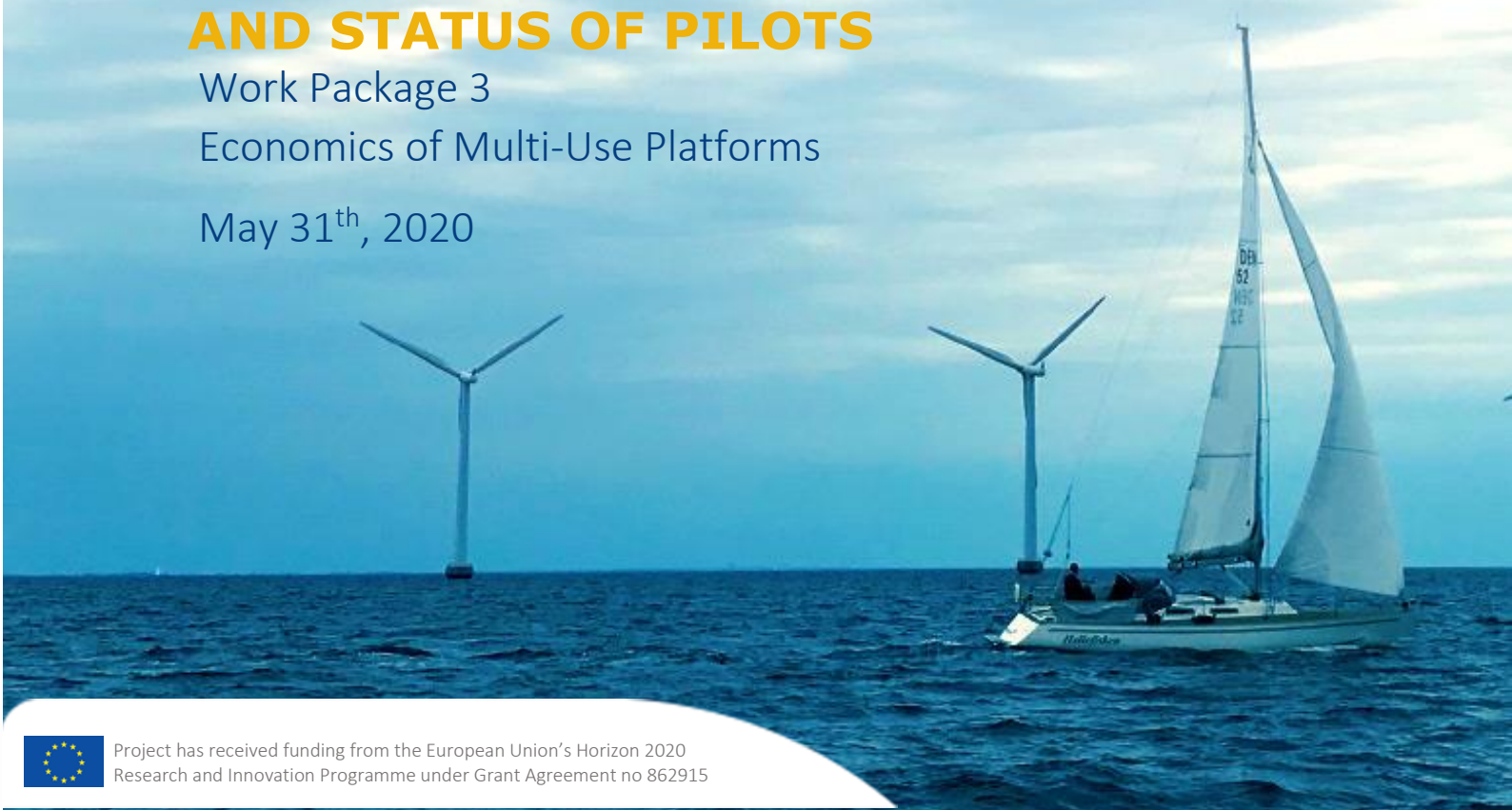
# DELIVERABLE 3.1 – FINAL REFORT FOR EXTERNAL USE

# CURRENT ECONOMIC ASSESSMENT AND STATUS OF PILOTS

Work Package 3

Economics of Multi-Use Platforms

May 31th, 2020



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# ACRONYMES

| | |
|---|---|
| UNITED | Multi-Use offshore platforms demoNstrators for boosting cost-effecTive and Eco-friendly production in sustainable marine activities |
| OWF | Offshore Wind Farms |
| MUCL | Multi-Use platforms and/or Co-Location at platforms |
| TRL | Technological Readiness Level |
| FuE | R&D Centre Kiel University of Applied Sciences (Forschungs- und Entwicklungszentrum Fachhochschule Kiel GmbH) |
| PES | Payment for Ecosystem Services |
| TBD | To Be Determined |
| DoA | Description of Activities |
| GESAMP | Joint Group of Experts on Scientific Aspects of Marine Environmental Protection |
| FAO | Food and Agriculture Organisation |
| BMU | Federal Environment Ministry (Germany) |
| BMWI | Federal Ministry of Economics (Germany) |
| BSH | Federal Maritime and Hydrographic Agency |
| ha | hectare |
| MW | Mega Watt |
| WUR | Wageningen University and Research |
| UGent | University of Gent |

# EXECUTIVE SUMMARY

The H2020 project UNITED aims to develop economically feasible offshore multi-use combinations for five pilots across European regional seas. The economic feasibility of multi-use combinations will be evaluated by a multi-criteria economic assessment framework. This report, developed under task 3.1 of UNITED, describes the current status of each pilot in terms of current activities, planned activities, their level of development, scale-up potential, perceived synergies and identifies potential sources of information that can inform economic analyses in the next phase of the project.

This stock-taking exercise of currently available information and views will help identifying key issues and research questions that should be addressed in the economic analyses of multi-use combinations tested in the UNITED project. The report builds on the review of compiled available information from pilots' background information in the proposal complemented by the results from a questionnaire that was filled-out by each pilot.

Table 1 introduces a summary of the stock-taking exercise for each of the pilots.

Some key messages for the development (task 3.2) and implementation (task 3.3) of economic assessment frameworks and business models within UNITED are summarized in the following:

- Similarities in proposed multi-use combinations exist across pilots requiring potentially similar economic evaluation methods and business models.
- Differences in status between pilots in terms of their current stage of implementation of single-use and multi-use activities will raise different economic questions and consequently require different types of analysis; in order to make research questions/requirements explicit baseline references and alternatives need to be carefully developed for each pilot.
- It remains unclear whether pilots' TRL levels and ambitions were set with regard to the planned multi-use concept or with regard to the development of one of these uses; this needs to be further clarified and is essential for developing baseline references.
- Synergies due to the combined use (cost-savings and economies of scales) and positive externalities (social acceptance, ecosystem services) are perceived as the main benefits of multi-use by the different pilots. Information on positive externalities is key for increasing public support which in turn is important for the wider uptake of multi-use concepts. These factors should be key elements of any future economic analysis.
- Future economic analyses should also consider the value (or opportunity cost) of marine space for the optimal design and establishment of multi-use schemes. Optimal refers to a combination of an offshore location and economic activities that generates the highest value among alternative locations/activities.
- The provision of ecosystem services could become a variable of the financial analysis through the development of compensation or Payment for Ecosystem Services (PES) schemes. The possibility to develop such schemes should be further investigated in the next phase of the project, paying particular attention to country-specific institutional arrangements.

*Table 1 - Synoptic overview of available information across the UNITED pilots*

| | Germany | Netherlands | Belgium | Denmark | Greece |
|---|---|---|---|---|---|
| Actual activities | Single-use research activities | Single-use research, upscale of offshore innovations | Multi use combination: mussel farming and OWF | OWF with sporadic touristic visits to the platform | Aquaculture on-site<br>Touristic activities existing at the regional scale |
| Planned combined activities | Integrating mussel farming and OWF | Floating solar power, OWF, aquaculture, nature restoration. Final combination not clear | Extension with flat oyster aquaculture and oyster bed restoration, as well as cultivation of seaweed | Expanding existing and new touristic activities (e.g. diving, leisure fishing) | Integrating touristic activities with aquaculture |
| Scale-up potential | TRL5 – TRL7 | TRL5 – TRL7 | TRL5 – TRL7<br>Good potential: Belgian wind parks are restricted for fisheries, creating ample space for aquaculture and restoration activities | TRL6 – TRL8<br>Good potential: increasing interest in visiting wind farms and close proximity to Copenhagen | TRL 5 – TRL7 |
| Requisites for achieving potential | Cost-effectiveness, mussel prices, reduction of implementation/operational risks<br>Support of government authorities (financial and permits) | | Availability of equipment<br>Supply of biological source materials<br>Growing conditions | | |
| Expected synergies/ co-benefits | Economies of scale due to logistical improvements (e.g. shared use of vessels/vehicles)<br>Help to increase political support | Cost reduction due to economies of scale (e.g. better use of grid infrastructure, improved monitoring of aquaculture systems due to shared infrastructure) | Economies of scale due to logistical improvements (e.g. shared use of vessels/vehicles and port facilities) | Cost reductions due to combination of activities (e.g. sharing vessels) | Cost minimization (exploiting same space, sharing transportation and other infrastructure, coordination of logistics) |
| Expected synergies/ | Make obtained experience and information available for | Wave dampening effect of floating solar infrastructure | Generation of ecosystem services | Educational, environmental, and overall wellbeing benefits | Stimulation of touristic growth |

| | | | | | |
|---|---|---|---|---|---|
| co-benefits (continue) | others to encourage/increase multi-use<br>Help increase acceptability of OWF and aquaculture<br>Generation of ecosystem services | Blueprint for any similar offshore multi-use initiative, e.g. to reduce their dependency on subsidies (contribution to Blue Growth).<br>Increase social acceptance of offshore energy production and aquaculture | | (e.g. recreational opportunities) | Increase the social acceptance of aquaculture activities<br>Monitoring pollution threats to the marine area through same infrastructure used within aquaculture. |
| Business models | It is a research platform and therefore economic outputs/revenues are only a goal on a long-term perspective (20 years). | It is a research platform but focused on the upscale of innovation. Therefore, commercial rollout on the short to medium term is expected | Commercial. Multi-use already in place, but is intended to be expanded with seaweed and oysters | Commercial. Two activities already in place but not yet fully exploited or completely coordinated/integrated | Commercial. Two activities (OWF and tourism services) already in place but not coordinated/integrated as MU. |
| Expected from Work Package 3 | Better understanding of legal conditions and authorization<br>Gaining understanding of the target application and market, e.g. through cost-performance model or financial model for initial short- and long-term projections (costs, revenue, margins, etc.)<br>reduction of risk of implementation/ operation at affordable cost | Determining economic feasibility and developing a business case | Calculation of economic feasibility<br>Extensive risk analysis a part of the business case: estimation of costs for new risks or additional insurance policies; mapping costs of mitigating certain risks and insurances in a competitive manner (compared to traditional mussel production)<br>Quantifying and evaluating possible commercialization of ecosystem services | Develop a financial assessment (economic and financial feasibility) of alternative options to advise the business case development | Evaluate the overall benefits of businesses moving forward to synergies rather than acting individually in same marine space |

