculture infrastructure, waste management, other types of services needed fot the business, road construction.

Possible barriers that the local community has created to the business activities

The local issuing authorities in fact have seemed to pose certain barriers in the form of delays in issuing the proper licenses that the aquaculture unit needed for continuing its operations.

Regarding the pilot site's level of attraction to local community

The pilot site is currenty a unique attraction for local residents, local tourists as well as tourists coming from abroad. Visitors of the pilot site usually perform recreational activities such as swimming, diving, using private boats to explore the natural beauty of the area.

Touristic business activities in the site

Currently, only diving expeditions. In the past, there was also a food canteen in the islet Patroklos, which attracted a lot the tourists in the site.

Regarding local business owners' view on whether relations with local community should get better

Definately, relations with local community should significantly improve for the sustainabilty of the business in that particular spot.

Regarding the positive impact of the current business (aquaculture farm) to local economy

Through job creation. It has also indirectly contributing to the popularity of the site, by creating a unique identity of the specific area, making the place recognizable from visitors, by the aquaculture unit, referring to it as the «the aquaculture».

Yes/No Questionnaire

Does the local community think that existing activities at the site (yes/no):

a. **benefit wildlife :** Yes. The has been tremendous rise in fish population around the pilot site because of the the prohibition to fisheries in the area.
b. **make the scenery interesting :** This topic has received both affirmative and negative views.
c. **attract tourism :** Yes
d. **exclude recreational fishing :** Yes
e. **restrict public access :** No, on the contrary, the aquaculture has constructed a road to give access to the coast.
f. **enhance recreational fishing :** No, this is prohibited.
g. **Identity of place :** Yes, as mentioned before.
h. **change personal attachment to the area :** Maybe.
i. **cause local community to use other areas for their recreation :** No, because of the easy access to the coast, already mentioned.
j. **cause fewer people to visit the area :** No

Personal thoughts of the interviewee, on whether the multi-use solution that UNITED project will develop would bring added benefits to local communities

Yes, especially if new job opportunities arise through the multi-use.

5.3 Insights on local community's reactions to multi – platform use

From the interviews performed to the business owners (and operators) of the UNITED pilots, there are some significant outcomes for creating the societal profile of each pilot, as well as could be noted as insights for the multi-use. Four out of the five UNITED pilots have declared in the interview that the current view of the societal community is positive, while only the Greek pilot has expressed a feeling of dissatisfaction from a particular part of the local community. All of the pilots have expressed that the positive relationship with local community is important and should remain as is or even get better. The main means to establish this good relationship with the local community is through job opportunities creation. However, as we can see from the answers provided, each pilot site has unique characteristics and should therefore be approached in an individual manner.

Table 14 summarizes the main points of each interview.

Table 14: Summary of results of the pilot's interviews

	German pilot	*Dutch pilot*	*Belgian pilot*	*Danish pilot*	*Greek pilot*
Regarding the current local community view towards the active business operations in the site	*Generally high acceptance of an integration of marine aquaculture and offshore wind energy among most stakeholders. However, various concerns regarding social, legal, economic, environmental or technical issues were raised.*	*Very positive, in 2016 an elaborate stakeholder consultation was performed where most stakeholders ex-pressed themselves as very positive towards development of new economy of the coast of The Hagua.*	*The offshore windpark zones are protected and secured zones and not accessible for third parties, but new activities, in agreement with the windpark owners, are now possible and the local community is very pleased that integrated multiple activities are possible in the limited zone*	*Positive; it creates business and jobs*	*Residents of Palaia Fokaia are totally negative towards the aquaculture unit. The view of citizens of Lavreotiki can be characterized as a combination of positivity and neutrality.*
Regarding any reports of complaints on the active types of business in the site	*No complaints are known. However, there were concerns of environmentalists at the beginning of the construction of FINO3, but so far, no negative long-term effects of FINO3 on the environment have been detected.*	*Not really. In the early days there were some concerns from small professional fishers but as soon as they realised it was a small operation in the scheme of things, they were not longer concerned. This was back in 2016.*	*No complaints regarding the active types of business in the actual site.* *In the past, intrusions from fishermen (mainly Dutch fishermen) into the secured zone, but now we see that this is normalized.*	*None*	*No formal reports of complaints have occurred through the years. There was just a general dissatisfaction on the aquaculture infrastructure, claiming that it is ruining the landscape.*

