DELIVERABLE 1.3

BUSINESS ANALYSIS OF UNITED PILOTS

DELIVERABLE 1.3

Work Package 1

Framework and Facilitation of System Learning and Upscaling Multi-use

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ACRONYMS

APX	Amsterdam Power Exchange
BMC	Business Model Canvas
EIA	Environmental Impact Assessment
EPCI	Engineering, Procurement, Construction, and Installation
EPEX	European Power Exchange
MUCL	Multi-Use and/or Co-Location Platforms
NGO	Non-Governmental Organisation
NPV	Net Present Value
OWF	Offshore Wind Farm
PESTEL	Political, Economical, Social, Technological, Environmental, Legal
ROI	Return On Investment
SWOT	Strengths, Weaknesses, Opportunities, Threats
TRL	Technology Readiness Level
UNITED	Multi-Use offshore platforms demoNstrators for boosting cost-effecTive and Eco-friendly proDuction
WP	Work Package

EXECUTIVE SUMMARY

The H2020 project UNITED aims to demonstrate the technological and economic viability of Multi-Use and/or Co-Location Platforms in offshore sites by implementing multi-use concepts in five pilots (Danish, Dutch, Belgium, German, and Greek) across European regional seas (the North Sea, the Baltic Sea, and the Mediterranean Sea). The pilots participating in the UNITED project are in two different phases. Some of the pilots are already in the commercial phase. This is, in particular, true for the pilots where single uses already are in place and are financially viable, such as the Greek pilot (that combines tourism activity, e.g. scuba diving, with aquaculture activity), and the Danish pilot (that combines tourism activity with Offshore Wind Farms, e.g. educational tours to visit the wind turbines). For the other pilots, some single and combined activities are still in the research phase. The other pilots consist of the Dutch pilot (that combines, offshore wind energy, with floating solar and aquaculture activity), the Belgium pilot (that combines offshore wind energy with aquaculture and seaweed activities), and the German pilot (that combines offshore wind farm and aquaculture activity).

This report aims to assess if the concept of multi-use is financially attractive, through conducting evaluations of business models for each pilot. We apply the Business Analysis Framework developed under Task 3.2 and reported in Deliverable 3.2 of the UNITED project (see UNITED, D3.2)[1]. In addition, the business analysis will be useful to identify business needs, define solutions to potential problems, and propose ways to seize opportunities that may arise during the execution of ocean multi-use.

The application of the business analysis is done by following a methodology composed of six different steps:

1. Describing the MUCL project and its TRL level;
2. Mapping the pilot context – PESTEL analysis;
3. Business model canvas;
4. SWOT analysis;
5. Financial analysis,
6. Evaluation and control; and
7. Conclusion.

The implementation of the business analysis framework in the five different UNITED pilots is done by collecting information from different sources: a) past deliverables and project reports, and b) interviews with company partners and technology providers in the pilots. Summaries of the main results of the analysis are reported in the following sections of this executive summary. More details can be found in the main body of the report.

The following of this section presents briefly the main results obtained per pilot.

German pilot

The German pilot aims to develop, operate, and evaluate an offshore demonstration aquaculture farm with mussels (Mytilus edulis) and macroalgae (Saccharina latissima) at the research platform FINO3. FINO3 is located in the German North Sea, 80 kilometers west of the island Sylt, and can be considered exemplary for the operation of wind turbines. However, because of its research nature, the pilot does not aim to develop a commercially viable multi-use operation of wind power and aquaculture.