# 1. INTRODUCTION

UNITED aims to provide practical promising designs, technological proposals and models for combining offshore activities, by implementing multi-use concepts in five pilots across European regional seas. Business models of offshore multi-use combinations and insight in their financial viability and socio-economic impacts, will be developed to support the effective design, optimization and implementation of multi-use concepts in the pilots and to enhance their up-scaling potential and the possibility to seize emerging commercialization opportunities.

Work Package 3 of UNITED addresses the 'Economics of Multi-use Platforms'. It will support the economic assessment of multi-use combinations by providing and applying a multi-method economic assessment framework. The outcomes of the assessment framework can steer future decisions regarding multi-use of the different pilots.

The first step of this Work Package, and in particular of its task 3.1 'Revision of the current economic assessment and status of pilots', is to describe and characterize pilots and to identify most up-to-date sources of socio-economic information related to each pilot. These sources of information will be used at a later stage to develop the baseline (or reference) scenario of each pilot in task 3.2 and task 3.3. The baseline scenarios will allow accurate economic analyses and accounting of results along the project. The pilot information presented in this report will feed in particular to the development of an economic assessment framework (task 3.2 and task 4.2) and will support its application in the pilots (tasks 1.3, 3.3, 3.4 and 8.2). This report does not report on economic barriers as this is part of deliverable 1.1.

This deliverable describes the methodological approach proposed for updating the current status[1] of the pilots and stock-taking of available economic information (section 2), the results of this stock-taking exercise are then presented for each pilot (section 3 to section 7). The report concludes with a comparison of available information across pilots, providing an outlook on the implications of socio-economic information availability for the development and implementation of the economic assessment framework within the UNITED project.

[1] Updating of the current status refers to the actualization of pilot information on current/planned activities and TRL levels compared to the pilot information provided in the project proposal.

# 2. METHODOLOGICAL APPROACH

The stock-taking and analysis of the available information followed a four-step approach, see Figure 1.

- As a first step, background information provided by the pilots during the project proposal phase was collected and reviewed.
- This information was then complemented (second step) by the development of a questionnaire for updating available information and identifying additional sources of socio-economic evidence on the different uses connected to the pilots. The full questionnaire is available in Annex 1. This stock-taking questionnaire was part of a wider initiative to collect information from pilots at the start of the UNITED project. The overall development, integration and implementation was led by Wageningen Economic Research jointly with consortium partners. The questionnaire was programmed with the Qualtrics survey management tool. After a two-week processing period, the pilot leads submitted their answers. More details on the survey is provided in Deliverable 1.1. The answers to the status update and stock-taking questionnaire of pilots are available in Annex 2 to Annex 6.
- As a third step, information and data from the background reports and from the questionnaire were integrated and reported in a first draft of this report.
- As a final step, pilot leads were asked to review and complete the reported information during an internal project review. Based on their feedback, the status of pilots and the stock-taking of economic information were revised in the final report.

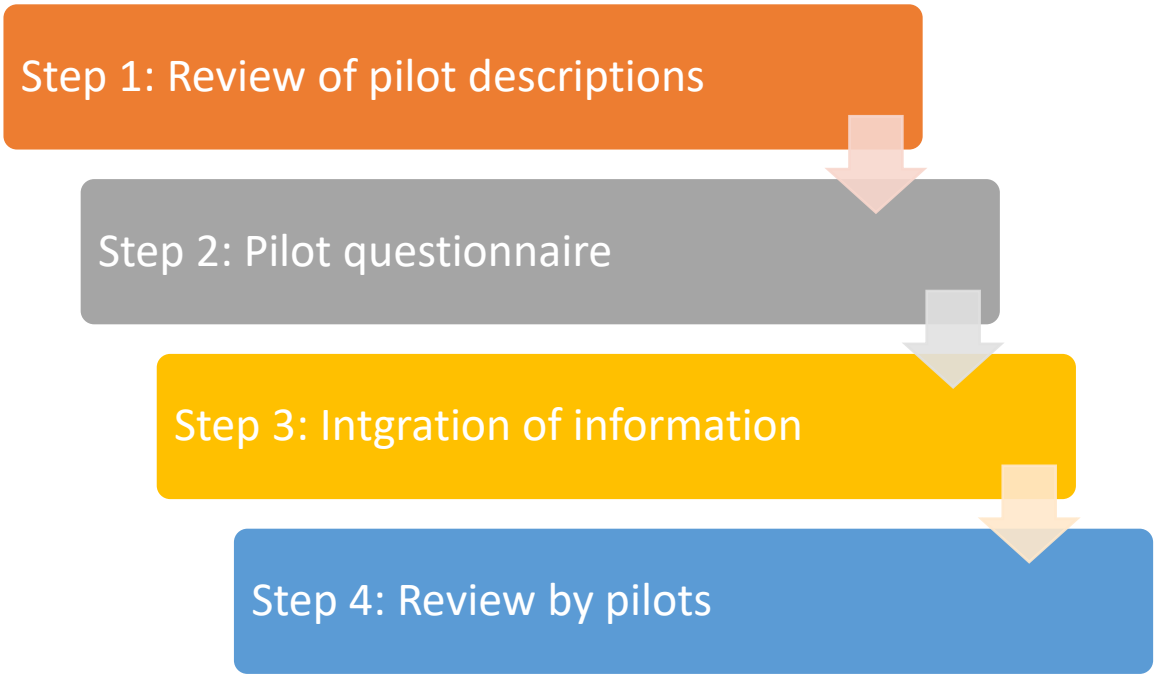


*Figure 1 - Methodological approach*

Section 3-7 present the results of the analysis per pilot, following the same structure as the questionnaire, i.e.: 1. Description of the current activities in the pilot area, 2. Planned combined activities in the pilot, 3. Expected potential to scale-up proposed combined activities, 4. Partners and other stakeholder involved in the pilot, 5. Expected synergies of combined offshore activities, 6. Available economic and financial information, and finally, 7. Expectations with regards to follow-up Work Package 3 activities and outputs.

# 3. GERMAN PILOT

## 3.1. Current activities in the pilot

The German pilot of the UNITED project is located in the German North Sea, 80 km away from the coast. A research platform called FINO 3 was built in 2009 and is operated by the UNITED project partner R&D Centre Kiel University of Applied Sciences GmbH (Forschungs- und Entwicklungszentrum Fachhochschule Kiel GmbH - FuE). Because it is a research platform, activities undertaken at FINO 3 do not aim for economic profitability for their research activities, but should lead to optimal decisions (also in economic terms) for a potential commercial roll-out of the research activities. Several research activities are currently undertaken (UNITED being one of them) to run tests in an offshore environment. These research projects are providing the basic funding for the research platform and its maintenance.

These research activities include, for example:

- Model-scale wave power plant: The test facility serves as a new energy research infrastructure with a "real laboratory" character.
- Scratch resistant anti-biofouling coatings: Sensorial monitoring systems typically have significant deficiencies in corrosion resistance and inhibition of growth, severely limiting the life of these devices.
- Current and sea loads: The sea loads of large monopile structures are determined by means of a simulation method for free-surface frictional flows in order to be able to construct larger, more efficient offshore wind turbines with high stability in the future.
- Bird migration: FINO 3 belongs to a network of automatic receiving stations in the area of the German Bight, which receive signals from songbirds, which are equipped with tiny radio telemetry transmitters.
- Hydrography: Oceanographic data are collected on and in the immediate field of the platform by means of a sea buoy, an acoustic flow meter, a CTD-device[2] and oxygen probes.

In general, the research platform is unmanned, but maintenance personnel and researchers work on the platform at regular intervals. The basic fundament of the platform follows the same characteristics as the ones of constructed Offshore Wind Farm (OWF) turbines in the area. The experiences from its operation and the results of the numerous scientific research projects carried out so far, on and at the platform, have helped the wind farm operators and wind turbine manufacturers in the planning, building, and future operation of OWFs. The dynamic characteristics of this region including stormy winters, remote access, and high demand of automation makes the application of automation and optimization measures between wind turbine parks and planned bivalve mariculture uses very reasonable.

## 3.2. Planned, combined activities in the pilot

The planned activities at FINO 3 aim to demonstrate the societal acceptance multi-use offshore plants and their benefits. FuE will install a mussels and seaweed farm, operate it and evaluate different scientific aspects. FINO 3 is well placed to take up an offshore wind and aquaculture demonstration project and advise its development from pilot scale to potential commercial application.