The overall local community benefit from current the activities	*Stakeholders (research institutes, fish/ mussel/seaweed farms, supplying industries) have a general interest in expanding this economic branch, but are critical regarding the feasibility.*	*The local community has indeed benefited over the years. As indicated above, almost all stakeholders were very positive and that has really helped to get support from the municipality and in general just hands on support in the harbour.*	*Renewable energy is the main benefit that the local community has gained. Offshore wind energy will pro-duce approximative 10 % of the BE total energy consumption.*	*The current business activity creates business opportunities to the local community.*	*Local community has benefited by the active business in the pilot through the years, via the opening of many job opportunities such as technical jobs for the aquaculture infrastructure, waste management, other types of services needed fot the business, road construction.*
	German pilot	*Dutch pilot*	*Belgian pilot*	*Danish pilot*	*Greek pilot*
Possible barriers that the local community has created to the business activities	*Environmentalists had the concern that noise might cause marine mammals to be driven out of their habitat and could suffer from serious hearing impairment (Dolphin Rescue Society, 2008).*	*None*	*No difficulties were expired from the local community.*	*None*	*The local issuing authorities in fact have seemed to pose certain barriers in the form of delays in issuing the proper licenses that the aquaculture unit needed for continuing its operations.*
Regarding the pilot site's level of attraction to local community	*There is a strong interest of the local community in northern Germany to expand offshore activities.*	*The site is relatively far offshore, 12km and not suitable for visits by members of the local community. There are plenty touristic activities though in the harbour where we operate from.*	*The pilot site is currently not attractive to the local community due to the distance to shore and the accessibility of the site.*	*Yes*	*The pilot site is currenty a unique attraction for local residents, local tourists as well as tourists coming from abroad.*
Touristic business activities in the site	*There are no touristic activities going on around the FINO3 site or close to the wind farms Butendiek, Dan-Tysk and*	*- Fishing - Boat trips - Sailing - Surfing*	*At the location of the Bligh Bank, no touristic activities are ongoing (distance and vicinity of the shipping lane).*	*Yes*	*Currently, only diving expeditions. In the past, there was also a food canteen in the islet Patroklos, which*

	Sandbank as it is prohibited to enter the safety zones of the wind farms and FINO3.				*attracted a lot the tourists in the site.*
Regarding local business owners' view on whether relations with local community should get better	*Yes, there is a strong need to have common reliable regulations for planning future activities and to attract investors*	*This is not really relevant here as the business owners are to a large extent local community.*	*Relations are already positive, so it will be good to maintain this.*	*Yes – if possible as we have no problems today*	*Definately, relations with local community should significantly improve for the sustainabilty of the business in that particular spot.*
	German pilot	***Dutch pilot***	***Belgian pilot***	***Danish pilot***	***Greek pilot***
Regarding the positive impact of the current business to local economy	*Small scale energy producers and municipal utility companies benefit from wind farms, as they have an op-portunity to fill the "energy" gap resulting from the shutdown of nuclear as well as coal-fired power plants.*	*Yes, the pilot will be operated from the Scheveningen harbour and for this local businesses are involved.*	*Parkwind employs more than 95 people and supports indirectly about 100 jobs per windpark in supplying sectors like engineering companies, shipping companies, maintenance companies. Local hotels and other facilities take advantages from our activities.*	*The current business activity creates business opportunities to the local community.*	*Through job creation. It has also indirectly contributing to the popularity of the site, by creating a unique identity of the specific area, making the place recognizable from visitors, by the aquaculture unit, referring to it as the «the aquaculture».*
Regarding the positive impact of the current business to job creation	*New jobs were created.*	*For this the pilot, activities are still too small. Hopefully this will change in the future*	*Parkwind employs currently 95 people.*	*New jobs were created.*	*New jobs were created.*

6. CONLUSION

6.1 Summary of pilots' faced challenges and proposed solutions

As an overview of the planned solutions that each pilot will develop:

All pilots need to face the lack of general technological knowledge from the industry involved in MUPs in general. This should be addressed in collaboration with WP7 and WP9 in organizing training sessions to educate the related stakeholders on availability of technical solutions and their proper use. Another matter to be taken into consideration, faced by the pilots that include aquaculture infrastructure (all pilots except the Danish one), is the potential damage due to extreme adverse environmental events (storms or underwater earthquakes) with risk of damage in case of mooring failure (in the cases applied) due to severe weather conditions. Technical installations and exhaustive testing of the hardware and infrastructure during the pre-operational phase is crusial, with WP7 and WP2 to provide insights regarding the most appropriate deployments. In the case of vessel use, all pilots face the issue that vessels depend even more on fairly low winds and waves (especially for the Danish and Greek pilotthat involves vessels for touristic activities). WP2 could advise on technology solutions to provide accurate weather predictions to prevent any accidents in this case.

WP7 and WP2 could also cooperate in the handlying of automation of remote data recording via sensors and biofouling for the aquaculture specific pilots. Challenges related to economic issues were also identified by all pilots, pointing out the lack of certainty of effects of far offshore MUP on fish or oysters in aquacultures (with regard to economic effects) (for the German pilot) as well as the lack of united business models coming from the synergies, as well as the lack of standardized procedures to co-use aspects related to the MUP High maintenance cost of aquaculture sites. In the cases applied, the high cost of decommissioning of the MUPs was also taken into account, as well as the cost of maintenance. WP3 in this case should coordinate with WP1 to create concrete business models and identify business opportunities for the developed MUPs.

High insurance costs and lack of legislation guidance should be addressed by the WP6 while social acceptance and stakeholder involvement at all stages of operation should be guided by WP5.

6.2 Deliverable summary

This deliverable has performed an extensive description of the multi-use solutions per pilot as well as described them with similar multi-use solutions of previous projects from the "Oceans of tomorrow" and other relevant co-use projects. A review of the existing technological solutions in the site is described in chapter 3, with an analysis of the pilot cases as well as the definition of the technical multi-use case requirements for each pilot. The deliverable also carries out an analysis of the challenges identified for success for each pilot, mapped with the identified challenges, risks and barriers of previous multi-use projects. Finally, the deliverable reports on the interviews that were performed with the local business stakholders in an attempt to gain insights for the potential multi-use, as well as to create a societal profile based on the opinions of the involved local business stakeholders. This deliverable plans to inform the other work packages in order to continue with a more focused analysis and implementation of this deliverable's work.

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