Wind power and aquaculture multi-use projects in Germany can take advantage of existing political support at the national and European levels for aquaculture, renewable energy, the blue economy, and multi-use. There are

[1] Araujo A.; Lago M.; McDonald H.; Röschel L.; Stelljes N.; Duinen R. V.; Zaiter Y. (2021). Deliverable 3.2: Assessment Framework to Determine Economic Feasibility of Multi-Use Platforms. UNITED Report.

existing markets for mussels and developing markets for macroalgae, as well as additional business opportunities for these products to be developed in the future. The societal attitude towards multi-use is generally positive. In addition, there are some suitable key environmental factors for the growth of the proposed mussels and macroalgae species at this offshore location. However, there are also several external challenges, such as a lack of political incentives and support for multi-use projects in Germany and a lack of finance. There are also social acceptance issues regarding aquaculture products and insufficient connection and trust between the wind and offshore sectors. In addition, the high-energy offshore environment is challenging, and there is a lack of certainty about regulations and difficulties to obtain permits.

Offshore wind power and aquaculture multi-use projects would require significant investments and thus be only profitable in the medium to long-term. Unknown growth rates of mussels and seaweed at offshore locations, long distance transportation of products, as well as fluctuating market prices for aquaculture products, need to be taken into account when developing a business model in this field. However, there are opportunities for cost savings from sharing transportation, monitoring, and maintenance work, land-based and offshore facilities, staff and training, as well as insurance premiums between the aquaculture and offshore wind partners. To motivate the participation of the offshore wind sector in multi-use (non-financial) social and environmental benefits are important, especially if they would lead to a simplified licensing process for new offshore wind farms, increased social acceptance of offshore wind farms, or reduction of conflicts between the offshore wind sector and marine fisheries. The business model for the German pilot, which is currently being implemented at FINO3, does not yield a profit, because it is a research project with a duration of only four years and is not targeted at reaching the commercialization stage. However, already in this short time of implementation, it derives some financial benefits from synergies with the FINO3 research platform where it is located.

Dutch pilot

The test site is located in the North Sea, 12 kilometres offshore, of the coast of The Hague. The following activities are combined: offshore wind farms, floating solar panels, and net-substrate-based seaweed cultivation. The value proposition of the pilot is that it contributes toward large commercial-scale offshore seaweed cultivation and towards commercial floating solar energy, using the project for testing and demonstration of certain aspects to a higher TRL level. The target groups interested in this pilot are electricity companies and final electricity users as well as the European food, feed, chemical, materials, medical industry. External/internal factors influencing the pilot include Covid-related delays, meto-ocean conditions, availability of vessels, and various challenges in the supply chain (either sourcing or TRL related).

The Dutch pilot creates, captures, and delivers value from the three activities involved. Offshore wind energy, produces green energy and sells it to energy companies. Concerning solar energy, it produces electricity and helps in reducing the intensity of waves through the wave dampening effect[2] , which is potentially beneficial for the safety of seaweed cultivation on the plot. As for seaweed cultivation, it conducts various activities and provides seaweed and seaweed-based products, reaching a broad range of customers such as restaurants, farmers (fertilizer, animal feed), pharmaceutical companies, and bioplastics producers.

One of the main strengths of the Dutch pilot is the strong cooperation between all partners. Furthermore, the offshore pilot allows for experimentation and testing, making a solid showcase, especially with the strong political will to develop multi-use at sea. However, it is also faced with weaknesses like, for example, the cost of production that challenge the business case for large-scale seaweed farming and floating solar.

[2] Floating solar infrastructure could offer an elastic solution that provides a dampening effect that neutralizes shocks (or peak load effect) from wave and wind forces (https://cleantechinsurance.com.au/wp-content/uploads/2019/03/Crunching-the-numbers-on-floating-solar.pdf)

The pilot can take advantage of several opportunities, such as the growing market demand for green energy and cultivated seaweeds. However, it faces various threats that it needs to deal with, such as the lack of technologies for operating offshore and the competition for funds with other sustainable activities such as hydrogen, etc.

Belgian pilot

The Belgian pilot is located in the Belgian part of the North Sea and combines three activities: 1) Offshore wind energy, 2) Flat oyster aquaculture and reef restoration, and 3) Seaweed cultivation. The pilot is aiming to a) evaluate if the offshore wind farms (OWFs) are suitable locations to restore native flat oysters, and b) to compare the growth of sugar kelp grown offshore and nearshore.