Based on the results of a feasibility study (Geisler et al., 2018[3]), the most feasible scenarios with the best scoring results (considering a wide range of biological, economic and technical factors) were the cultivation of Mytilus edulis and Saccharina latissima. The preparations for the implementation of a mussel and a seaweed longline

[2] CTD is a device to measure conductivity, temperature, and depth

[3] Geisler, R., Schulz, C., Michl, S., Strothotte, E. (2018) : Offshore-Aquakultur am Standort der Forschungsplattform FINO3. Machbarkeitsstudie im Auftrag der Wirtschaftsförderung und Technologietransfer Schleswig-Holstein GmbH. Online : https://www.fh-kiel-gmbh.de/files/aktuelles/pdf/Machbarkeitsstudie_Offshore_Aquakultur_FuE-GmbH.pdf, last consulted 07.05.2020

cultivation at FINO 3 is planned. No equipment has yet been installed. The compilation of requirement specifications for the planned offshore set-up are in progress and firstly equipment tests will be run (during the pre-operational phase) before the installations will be conducted at FINO 3 (in the operational phase).

The German pilot will engage multiple interested OWF developers but will ensure full transparency of the project results so that these could be taken into consideration in future OWF planning rounds, by both industrial players and authorities. Additional project outputs and potential products for interested OWF operators, operators/owner of decommissioned oil platforms and maritime coastal planners are:

- Providing a database dealing with the effects of offshore installations on the environment, e.g. creating information on site attractiveness for invertebrates and fishes, use as fish habitat, fish refuge acting as nursery area, all potentially affect windfarms and operators should know about these situations while using them as compensatory measures.
- Improving Health, Safety and Environment: develop a concept to be used for other offshore projects (e.g. involvement of other stakeholders, such as tourist attractions which can also be used to enhance public knowledge and public acceptance).
- Creating public awareness and public acceptance: The course development could finally lead to a guideline or learning manual.
- Providing solutions, blueprints on how and to what degree synergies can be used.
- Identifying risks and critical points for future multi-use projects.
- Developing recruitment options of staff for multi-purpose industry of the future.
- Conducting risk assessments for future insurance procedures.
- Testing the remote automated recording of environmental data Moreover, the demonstrator project will provide small and medium-size companies or EU institutions with an opportunity to build up reference guidelines and demonstrate their performance capability under realistic conditions.

The FINO 3 research platform was funded from public funds, starting in 2005. The research and measurement results are therefore generally available to the public. The maximum grant for the FINO 3 research platform can be found on the homepage of the Federal Environment Ministry (BMU), Federal Ministry of Economics (BMWI) or the responsible project executing agency.

## 3.3. Expected potential to scale up proposed combined activities

The German pilot is currently at technological readiness level (TRL) 5 and is supposed to reach TRL7 with the input of UNITED. In order to reach TRL7 the following aspects need to be addressed:

- Functionality of Multi-Use platforms and/or Co-Location at platforms (MUCL): Evidence on the effectiveness of MUCL is needed, while reducing the risk for implementation/operation at affordable costs.
- Administration/ government: Solutions for governance (obtaining permissions and licenses) that comply with legal standards need to be found/described.
- Investors and sales plan: The decision-making process on investing into MUCL needs to be simplified with special/reliable offers for investors regarding financing models/business plans while reducing the overall economic risk (defining risk government actions).
- Effective marketing strategies need to be defined to generate a stable turnover of products, there is no "go to market strategy" for the products (mussel, seaweed) yet.
- Standardized infrastructure: A whole infrastructure for operating a MUCL needs to be created in order to reduce various risks: training certified offshore staff, optimizing the scheduling of logistics, transportation and maintenance work, reducing energy need, etc.
- Technological development: Technological feasible/affordable concepts for the offshore installation of semi-submerged longlines in high energy environments need to be tested and confirmed.
- Environment: environmental data is required to investigate the impact of MUCL on the environment at that location. If there are negative impacts, these need to be known before any upscaling can happen.

Potential usage scenarios of multi-use solutions could be:

- Other windfarms
- Decommissioned oil rigs
- Cable lines/pipelines
- Certain tourist spots
- Creating "artificial reefs"

Markets for seaweed:

- Seaweed: cosmetics industry/pharma industry
- Seaweed: restaurants/organic food
- Seaweed: trade/construction (insulating material)
- Seaweed: water remediation systems, sewage treatment plants

Markets for mussels:

- Mussels: restaurants/organic food
- Spat mussels: for commercial nearshore mussel aquaculture farms

Mussels: animal food production. The environmental impact would have to be proved for each location separately in case of a scaling up due to its own characteristics. In general mussels and seaweed have a low, no or even positive impact on the environment. One reason is the fact that no additional nutrients (e.g. like fish food in fish aquaculture) will be added to the ecosystem. The potential carbon uptake can be highlighted as environmental service.

Economic impacts: shellfish producer in the EU are predicted to increase their output by 30% by 2030, while the current annual growth rate is just 1.3%[4]. In most of the Member States mussel aquaculture has been considered the most promising type of aquaculture for multi-use with OWFs. The North Sea is a suitable option for developing a pilot as it is the most advanced in examining different technological options for this combination. The seaweed market is expected to grow in Europe. There is a strong potential for seaweed cultivation in the North Sea, especially to produce feed additives and chemical building blocks. The German 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 context. Moreover, seaweed can be cultivated for food, animal feed, bio-chemicals, energy and other valuable products. We assume that a proof of concept is necessary before engaging with investors more actively. For this reason, it is important to work together with OWF operators and developers to demonstrate the feasibility and benefits of multi-use within the FINO 3. Some of the questions to be addressed include:

- What are suitable (financial, regulatory) incentives for multi-use to happen, what EIA requirement should be imposed. Therefore, the pilot will involve established businesses to address the aquaculture sector and traditional fishermen, willing to invest in this future sector. Due to reduced fishing quotas and declining fish stocks, aquaculture at OWFs can represent a profitable alternative future for fishermen.
- Making such business cases visible and attracting other commercial actors and investors, such as retail, utilities, and established aquaculture businesses, is an important step to increase the commercial readiness level of such combinations in the future by building up references and demonstrate the performance capability under realistic conditions.
- Regulatory and financial incentives from high-level policy support are pre-requisites for these endeavours. Such frameworks have so far been established in Belgium and the UK, attracting financiers to investigate the potential for commercialization of such multi-use solutions. Due to its overall low presence in Europe, individual seaweed businesses have, so far, had limited capacity for engagement with multi-use concept.

In most projects where OWF companies have been engaged so far most of the business models and main project findings have stayed proprietary, not available to other developers and interested investors. With low transparency of projects and involvement only of some OWF companies, multi-use project results are less likely to be exploited. 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 development in regard to shared costs, better social/environmental image of involved businesses and overall increased financial yield for investors. An opportunity for certain eco label/small spatial footprint certification can also be explored, both for marketing the aquaculture products as well as for the renewable energy derived from the multi-use site. In this, it also seems promising to examine a technology utilization concept that is needed in aquaculture and, in cooperation with the established industry, to introduce niche products into the global market in order to gradually increase their share. With such partners, market shares can be expanded on the basis of "win-win" scenarios, while many operational requirements can be further exploited, and learning processes can be designed cost-effectively. This way, costs for parallel and future-oriented developments could be minimized. These measures will help to attract "newcomers" and develop a basis of trust for long-term cooperation and division of labour.

Based on the results of the feasibility study, the implementation of mussel longline cultivation has proven to be applicable and when following a long-term approach (20 years) will enable positive revenues. Due to technical and biological challenges and the high level of required investment, there are still considerable problems and open questions regarding the scale-up potential. So-called "multi-use" approaches are considered, to still be part

[4] European Union (2014): The long-term Economic and ecologic impact of larger sustainable aquaculture. Policy Department B: Structural and Cohesion Policies. Brussels. https://www.europarl.europa.eu/RegData/etudes/STUD/2014/529084/IPOL_STU(2014)529084_EN.pdf

of the research and experimental stage with no commercial operation of such a plant in Germany. In addition to the selection of suitable organisms that can withstand the harsh offshore conditions, the use of stable and safe techniques for installation and operation as well as very good organisation and management of these offshore facilities are essential.

## 3.4. Partners and other stakeholders involved in the pilot

Table 2 presents project partners and other external stakeholders involved in the pilot.

*Table 2 - Stakeholders of the German pilot*

| Stakeholder | Project partner/external stakeholder | Role | Interest |
|---|---|---|---|
| KMF | Project partner | Nearshore site operation/producer/Consultant | Research results |
| 4HJena | Project partner | Responsible for technical functioning, solutions, software of sensors, and monitoring devices | Research results, improving the remote automated data recording of sensors |
| BSH Federal Maritime and Hydrographic Agency | External stakeholder | Approves/supervises maritime legislation | Granting licence for the pilot controls that the implementation, operation and decommissioning of the pilot is according to national legislation |
| Shipping company | External stakeholder | Offshore vessel for implementation, maintenance, decommissioning, transport of material and staff | Economic interests, obtain contracts |
| Helicopter company | External stakeholder | Transport of material and staff | Economic interest, obtain contracts |
| Supplier of industrial divers | External stakeholder | Implementation and decommissioning phase, connecting aquaculture farm with platform via searchable | Economic interest, obtain contracts |
| Tank shop company | External stakeholder | In charge of filling up the tank at FINO 3 | Subcontractor of FINO 3 |
| Insurance company | External stakeholder | Insures the pilot | Subcontractor of FINO 3 |
| Other projects conducted at FINO 3: Model-scale wave power plant, Scratch resistant anti-biofouling coatings, Current and sea loads, Bird | External stakeholder | No active participation, however other projects will take place at the same location at the same time | Research results |

| | |
|---|---|
| migration, Meteorology, Hydrography, Georeferencing, Water quality, Gamma radiation | |

## 3.5. Expected synergies of combined offshore activities

Synergies between the OWF operators and aquaculture are possible on several levels. With respect to financial benefits, shared activities can have positive impacts. 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. For example, shellfish (mussels, oysters, scallops) usually require a 2-day window for distribution to the distributor. For far-offshore locations (like FINO 3) it is difficult to predict when harvesting and subsequent distribution can take place. Also, storage space and workshop at the offshore site will be shared.
- *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.
- *Planning and maintenance work*: Means of communication, timetables for maintenance, training requirements and procedures (emergency response) for minimizing risks at the site.
- *Energy*: The whole 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.
- *Social Acceptance*: Workshops will be conducted to demonstrate students (offshore engineering, architecture and aquaculture students) as well as other stakeholders' benefits and challenges when developing multi-use offshore.
- *Insurance*: The German pilot addresses the question of how insurance premiums required by the insurance companies, are to be shared between the two developers (aquaculture and offshore wind).
- *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.

Some of these activities that can be handled jointly, can even be more efficient when outsourced. The following operational activities could be outsourced:

- Environmental monitoring data and surveillance.
- Permissions and licences.
- Certified offshore staff (including multi-disciplinary education of personnel).

## 3.6. Available economic and financial information

### 3.6.1. Economic / financial feasibility studies / information

Prior to the UNITED project, an extensive feasibility study (only in German) was conducted (Geisler et al., 2018), assessing five different multi-use concepts at the given offshore location, including business plans, risk assessment studies and demands of the international aquaculture industry. The FuE holds all financial information regarding the operation costs of the platform. However, some data will have to be handled confidentially.

The feasibility study was conducted for the particular location at FINO 3. The objective of the feasibility study was to analyse if it is possible to operate any aquaculture at this location and what sort of aquaculture could be recommended for a research project with the focus of upscaling. So, five different scenarios were investigated:

mussel longline cultivation (Mytilus edulis), Macroalgae (Saccharina latissima), Oysters (Ostrea edulis), trout in cages (Oncorhynchus mykiss) and IMTA (Mytilus edulis and Saccharina latissmia). However, neither scenario was discussed in such detail as if it were the object of a single feasibility study, so more details may still be required for mussel/seaweed cultivation.

In addition to this study recent reports (Buck 2009[5] Krost et al. 2011[6]), show that OWF developers consider combination with extractive aquaculture more favourably compared to fed aquaculture, as it entails less frequent visits to and smaller-scale operations taking place within the OWF. 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.

Moreover, a risk assessment as part of the feasibility study (Geisler et al., 2018) with a list of specific risks and their evaluation was carried out according to GESAMP (Joint Group of Experts on Scientific Aspects of Marine Environmental Protection, 2008)[7] and FAO (2008)[8].

- The feasibility study was based on the five different scenarios and were evaluated based on 22 criteria. The criteria were roughly divided into three blocks: biological, technical, and socio-economic suitability. For the socio-economic suitability following criteria were considered: Investment expenditure, operating expenditure, income: Investment and operating costs are generally high in the offshore sector due to the exposed location. The level of costs is also determined by different additional constructions and tests, training of personnel, and possibilities to use existing structures. For these reasons, the revenue opportunities had to re-examined for each scenario, especially with regard to product diversification.
- Robustness of scenario: The robustness of single scenarios against various offshore forces (e.g. salty air in combination with solar radiation, salt water, swell, wind, mooring possibilities) also impacts the life cycle and the level of maintenance and servicing costs.
- Stakeholder acceptance: Aspects like acceptance of consumers, politics, and other stakeholder are of importance. Also, aspects of tourism could be relevant for more nearshore activities (probably not relevant for FINO 3).
- Licensing Environmental law: The entire project from construction to operation and disposal must comply with various environmental laws.
- Licensing building law: Regulations for the construction of an installation in the offshore and onshore sector must be examined.
- Insurability: The design of an aquaculture facility must take into account its insurability.

#### 3.6.2. Socio-economic impact analysis

Socioeconomic factors were discussed in the feasibility study, but it was not the major focus of this study. For example, acceptance was one of the criteria. Overall, socio and cultural aspects were not part of the feasibility study.

#### 3.6.3. Business model / plan / strategy

Some information is available, but it was not the focus of feasibility study. For example, costs (investment, service/maintenance, transportation, equipment, decommissioning, etc.) and revenues (due to selling of mussels)

5 Buck, B. H. (2009): Meeting the quest for spatial efficiency: Progress and prospects of extensive aquaculture within offshore wind farms in Europe, The Ecology of Marine Wind Farms: Perspectives on Impact Mitigation, Siting, and Future Uses. Keynote Speaker. 8th Annual Ronald C. Baird Sea Grant Science Symposium. Newport, Rhode Island, USA, 2009.
6 Krost, P.; Rehm, S.; Kock, M.; Piker, L. (2011): Leitfaden für nachhaltige marine Aquakultur. Hg. v. CRM - Coastal Research & Management GbR. Kiel.
7 GESAMP (2008): Assessment and communication of environmental risks in coastal aquaculture. Hg. v. FAO. Rom (76)
8 FOA 2008: FAO (2008): Understanding and applying risk analysis in aquaculture. Unter Mitarbeit von Melba G. Bondad-Reantaso, James Richard Arthur und Rohana P. Subasinghe. Hg. v. FAO (FAO fisheries and aquaculture technical paper, 519). Online: http://www.fao.org/docrep/011/i0490e/i0490e00.htm, last consulted 07.05.2020.

of mussel cultivation at FINO 3 for a period of 4 years have been investigated in the feasibility study. But the feasibility study did not examine different business strategies in detail for each scenario.

#### 3.6.4. Environmental impact assessments

It was not required to carry out an environmental impact assessment study prior to the approval or construction of the research platform. The Offshore Installations Regulations in 2006 explicitly supported the possibility/idea of building offshore research facilities in the North Sea. The Offshore Installations Regulations stipulated that the competent authority, the Federal Maritime and Hydrographic Agency (BSH), is informed about the project's location, content, scope and construction. The Offshore Installations Regulations was amended in 2009. Today, a simplified approval procedure has to be passed. The FINO 3 research platform defined the basis for conducting environmental impact studies for offshore wind turbines in the North Sea and Baltic Sea. However, an overview of possible impacts as well as their probability and degree of severity are part of the feasibility study and were identified to assess the suitability of different usage scenarios.

Several research projects have already been carried out at the FINO 3 platform. However, ecological/environmental impacts of multi-use have not yet been measured with indicators yet. These finished projects can serve as additional information to measure the environmental impact of multi-use. The projects are:

- *Corrosion protection*: Development and testing of novel corrosion protection surfaces for use on offshore structures. (final report in German).
- *Pillar foundation*: The aim of the measurements is to investigate the mechanical dynamic phenomena in the soil and thus to clarify the question of which mechanisms must be assumed to be decisive in the investigation and proof of stability.
- *Structure of the ground*: Under dynamic load caused by currents, waves and wind pressure, changes in the sediment structure may occur in the immediate vicinity of offshore structures. The aim is to determine the temporal evolution and spatial extent of these effects through dynamic loading.
- *Wave behaviour*: Radar measurement of wave combs is designed to clarify the behaviour of large, steep waves at sea. The new process is being tested for the first time as a permanent operation on FINO 3. (Final report in German).
- *Wind turbulence*: The aim of the project is to investigate turbulences in on- and offshore wind. For this, piezoelectric sensors are used to measure high-frequency aerodynamic wind components at different locations. (Final report in German available, poster in English).

Projects with an environmental perspective (see also here: https://www.fino3.de/en/research/researcharchive/ecology.html) are:

- *Bird migration*: The research activities provide information on the spatial-temporal course of flight movements of birds as well as the variability of species-specific train intensities in the daily and annual course in the German part of the North Sea.
- *Acoustic field*: The objective is to measure the acoustic field at FINO 3 as well as possible change resulting from the building and operation of the DanTysk and Sandbank24 OWFs.
- *Sound pressure level*: The aim is to reliably forecast the sound pressure levels in the North Sea area, where wind farms are being built. The development of the forecast calculations is carried out depending on location and time and taking into account possible temporal overlapping of several construction projects.
- *Noise protection*: The aim is to minimize the risk to marine mammals by underwater noise. As part of the sound insulation concept, a bubble curtain was developed and kept in operation during ongoing pile driving, which was operated with maximum compressed air during the entire pile driving time.

## 3.7. Expectations of Work Package 3 activities and outputs

A strong need for action is required in the area of legal conditions and authorisation procedures, which at the present revealed great uncertainty about responsibilities and their overall relevance. These are only a few reasons that complicate the preparation and planning of an aquaculture project for stakeholders. Another reason which complicates the multi-use, is the long period when applying for permits.

Efforts in the past to establish large-scale aquaculture in Germany also failed due to a negative image of this industry. Therefore, it is indispensable to involve the public, local administration and politics in future projects from the very beginning. This includes different activities of a stakeholder outreach program.

The economic and financial tasks are seen as very important by the pilot lead, especially in regard to identify upscaling possibilities as well as engaging with stakeholders. While the technology might be viable (high technology readiness level), its application depends on the commercial readiness level of such solutions. This implies that a deep understanding of the target application and market is needed, including a:

- Comprehensive cost-performance model created to further validate the value of the business proposition.
- Financial model built with initial projections for short- and long-term costs, revenue, margins, etc.

# 4. DUTCH PILOT

## 4.1. Current activities in the pilot

North Sea Innovation Lab (NSIL) is an offshore incubator and independent test site for research, pilots and the upscaling of innovations in the field of seaweed cultivation, floating solar and co-use of wind farms. It is located 12 kilometers offshore, in front of The Hague and has the following characteristics:

- Surface: 600ha/ 6km$^2$
- Water depth: approximately 18-20m
- Officially demarcated (cardinal buoys and registered in hydrographic cards)
- Known area by stakeholders

Six plots are available of approximately 100ha each. Since 2019, four plots have been occupied by pilots. One of the plots will be used for the purpose of the UNITED project.