Activities of the pilot are positively influenced by the political factors where the new Belgian maritime spatial planning requires the OWFs to integrate other activities such as aquaculture or seaweed activities. Also, technological development and improvement allow an increase in the space and installation of long lines for aquaculture activity.

On the other hand, the pilot is facing different threats related to a) environmental factors where climate change may influence the development of the pilot, notably with the increase in the frequency of extreme weather events (such storms) and ocean acidification, b) economic factors notably related to the high cost of installation, insurance and maintenance, and c) legal factors related to the different European and national regulation, related to food safety, that the pilot must comply with.

The pilot is creating, capturing, and delivering value from all combined activities by targeting different customer segments (from niche markets to macro segments), and by having a unique value proposition for its customers (selling locally produced products). Many positive aspects can be associated with the multi-use project. These included financial benefits stemming from the reduced costs (e.g. using some bought for maintenance and/or harvest) when pursuing multi-use instead of single-use projects, even though the financial benefits would need more quantitative data evidence. But there are also other opportunities and benefits apart from the financial side. These can include environmental and societal aspects (e.g. solar panels' potential in reducing the intensity of waves through the wave dampening effect, which is potentially beneficial for the safety of seaweed cultivation on the plot).

Danish pilot

The Danish pilot was developed in the year 2000 at the reef south of the Middelgrunden island. The pilot is established 3.5 Km outside of Copenhagen harbour and combines two main activities: the production of offshore wind energy, and tourism activities related to visiting the offshore wind farm.

The success of the pilot is influenced by several external factors. Technological advancement can lead to a development in the pilot activities, particularly to the development of energy production and eventually to the development of tourism activities. The development of energy production activities could in turn attract more tourists interested in learning about solar energy, wave energy, and wind energy. Other positive influences are related to social acceptance of the pilot which facilitates the development of the pilot activities and might ensure its continuity. The main threat is related to political and legal factors where non-renewal of the lease to the location of the pilot leads to an immediate end of the operations, which will also cause a loss related to transport (boat) companies and tourist guides working within the pilot.

The main strength of the pilot is the absence of competition: no other places or pilots exist that offer the same services through the combination of similar single activities.

Cost savings and monetary gains were found for the tourism activities. The cost savings are translated by the use of the same vessel to do maintenance for OWF and tourism activities at the same time. For the OWF, there is no significant cost saving. However, an evaluation of the financial performance and estimations of the different financial metrics was difficult because of the lack of available information.

Greek pilot

The Greek pilot aims to evaluate how touristic scuba diving can be added on as a multi-use activity for an aquaculture site. The multi-use site is an existing aquaculture farm in Patrokolos, Greece, less than 100km from Athens. The multi-use activity consists of touristic scuba diving trips around the aquaculture farm, which are of potential interest due to the relatively high amount of fauna attracted to the aquaculture site, as well as the interest of the aquaculture farm itself. In addition to the potential economic benefits for the scuba diving company, the multi-use concept is also attractive to both companies as there are potential social and regulatory benefits.

Key external drivers for the multi-use project are political, legal, and economic conditions. In particular, the still-under-development political and legal framework related to maritime spatial planning and licensing for maritime space use in Greece will have a large impact on whether the pilot continues or can be replicated elsewhere in the country. Economic factors in each sector are also important and both activities are subject to economic challenges related to COVID-19 and the related impacts on tourism and the hospitality sector.

The aquaculture farm produces fish and sells them through their restaurants to tourists and residents, as well as selling wholesale. The scuba diving farm sells diving trips to Greek and foreign tourists as well as residents. The key overlap that enables multi-use is the aquaculture farm site. Other potential synergies exist around shared costs such as boat use, visiting the site, and licensing, among others.