## 4.2. Planned, combined activities in the pilot

For UNITED a specific pilot on an area of max. 100ha would be possible. Within this pilot a combination of seaweed, floating solar (400m$^2$) mussels, nature restoration and offshore wind would be most interesting. The pilot aims to:

- Demonstrate the potential to integrate offshore solar in OWFs
- Demonstrate safe operation for the commercial roll-out of seaweed in OWFs
- Quantify effects of wave dampening of a floating solar array
- Demonstrate technical feasibility of connecting the aquaculture and solar production systems for transfer of energy and communications

## 4.3. Expected potential to scale up proposed combined activities

The current technological readiness level (TRL) is 5. Several research questions will be investigated concerning the design, deployment and monitoring of the planned combined activities. Prospective activities include:

- Development of an integrated mooring/anchor design for seaweed and floating solar
- Monitoring of structural integrity of floating structures.
- Design, deployment, and monitoring of the behavior of a cable from the floating solar array to the seabed and to the buoy
- Combined environmental monitoring including the effects of structures on marine life
- Wave dampening modelling based on various configurations of structures (seaweed, floating platforms, combinations)
- Basin testing of combined seaweed and floating solar structures

The pilot aims to reach TRL 7 by the end of the UNTIED project and to push the proposed multi-use combination towards commercialization and implementation by developing a blueprint for any similar offshore multi-use initiative, regardless of their current TRL.

The pilot's ambition is to contribute to the 'autonomous' development of multi-use in oceans, meaning that commercial parties develop initiatives and reduce their dependency on subsidies and thereby contribute to the

achievement of Blue Growth strategies. The results will help industries with the development of large-scale offshore solar farms and address important bottlenecks which are currently impeding such implementations. It will also help OWF owners with the development of large-scale offshore seaweed farms in existing wind parks and with the development of new OWFs offering integrated wind/aquaculture activities in the tender-phase.

Partners and other stakeholders involved in the pilot

Table 3 presents project partners and other external stakeholders involved in the pilot.

*Table 3 - Stakeholders involved in the Dutch pilot*

| Stakeholder | Project partner/external stakeholder | Role | Interest |
|---|---|---|---|
| Oceans of Energy | Project partner | Company floating solar | Towards commercial floating solar energy, uses project for testing and demonstration of certain aspects to higher TRL level |
| The Seaweed Company | Project partner | Commercial seaweed company | Towards commercial large-scale offshore seaweed cultivation |
| TNO | Project partner | Support research on floating solar energy offshore | Research |
| Ventolines | Project partner | Service provider of onshore wind and solar and offshore wind projects | Role in future development |
| Deltares | Project partner | Support technical questions | Research |
| Governments | External stakeholder | TBD | TBD |
| Commercial shipping | External stakeholder | TBD | TBD |
| Recreation | External stakeholder | TBD | TBD |
| Offshore wind | External stakeholder | TBD | TBD |

Engagement of external stakeholders to demonstrate that offshore multi-use activities are a chance rather than a threat is important to increase social acceptance. To a large extent these contacts have already been established and can be mobilized for the purposes of this pilot.

## 4.4. Expected synergies of combined offshore activities

The following synergies are expected:

- Cost reduction due to the combination of activities.
- Wave dampening effect of floating solar infrastructure, which is potentially beneficial for the safety of seaweed cultivation on the plot (or other activities).
- Generally, it is difficult to monitor the "health" of offshore aquaculture production systems. Offshore aquaculture could profit from solar power production sensors (e.g. temperature, light, turbidity, algae, nutrients etc.) that are able to transfer measurements to onshore monitoring stations.
- On land, it is proven that wind grid infrastructure can be improved by adding solar power generation to the transmission infrastructure, resulting in cost savings and better economic performance of ancillary equipment. At sea (offshore and nearshore), even larger benefits are expected because of the higher costs of the infrastructure and the need for multifunctional use of the sea space.

## 4.5. Available economic and financial information

### 4.5.1. Economic / financial feasibility studies / information

No information on the financial feasibility of the proposed multi-use combination is available. This information may become available during the project.

### 4.5.2. Socio-economic impact analysis

No information on socio-economic impacts is available. This information may become available during the project.

### 4.5.3. Business model / plan / strategy

No information on business models is available. It should be noted that the pilot is an incubator for sustainable multi-use activities and that commercial exploitation other than as part of a test is not permitted. Many local contractors are available to provide logistical or technical support/services. No information on pilot budgets is available. This information may become available during the project.

### 4.5.4. Environmental impact assessments

No information from environmental impacts assessments is readily available.

## 4.6. Expectations of Work Package 3 activities and outputs

Further information regarding the topic areas covered in this stock-taking exercise are expected to be gained through the work of the UNITED project by the involved partners. It is extremely important to focus on a solid business case for future development of multi-use activities in OWFs. Economic feasibility should therefore be one of the focus points in the pilot development and project. Based on input of the pilot sites and companies involved, the business case for large scale multi-use should be defined.

# 5. BELGIAN PILOT

## 5.1. Current activities in the pilot

At the end of 2020, a total of eight OWFs will be operational in the Belgian part of the North Sea, with an installed capacity of 2262MW). On two of the OWFs, C-Power NV (www.c-power.be) and Belwind NV (one of the parks of Parkwind, www.parkwind.eu/en/projects), an offshore mussel aquaculture pilot project Edulis had been running since September 2016 till August 2019 under UGent project management. As such, the OWFs have already experience with offshore longline systems and operational challenges.

Parkwind develops, finances, builds and operates OWFs in the North Sea since 2012. The vast experience of the Parkwind team builds on the success of the OWF Belwind (56 wind turbines – 171MW), Nobelwind (50 wind turbines – 165MW) and Northwind (72 wind turbines – 216MW). Parkwind today operates 552MW in the Belgian territorial waters and has approximately 800 MW of offshore wind in the pipeline in Belgium (Northwester 2 – 219MW), Ireland (Oriel – 330MW) and Germany (Arcadis Ost I – 247MW). The nearshore site of Westdiep has several longlines since April 2017, being part of the Belgian projects Value@Sea and Symapa, and privately owned by Brevisco (partner). The lines are currently used for test productions of flat oysters, blue mussels and seaweed.

## 5.2. Planned, combined activities in the pilot

The pilot aims to improve the design and deployment methods of offshore aquaculture activities at OWFs and more specifically flat oyster culture and oyster bed restoration, as well as grow-out of seaweed.

## 5.3. Expected potential to scale up proposed combined activities

The current TRL is 5. The pilot has a high potential to scale up the proposed combined activities because Belgian wind parks 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:

- Identification and supply of biological source materials
- Understand bio-security measures regarding seaweed spores and flat oysters' importation and production
- Identification of optimal off-shore equipment (grow-out systems, long lines, scour material, seed collector, holding system, 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 spatfall, changes in biodiversity, fouling organisms and differences in seaweed growth and quality between nearshore and offshore
- Development of a predictive model for flat oyster growth in the Belgian North Sea)
- Quantification of ecosystem services of reef restoration
- Identification of appropriate areas for oyster reef restoration in wind parks where trawling activities are not allowed

## 5.4. Partners and other stakeholders involved in the pilot

Table 4 presents project partners and other external stakeholders involved in the pilot.

*Table 4 - Stakeholders involved in the Belgian pilot*

| Stakeholder | Project partner/external stakeholder | Role | Interest |
|---|---|---|---|
| UGent | Project partner | Lead | Research results |
| Jan De Nul | Project partner | Responsible for technical functioning offshore, design structures offshore, design gabions or other solutions | Results |
| Brevisco | Project partner | Responsible for technical functioning nearshore | Results on aquaculture product |
| Parkwind | Project partner | Facilitator of the windmill parks, insurance | Applicability of multi-use of space |
| Colruyt | Project partner | LCA, economics | Possibility of producing oysters and upscaling feasibility |
| RBINS | Project partner | Biological studies, Ecological implications | Research results |

## 5.5. Expected synergies of combined offshore activities

The ban of fisheries and vessels to enter the wind parks 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 windmills, restoration and aquaculture activities
- Synergies in the use of service vehicles
- Synergies in the use of port facilities

## 5.6. Available economic and financial information

### 5.6.1. Economic / financial feasibility studies / information

There is some information readily available, but confidential. Along the project, a financial analysis and business case will be developed for the production of flat oysters and seaweed. The added value of integrating the three activities (aquaculture in combination with energy production in wind parks and ecological restauration) is evaluated and quantified. As an example, AMC Center (2014) from the Netherlands speaks of a synergy factor of up to 10% between the activities of mussel farming and the wind park. Although test projects with mussels in OWFs in the UK (2010) report that there would be no negative impact for the wind park operators (Syvret et al., 2013), the costs of mitigating certain risks and insurances also need to be mapped and in a competitive manner (compared to traditional mussel production) are covered by the chain. An extensive risk analysis is therefore an integral part of the business case, which allows to estimate the costs for certain new risks or additional insurance policies.

The economic analysis will calculate the Net Present Value and the break-even point for the cultivation of consumption oysters and seaweed. The techniques for calculating this are known techniques from the financing

analysis. The crucial point is to collect the correct input data. Drivers for a business case are production costs (investments, personnel, boats), scale (automation) and sales prices (consumer), with the yield as the major risk factor.

#### 5.6.2. Socio-economic impact analysis

No information is readily available. The study will identify impacts on employment of the proposed multi-use solution and other potential benefit such as impacts on education and tourism if oysters are commercially cultivated in OWFs.

Ecosystem services of reef restoration may pay up for additional infrastructure costs to wind parks. The economic and ecologic benefits of reef restoration using scour protection will be evaluated for a scenario of full-scale restoration. The impact on the total cost of energy production will be evaluated and the study will reveal to what extend consumers are accepting a higher energy price to support this inclusive way of energy production. (1) A nitrogen balance will be made to evaluate the effect of full-scale restoration on the eutrophication levels in the Belgian Part of the North Sea. (2) A larval dispersal analysis will display the connectivity with other native oyster populations or restoration projects. Connectivity is beneficial since genetic variation can be low using hatchery seed. (3) Since reefs are important nursery areas for fish larvae, the beneficial effects of oyster reef restoration on fisheries will be investigated.

#### 5.6.3. Business model / plan / strategy

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 (*Ostrea edulis*), seaweed (*Saccharina latissima*, energy and other ecosystem services. Target markets are consumers of seafood and green energy, and users of ecosystem services. Research on oysters 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, additives, bioenergy, and bio refinement markets.

#### 5.6.4. Environmental impact assessments

An environmental impact assessment is readily available. The nearshore experimental phase of the pilot is located in a Natura 2000 area and, therefore, an evaluation had to be made during the pre-operational phase. The results will be included in the risk analysis, but environmental risks are expected to be small during the operational phase. Possible risks include:

- Effects of culture systems on sea mammals
- Effects of paint release due to loose aquaculture systems rubbing against the turbines
- Collison of crew vessels with loose aquaculture systems and leading to loss of fuel

## 5.7. Expectations of Work Package 3 activities and outputs

Work Package 3 is expected to contribute to the calculation of economic feasibility and to the identification of possible synergies that can ameliorate the economic feasibility by gathering data throughout the project. The pilot has some economic expertise through the involvement of Colruyt Group, a Belgian retailer with good knowledge of market prices, consumers preferences, and volumes.

# 6. DANISH PILOT

## 6.1. Current activities in the pilot

Middelgrunden is an OWF 3.5km outside Copenhagen (Denmark) which was established in 2000. The OWF consists of 20 turbines (each 2WM) and has a total capacity of 40MW; thereby it delivers approximately 4% of the electricity consumption of the city of Copenhagen.

Two touristic attractions are offered along with the offshore farm: 1. Boat tours to the OWF and 2. Lectures on the Middelgrunden Wind Turbine Cooperative either organized in the office 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 members 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.

## 6.2. Planned, combined activities in the pilot

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 OWFs so that it opens up opportunities to attract new target groups and eventually can be a part of the general tourism offer in Copenhagen and its region.

Planned combined activities include:

- Offshore windfarm sightseeing boat tours combined with angling or restaurant facilities.
- Diving.
- Leisure fishing.
- Educational tours for locals to increase local knowledge about the importance of green energy.
- Shared onshore facilities such as an offshore related information center.

## 6.3. Expected potential to scale up proposed combined activities

The existing offshore wind farm platform may need to be improved as to better accommodate tourist activities. The current TRL is corresponding to level 6: 'technology demonstrated in relevant environment.' The TRL is expected to be increased to level 8 'system complete and qualified' and should ensure economically viable continuation of the activity that also provides societal and environmental benefits to the region.

The combination of an offshore wind farm with tourist activities is expected to have a good scale-up potential. Middgrunden Wind is one of the rare offshore wind farms where tourism boats can approach closely the turbine and visitors can climb the nacelle. The combination of tourism and offshore wind farms is increasingly gaining interest in Europe as shown in the TROPS, MUSES, etc. projects as it can derive long-term benefits for local communities by encouraging/promoting innovation, entrepreneurship and job growth. This can be especially a good opportunity for rural areas in a need of an economic boost through tourism development.

Mediterranean countries are increasingly considering offshore wind farm developments and, given the strong tourism sector in this sea basin, such multi-use combinations could be very successful. Northern and central Baltic countries are also committed to developing offshore wind farms. For example, Poland is dependent on offshore wind farms to fulfil its EU renewable energy obligations and the nine binding concessions already given for offshore wind farms. These concessions are close to important tourist destinations and an ongoing marine spatial planning process, including engagement and discussion with the maritime business community, is supporting the multi-use concept. Partners and other stakeholders involved in the pilot

## 6.4. Partners and other stakeholders involved in the pilot

Table 5 presents project partners and other external stakeholders involved in the pilot.

*Table 5 - Stakeholder involved in the Danish pilot*

| Stakeholder | Project partner/external stakeholder | Role | Interest |
|---|---|---|---|
| Boat providers | External stakeholder | Service provider | Develop boat trips |
| Copenhagen sport divers | External stakeholder | Wants to provide services | Develop diving opportunities |
| Insurance company | External stakeholder | TBD | TBD |
| Public authorities | External stakeholder | TBD | TBD |
| Windfarm shareholders | External stakeholder | TBD | TBD |
| Local intermediaries (tourist boards/local councils), State of green | External stakeholder | | Initiating/supporting the long-term functioning of this multi-use, mainly by identifying opportunities, facilitating cooperation and promoting MU concepts |
| Local museums, exhibitions and information centers | External stakeholder | TBD | TBD |

## 6.5. Expected synergies of combined offshore activities

Cost reductions due to the combination of activities are expected to be important. Synergies will be defined along the project.

## 6.6. Available economic and financial information

### 6.6.1. Economic / financial feasibility studies / information

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. Demonstrating profitability and developing and publicly sharing viable business models are perceived to be main steps forward in the pilot. The pilot aims to develop a financial assessment of alternative options to advise the business case development. Key factors that will determine the viability of a business case are expected to be: the design of a vessel scheduling system, trip duration (weather and tide conditions), offshore distance, fuel consumption, working hours of personnel, efforts to keep tourists entertained and seasonality.

### 6.6.2. Socio-economic impact analysis

No information on socio-economic impacts is readily available. A social cost-benefit analysis is foreseen in the project, including social and environmental impacts. The pilot aims to use the socio-economic impact analysis to optimize the proposed multi-use design by maximizing social and environmental benefits. Expected benefits include educational, environmental and overall wellbeing (e.g. recreational opportunities) benefits. The socio-economic impact analyses of combined offshore wind farm and tourist activities will explicitly consider the importance of geographical location in combination with touristic pressures (in crowded areas it can function as an opportunity to disperse tourism activities and reduce pressure on touristic hotspots whereas in remote (or de-

clining population/slow economy) areas it could be a mean to boost the local economy by providing job opportunities and stimulating the regional economy through tourist demand and expenditures on local services, such as restaurants.

#### 6.6.3. Business model / plan / strategy

A business model has not yet been developed. The pilot aims to develop general business models from existing examples to support financial viability of future developments in other areas. The business model will include guidance for cost-benefit analysis. An important issue that will be considered is that the multi-use concept is often initiated on a temporary basis, usually as part of the offshore developer's corporate social responsibility local outreach campaigns during the pre-planning stage when local acceptance needs to be secured for the offshore wind farm project to continue. There is a need to develop business models that will take into consideration the full value chain and that prove long-term profitability of the multi-use concept. No information on pilot budgets is readily available.

#### 6.6.4. Environmental impact assessments

No information from environmental impacts assessments is readily available.

## 6.7. Expectations of Work Package 3 activities and outputs

The pilot expects that Work Package 3 contributes to the development of business models and to the analysis of economic and financial feasibility of the proposed multi-use concept and judges its importance in the project as essential and complementary to available knowledge.

# 7. GREEK PILOT

## 7.1. Current activities in the pilot

Kastellorizo operates a fish-farming unit, on floating facilities in the marine area near islet "Patroklos" which is located 850 meters offshore. Skironis aquaculture SA operates the unit mainly for the production of gilt-head bream (Sparus aurata), European bass (Dicentrarchus labrax), as well as shellfish and other types of fish such as sheepshead bream (Diplodus puntazzo), red sea bream (Pagellus bogaraveo), scup (Stenotomus chrysops), common pandora (Pagellus erythrinus), common dentex (Dentex dentex), sand steenbras (Lithognathus mormyrus) and flathead grey mullet (Mugil cephalus). The aquaculture total annual production of marine Mediterranean fish in that area is 230 tonnes.

Islet Patroklos has an attractive coastline where local people as well as tourists from the wider Attica area enjoy swimming and spending time on the beach. Access to the islet is only by private boats, in summertime a private vessel transfers tourists to the islet. 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 are an underwater car cemetery next to the aquaculture site, as well as a shipwreck on the opposite side, near islet Patroklos.

There are currently scuba diving tours taking place in the pilot site wider area, one of the is visiting a shipwreck near Patroklos islet. On 12 February 1944, SS Oria sank in a storm on the south east rocks of Patroklos island with 4,074 killed, most Italian military internees. Another scuba diving tour that is currently taking place in the pilot site, is that of visiting an underwater cemetery of cars. The reasons these cars were placed is probably due to people stealing them and then throwing them in the sea not to leave trace.

## 7.2. Planned, combined activities in the pilot

The plan is to combine aquaculture and touristic activities for the benefit of both and to investigate possibilities to integrate leisure scuba-diving at aquaculture sites. The following activities could take place:

- Boat tours using the aquaculture facilities as a stop
- On-board lectures of aqua-culturist and serving of their products
- Scuba-diving activities (to aquaculture sites or other interesting underwater sites) in combination with the boat tours

## 7.3. Expected potential to scale up proposed combined activities

The current TRL is level 5 'technology validated in relevant environment'. Several actions will be taken to increase the TRL to level 7 'system prototype demonstration in operational environment. Two stages are envisaged. The first stage is to enhance the fish-farm unit with technological tools to enhance the operations and monitoring of the site. The pilot aims to increase aquaculture production efficiency, monitor technologies to synchronize activities, and demonstrate the use of Decision Support System for new development. The second stage is to create a set of touristic activities that will require both businesses such as scuba-diving tours in the aquaculture site as well as scuba diving equipment to enhance the operations of the aquaculture site. The pilot will investigate challenges in term of insurance issues, profitability, risk/health impact, economic sustainability, while minimizing pollution prospects and facilitating touristic growth and social acceptance of aquaculture activities

The potential to scale-up the proposed combined activities will be investigated in the technological pillar of the project. Monitoring infrastructure will be deployed on-site to assure that environmental conditions remain undisturbed and to assure that aquaculture products will not be affected by the combined activities (behavior monitoring of fish through cameras).

Partners and other stakeholders involved in the pilot

Table 6 presents project partners and other external stakeholders involved in the pilot.