The partners involved have several strengths that support the success of the pilot: they both have economically self-sufficient businesses that give them space to experiment, as well as technical know-how and a site that is attractive to tourists. Potential weaknesses include legal/regulatory uncertainty and exposure to COVID-19 impacts. Threats and opportunities are related: they centre around licensing and regulatory change.

The main revenue impacts of the multi-use case are increased revenue for Planet Blue associated with the additional scuba diving visits. The financial analysis concludes that direct costs and benefit impacts for Kastelorizo (aquaculture) are marginal. However, Planet Blue is faced with some potential cost savings (advertising, boat costs) and revenue increases (training) from multiuse.

Conclusions

The analysis has shown that multi-use projects can benefit from synergies between the different opportunities. These can result in cost savings, for example from sharing transportation, monitoring, and maintenance work, land-based and offshore facilities, staff and training, or insurance premiums. Based on the available data it was not possible to definitively assess the scale of the financial benefits of multi-use, but these are likely to be significant. However, realising these benefits requires trust and cooperation between different blue economy sectors, which still need to be strengthened in most pilots.

Further, the analysis showed that in some cases the financial benefits of multi-use are not evenly shared between the single activities that are involved. In the Greek and German case, for example, financial benefits will likely not be significant for some of the multi-use activities (i.e. the aquaculture farm in Greece, or the OWF in Germany), but only for the activity that is enabled by multi-use (i.e. the scuba diving tours around the aquaculture cages in Greece, or the offshore aquaculture in Germany anchored to the OWF infrastructure).

This highlights the importance of motivating factors beyond purely financial metrics for realising multi-use projects, such as environmental or social benefits. The Danish, Greek, and German pilots unveiled increased social acceptance as a key motivating factor for multi-use. In addition, regulatory benefits could incentivize multi-use, such as easier access to planning permission or allocation of subsidies. At the moment, only Belgium has a political requirement for multi-use among all cases considered.

In general, political and legal insecurities with regards to multi-use are a challenge for the scaling up of projects and result in economic risks. Economic risk also stems from the implementation of complex technical projects in harsh offshore environments with little pre-existing experience, especially in the German, Dutch and Belgian cases.

There are further key messages that come out of this report:

- Financial benefits are not always the only factor motivating businesses to engage in multi-use activities. This is especially relevant because the financial benefits of multi-use are often more significant for one partner than the other. If the multi-use consists of one already existing and one added activity, the financial benefits are often larger for the latter. The benefits are often larger for one activity than the other. This is, in particular, true for the added activity and not for the activity that is already in place. In the absence of a strong financial motivation for multi-use, other factors such as societal benefits, Corporate Social Responsibility, and/or environmental benefits are important to motivate companies to engage in multi-use
- Political incentives or requirements (e.g. subsidies, easier access to permits, requirements for multi-use, etc.) are important to encourage companies to engage in multi-use activities, especially when the financial benefits from multi-use are less significant
- Multi-use projects often depend on existing investment decisions and/or existing infrastructure (e.g. existing OWF or aquaculture infrastructures). In these cases, the baseline for the evaluation of multi-use is not an absence of activity, but rather the existing use of marine space.
- Looking at conservation goals and rewilding, to achieve a set number of activities, the only way a full additional activity can exist within reduced space is by interlacing and combining activities – desired economic activity within confined space (compliance with policy and limits).
- Multi-use depends on an effective, trusting relationship between partners from different industries, especially in the early testing/piloting stages.

Next steps and limitations

This report has explored the business case for ocean multiuse through the application of a business framework analysis in the UNITED pilots. In this respect, the different tests conducted illustrate many arguments for the financial viability of multi-use. However, it has been difficult to evaluate the financial performance of the pilots to determine their business feasibility. Hence, at this stage, calculation of the financial metrics such as the Return on Investment (ROI), the Net Present Value (NPV), the debt-to-asset ratio, and the return on equity is challenging and cannot be done accurately because of the lack of information. Further investigation on the financial performance of each activity once multiuse is fully operational and matured would still be needed to run these financial tests.