*Table 6 - Stakeholders involved in the Greek pilot*

| Stakeholder | Project partner/external stakeholder | Role | Interest |
|---|---|---|---|
| **Wings** | Project partner | First point of contact/coordinator | Project purposes |
| **Stavros Iatrou** | Project partner | Aquaculture business | Project purposes |
| **Maria Karavasiliadou** | External stakeholder | Financial manager of aquaculture | Project purposes |
| **Kostas Thoctaridis** | Project partner | Scuba diving center owner | Project purposes |
| **Caterina Callitsis** | Project partner | Point of contact for scuba diving center | Project purposes |
| **Local ministry office** | External stakeholder | TBD | TBD |
| **Local community representatives** | External stakeholder | TBD | TBD |
| **Local chamber of commerce** | External stakeholder | TBD | TBD |
| **Tourist offices** | External stakeholder | TBD | TBD |

Other identified external stakeholders that will be engaged are the local ministry office, local community representatives, the local chamber of commerce and tourist offices.

## 7.4. Expected synergies of combined offshore activities

The following synergies are expected:

- Technologies and information systems for improved monitoring and management that:
  - Allow more effective aquaculture production (monitoring parameters such as salinity, water quality, fish behavior and stress levels).
  - Facilitate synchronization of logistics of multiple operations of touristic boats, recreational activities and operational vessels to the aquaculture site.
  - Allow timely signaling pollution threats to the marine area.
- Mutualization of management and planning decisions to guarantee new optimized developments, such as an extension of the aquaculture unit in such a way that it does not intervene with current touristic and recreational activities.
- Business development aimed at cost minimization for both activities:
  - Benefits from exploiting same marine space.
  - Co-use of transportation (vessels currently used for aquaculture activities only).
  - Co-use of offshore experience.
  - Time management by multi-sharing of infrastructure such as use of existing platform for aquaculture, diving or third-party vessels.
- Stimulation of touristic growth.
- Social acceptance of aquaculture activities.

## 7.5. Available economic and financial information

### 7.5.1. Economic / financial feasibility studies / information

No information on the financial feasibility of the proposed multi-use combination is readily available. This information may become available during the project.

### 7.5.2. Socio-economic impact analysis

No information on socio-economic impacts is readily available. This information may become available during the project.

### 7.5.3. Business model / plan / strategy

No information on business models is readily available. This information may become available during the project.

Regarding the scuba-diving center, the plan is to introduce to their customers/members a new promising attraction and potentially increase the interest for scuba-diving tours. Diving in aquaculture sites is a rising trend that gives scuba divers the ability to enjoy the natural beauty created by the aquaculture (wild fish gathering to be fed by the food provided to fish inside cages).

Regarding the aquaculture business, the monitoring and decision support platform that will be provided to them from this project will help them gain more control over their business, schedule better their operational activities and act timely to events (alerts and notifications will be sent to them through the platform). This overall improvement of operational activities will reflect to the product of the aquaculture business. The scuba diving center will also enhance their costly operational activities, by providing equipment such as ROVS (remote operating vehicles) for infrastructure inspections that are difficult to be carried out (such as anchors inspection).

No information on pilot budgets is readily available. This information may become available during the project.

### 7.5.4. Environmental impact assessments

No information from environmental impacts assessments is readily available.

## 7.6. Expectations of Work Package 3 activities and outputs

The economic/financial tasks within the UNITED project will help to evaluate the overall benefits of businesses moving forward to synergies rather than acting individually in same marine space. Expected outputs are:

1. Social acceptance of planned combined activities by the local community
2. Growth of touristic interest in the area
3. Advertisement of aquaculture products (aquaculture owner also owns a great number of restaurants - potential benefit from UNITED synergies in the site)
4. Local stakeholders (other local businesses such as local travel agencies, local restaurants, local press, and public ministry) to support the synergies for long term benefit of the wider area

# 8. AN OUTLOOK ON ECONOMIC/FINANCIAL DATA COLLECTION AND ANALYSIS

This report describes the current status and identifies sources of socio-economic information for the five UNITED pilots based on background information from the project proposal (DoA) and responses to a questionnaire. The questionnaire responses were varying across pilots with regard to the amount of provided information. A possible explanation could be that the status of these pilots has not changed since the project proposal phase and that, therefore, the background that was compiled at the time of the proposal provides the most up-to-date information about the pilot's status.

Work Package 3 of the project has the remit to develop economic frameworks and business models that are fit-for-purpose for the effective design, optimization, and implementation of multi-use concepts. This does not only concern their application in the UNITED pilots but also their eventual enhancement of their up-scale potential and commercialization opportunities as final outputs of the project. The following task 3.2 aims to develop an economic assessment framework to guide the economic evaluation of the added value of Multi-Use Platforms in Europe. The Work Package 3 framework will be structured to assess the financial costs and revenues of MUCLs and their economic efficiency (value for money). In addition to Work Package 3 objectives, the information on multi-use pilots provided in this report will be useful for the analysis of business necessities (task 1.3), their associated financial requirements for investment (task 7.1), their social acceptability (task 8.2), as well as the socio-economic implications of their environmental impacts (Work Package 4).

## 8.1. Comparison of available information across pilots: similarities

As a starting point, the questionnaire has helped to illustrate the potential synergies for the type of socio-economic assessments between the different pilots. Table 7 offers a broad summary of the proposed multi-use activities that will be investigated in each of the pilots. Different sub-types of activities, for example caged, longline aquaculture and seaweed production, were grouped into one main economic activity as there is no need to keep this distinction for economic analyses. From an economic perspective, these economic activities have similar cost structures, create similar income streams and have comparable socio-economic impacts and, therefore, they probably require similar economic evaluation methods/business models.

*Table 7: Comparison of multi-use activities across the five UNITED pilots*

| | *DE* | *NL* | *BE* | *DK* | *GR* |
|---|---|---|---|---|---|
| Renewable energy generation | X | X | X | X | |
| Aquaculture and seaweed cultivation | X | X | X | | X |
| Recreational activities | | | | X | X |

There is a broad range of expected businesses that will share the marine space in the different pilots, for example renewable energy generation, aquaculture and seaweed cultivation and tourism activities. These can be further divided into offshore wind farming; installation of floating solar panels; aquaculture of Mediterranean fish species; long line flat oysters, blue mussels and seaweed cultivation; leisure diving and sightseeing. The diversity of economic activities, spatial scales of economic performance and impacts, as well as the potential synergies in terms of assessment criteria requirements should be considered in the development of the economic impact and financial performance methods. Together, the assessment criteria and economic evaluation methods will form the basis for the development of the UNITED economic assessment framework.

Results from stakeholder reporting show that relationships with project partners are established. For the economic analyses that are foreseen in the next steps of the project, it will be essential to exchange economic data across partners in order to achieve financial feasibility calculations of the proposed business models, but also to demonstrate the added-value of the multi-use combination concept compared to single use.

Four of the pilots have identified potential synergies of the proposed multi-use combinations on their locations. The synergies can be grouped into main categories:

- More effective production/service provision, cost savings and improved knowledge of environmental impacts signalling through joint monitoring
- Cost savings related to the optimization of transportation and logistics through the joint use of transport vehicles (vessels, helicopters etc.) and port and offshore facilities
- Cost savings due to the economies of scale and optimization of planning and maintenance work
- Increased societal acceptance of MUCL
- Cost-savings due to faster licensing
- Direct benefit from service provision of one activity by the other use (direct use of OWF energy by monitoring equipment for aquaculture in the FINO3 pilot, wave dampening effects of floating solar on the safety of aquaculture production in the North Sea Innovation Lab pilot)
- Cost-saving related to the technical improvements from use combination
- Economies of scale due to of offshore experience

These synergies should be taken into account in future economic analyses under task 3.2 and task 3.3. Besides the synergies mentioned above, economic analyses should consider the value of marine space for the establishment of multi-use schemes. Ideally, a combination of an offshore location and a specific use should be identified that generates the highest value among alternative locations/uses. The opportunity costs of alternative uses and locations is an essential element to be investigated under the remit of Work Package3 in UNITED. It would also be very important to consider potential cost advantages to be gained if the multi-use is considered right from the start (and not as an "add on" for a given infrastructure).

## 8.2. Comparison of available information across pilots: differences

One of the main differences between projects concerns the already existing single and multi-uses in the sites. Only the Belgian pilot has already an established multi-use (OWF and mussels) in place, which is expected to be improved/expanded through the UNITED project. The Danish pilot has also to a certain extent an existing combination of activities (OWF and tourism), but touristic activities have been so far very sporadic and not really integrated in the sense of multi-use. Similarly, the Dutch pilot has a variety of different single uses that are coexisting under the same research site and their coordinated multi-use is intended to be further developed through the UNITED project. The German pilot is the only one where currently only a single use (OWF) is present on-site. The intention is to test whether a multi-use (combination with mussel farming) would be feasible. Likewise, the Greek pilot has already a single use (aquaculture) on-site, but boat tourism and scuba diving activities also already exist in the near area and therefore the purpose will be to explore their integration.

The difference in status in the development and implementation of single-use and multi-use activities between pilots raises different economic questions and consequently requires customized baseline references per pilot. For the German, Dutch and Belgium pilots, information on their baseline reference "single use" projects are currently missing. So-far the responses to the questionnaire tended to show a lack of clear differentiation between single and multi-use. If a single-use baseline reference is not available, the following questions remain: why they are not existing; whether there is a real need for additional infrastructure; whether the proposed activities could not be more efficiently undertaken elsewhere; and whether in this case separate single-use alternatives would not be more efficient than the proposed multi-use combination. In these pilots the comparison of no-use, single-use and multi-use concepts is an essential part of the economic debate. In contrary, the Danish and Greek pilots that have already established primary uses as the baseline reference for their investigations into the multi-use concept need to be considered differently. The economic analysis in these cases should be focus on the comparison between the economic performance of their single activities as opposed to their combined potential effectiveness as part of multi-use.

The definition of the baseline reference has implications in terms of the economic data that needs to be collected. The economic assessment will have to be set up so that information about different single uses, as well as to multi-uses, are accurately provided and evaluated (and account for their differences). For that, the development of baseline references and alternative scenarios are of key importance. However, the focus should be on understating if the proposed multiuse schemes offer the highest economic value possible of the use of marine space (opportunity costs of multiuse) as opposed to single individual uses or not use of marine space at all (when applicable).

The status of single-use and multi-use activities in pilots also raises the question whether in some of the UNITED pilots, TRLs developments have been set with regard to the planned multi-use concept or with regard to the development of one of these uses (e.g. further increasing capacity for OWF). Four of the pilots have reported to be currently at TRL 5 with a scale-up potential for the proposed multi-use combinations and proposed operational project activities to potentially reach a higher TRL 7 by the end of the UNITED project. Only the Danish project has reported a current TRL 6 and aims to achieve TRL8. However, there is no clear specification whether the mentioned TRLs apply to the different single uses or to the multi-use concept as a whole. In this context, further activities in Work Package 3 of UNITED will need to monitor progress and further clarify expected TRL developments in the pilots and if those have been set in terms of MU development.

A last difference that can be observed is that two pilots, the German and Dutch pilots, are research sites developed to test multi-use, whereas the other three sites (Belgian, Greek, Danish pilots) already have some form of commercial activity today. The German pilot is not counting on generating revenue on the short to mid-term (a time frame of 20 years is considered as possible to become profitable). On the other hand, the Dutch pilot has a research character as well, but it focuses on the potential upscale of innovations and on contributing to the economic autonomy of multi-use, independent from public funding. Thus, the Dutch pilot aims to generate revenue on a short to middle term. The other pilots have at least one commercial activity today, but partly rely on public budgets to realize multi-use as well. This highlights the need to take a careful look at public funding streams when performing the financial analysis and developing the business cases. Aspects that could be of relevance are for instance the time frame that public (research) funding is secured, its total amount, as well as factors upon which the continuity or amount are dependent on time. These will be included as part of the economic assessment framework to be developed in Work Package3.

## 8.3. Challenges and opportunities: how will these results be used in the UNITED project?

The comparison of information available across the different pilots (the differences and similarities) described in the previous sections allowed for identifying main challenges (bottlenecks) that project is facing in carrying out economic assessment, and at the same time it allow to already at this stage to pinpoint the opportunities (or directions) in which the framework and assessment should be developed in the next years of the project to gain useful results and to turn these challenges into opportunities.

For example, one of the challenges that we faced in all the pilots was a due to the use of a different terminology in the methodology. As the five pilots have provided information on the aspects that they would like to see assessed through financial analyses, be it overall financial feasibility of a proposed multi-use combination (all pilots), or more specific aspects such as the increased costs of extra risks that arise from multi-use (e.g. Belgium and Denmark). In cases where very specific outcomes are expected, such as in the Belgian pilot where "the net present value at break-even point" shall be determined, further information about what this exactly entails is necessary to well include these aspects in the indicators of the assessment framework that will be developed in task 3.2. To tackle this challenge, a more consistent vocabulary needs to be used (building on the development of a shared and well-illustrated glossary included in Deliverable D.3.2)) to refer to the elements of the economic analysis, namely the socio-economic, the financial and the business model components. A guidance document supporting the carrying out of economic analysis in task 3.3 will be prepared along with the economic assessment framework in task 3.2.

Another challenge/bottleneck of the assessment framework lays in the assessment of socio-economic impacts, as the responses of all pilots show a focus on the financial (projections of costs and revenues) and business (e.g. profitability and attractiveness for investors) components of the economic assessment. However, socio-economic impacts, such as generated ecosystem services, job creation, increase in social acceptance of multi-use, attractiveness of multi-use for social business investment generate positive externalities. Information on these benefits is very important for increasing policy support which is key to the wider uptake of multi-use platforms. Thus, to solve this challenge more information will be required to this respect for the development of the economic assessment framework in task 3.2.

In addition, all the pilots faced a challenge in the analysis of the provision of ecosystem services. For example, the Belgian pilot mentions that generated ecosystem services could pay up for additional infrastructure costs of the multi-use combination. As a result, it considers users of ecosystem services as a potential target market. This implies that the commercialization of ecosystem services provided by the proposed multi-use combination should be part of their business model. This example highlights the potential role that generated ecosystem services can have for the financial balances of pilots. Hence, ecosystem services could become a variable of the financial analysis within the economic assessment framework that will be developed in the context of Work Package 3, requiring further information on ecosystem services and their beneficiaries from all pilots. A possible approach could be to further explore the applicability of compensation or Payment for Ecosystem Services (PES) schemes within the different pilots, paying attention to possible (country-specific) institutional arrangements required to support such PES. This would help addressing the question of the possibility or feasibility to market ecosystem services to provide additional income.

Analysis of these challenges mentioned above gives us an important input for building further and exploring these opportunities in the next deliverables of this Work Package and helps to identify the next steps.

## 8.4. Next steps

Task 3.2 will deliver methodologies and guidance protocols to assess economic efficiency of the MUCLs, accounting for different types of costs, benefits and other relevant economic impact indicators (e.g. employment, ecosystem services). One objective of reviewing existing pilot approaches is to ensure that models and indicators to be developed will be useful. In this respect task 3.2, with the help of the pilots, will assess the role of impact assessments in private business decision-making. This will consider a review of existing sectoral business models and impact assessments as they are present in the activities included in the pilots (e.g. off-shore wind platforms, aquaculture, tourism, solar off-shore, etc).

# ANNEX 1 – QUESTIONNAIRE

1) What is the current status of economic activity in the pilot? *What is planned and what is the current stage of implementation?*

_____

_____

2) What are the plans regarding the economic exploitation (products, target markets and demand) of the pilots?

_____

_____

3) Please indicate which economic / financial information is currently available for your pilot:
   a) Financial feasibility study/information (definition: A feasibility study is an analysis that takes all of a project's relevant factors into account—including economic, technical, legal, and scheduling considerations—to ascertain the likelihood of completing the project successfully. Project managers use financial/economic feasibility studies to discern the financial pros and cons of undertaking a project before they invest a lot of time and money into it. Relevant information includes an overview of financial costs and benefits of multi-use platforms, examples of private costs and benefits are capital costs to construct hardware, platform development costs, operation and maintenance, and training costs; production and sales of energy, products or services, saving of expenditures, by-product sales and greater productivity).
      - Information openly available (please attach document or share web link)
      - Information available, but confidential
      - Information not now, but later available
      - Information not available

   Comments:

   _____

   _____

   b) Socio-economic impact analysis (definition: this is a quantitative evaluation of the utility of the projects. This method allows all social, environmental, economic and financial impacts of a project to be measured in a monetary unit. This then would include an overview of costs and benefits of multi-use platforms for a country or region; examples of impacts are: earning capacity and costs of aquaculture/energy/recreation/other maritime businesses, type and level of employment, income, impact on local/regional communities, impacts on consumer, the supply chain and the broader economy).
      - Information openly available (please attach document or share web link)
      - Information available, but confidential
      - Information not now, but later available
      - Information not available

   Comments:

   _____

   _____

   *c)* Business model/plan/strategy (definition: a pilot plan for commercialization identifying the products/services provided, target markets, sales and marketing strategies, and financial objectives. In this case we would

like to find out if business plans are available for the pilots in general and separately for each of the multi-use activities independently)

- Information openly available (please attach document or share web link)
- Information available, but confidential
- Information not now, but later available
- Information not available

Comments:

_____

_____

d) Pilot budget/cash balances (definition: forecast or overview of expenses and income for the coming/previous years)

- Information openly available (please attach document or share web link)
- Information available, but confidential
- Information not now, but later available
- Information not available

Comments:

_____

_____

e) Other, please specify:

_____

_____

4) Parties that collaborate through a partnership in the pilot project probably possess part of the information requested under question 3. It is important to take stock of all available financial and economic information to develop optimized business cases in the course of the UNITED project. If necessary, we would like to contact these parties to collect information in the next phase of the project.

| a) Could you identify the parties that collaborate through a partnership in the pilot project? | b) Is it a project partner or external stakeholder? | c) What is the role of the partner in the pilot project/which service do they provide? Examples of roles/services are: technology supplier (turbines, fish cages etc.), investor, operator, grant/subsidy provider | d) What is the main interest of the partner to participate in the pilot project? | e) Who is the main contact person (first name, last name, email address)? |
|---|---|---|---|---|
| *Partner 1* | | | | |
| *Partner 2* | | | | |
| *Partner 3* | | | | |

| | | | | |
|---|---|---|---|---|
| …… | | | | |
| …… | | | | |
| …… | | | | |

5) What are expected synergies of combined use of the offshore platform (definition: cost reduction due to combined use of, for example, port and storage facilities, ships, helicopters, cranes, personnel, purchase of equipment, powering of offshore facilities, maintenance)? Please name some specific examples.

_____

_____

6) Has any environmental impact assessment considering ecological impacts during the construction and operation phase been undertaken at the pilot or at the specific activity levels?
   - Yes, please attach document or share web link)
   - No

   comment:

   a) If yes: have ecological/environmental impacts of multi-use been measured with indicators? Please name,
      - Yes
      - No

   b) If yes, please specify or comments:

_____

_____

7) What is the potential to scale up the existing solution?

_____

_____

8) What would you like to obtain from business and economic analyses in UNITED in relation to your pilot: Which key socio-economic questions/challenges/aspects should be addressed for your pilot? Please ask your pilot partners also.

_____

_____

9) Bearing in mind the project's objectives and activities as described in the project proposal, how do you see the role of economic/financial tasks within the UNITED project with respect to your pilot?

_____

_____

10) Do you have economic / financial expertise within the pilot partners?
   - Yes
   - No

   a) If yes, please specify:

_____

_____