This report nevertheless has also identified other types of benefits and costs, beyond those of a market nature, that are important for some sectors to engage in multi-use activities with other sectors. This can take the form of environmental or social benefits. These will be explored in a future deliverable (Deliverable 3.3 of the UNITED project), which will aim to provide an answer to the societal added value of multiuse.

1. INTRODUCTION

1.1. Background

The H2020 project UNITED aims to demonstrate the technological and economic viability of Multi-Use and/or Co-Location Platforms (MUCL) in offshore sites, by implementing multi-use concepts in five pilots across European regional seas – the North Sea, the Baltic Sea, and the Mediterranean Sea. Figure 1 shows the different pilots of the UNITED project, their location, and the combined activities.

Some of the pilots participating in the UNITED project aim to address viable MUCL business models, in particular for the pilots that are already in place (e.g. the Danish and Greek pilots). The aim of developing a viable MUCL business model is to provide insight into the potential synergies conflicts, and economic risks from combined use and to identify long-term sustainable financial strategies to enhance the up-scaling potential of MUCL solutions and the possibility to seize emerging commercialization opportunities. The remaining pilots (e.g. German, Dutch, and Belgian), are still in the research phase and not targeted at full commercialization during the UNITED project. The following Table 1 summarizes the situation of the pilots as well as their TRL level

Table 1 Current situation of the UNITED pilots

Pilots	Phase	TRL of the combined uses
Danish	Commercial phase	6
Dutch	Research phase	6-7
Belgian	Research phase	5-6
German	Research phase	5
Greek	Research phase	3-5

Combining multiple economic activities at one offshore platform implies meeting several requirements, a first is cooperation between the combined activities and the development of synergies between the different sectors. A key question is whether there is a business case for promoting multiuse, emphasizing the importance of financial costs and revenues for the feasibility of investment by private and public parties. A recent study showed that important economic barriers such as high upfront capital investments and financial uncertainty could hinder the implementation of MUCL at offshore platforms (van den Burg, 2020).

To support the pilots, a Business Analysis Framework was developed under task 3.2 and reported in deliverable 3.2 (UNITED D3.2). Between March and December 2021, the Business Analysis Framework was applied to analyse the business models of the five pilots; the results are reported in this document.

Figure 1 Location of the five UNITED pilots

Source: https://www.h2020united.eu/pilots

1.2. Objectives of this report

The evaluation of the business models for each pilot will be done through the business analysis methodology, which identifies business needs[3], defines solutions to potential problems, and proposes ways to seize business opportunities that may arise during the execution of a business or a project.

The business needs are identified by asking several questions, e.g. what are the results desired or what are the objectives and goals? Business analyses are rarely applied to multiple economic activities at one location, they are rather applied to single-use economic activities. However, some recent examples in the context of multi-use platforms exist (van den Burg et al., 2017, Dalton et al., 2019, van den Burg et al., 2020). These studies show that two main research questions need to be addressed to develop viable MUCL business models:

1. What are the potential synergies and/or conflicts, as well as economic risks from combined activities? And how do these materialize in additional revenues and/or costs?
2. What are long-term sustainable financial strategies?
    - What is the potential role of public funding to provide financial incentives and security to investors (Dalton et al., 2019; van den Burg et al., 2020)?
    - What is the potential for the application of financial instruments for the monetization of MUCL services to generate revenues (e.g. payments for ecosystem services)?

The UNITED business analysis (Deliverable 1.3) aims to shed light on the first research question. The second research question will be addressed in future deliverables of UNITED, in particular, Deliverable 3.3 "Assessment on the Added Value of MUCLs within Pilots". Conclusions and opportunities for further upscaling of the project results will be discussed in deliverable 3.4, "The Business Case for Multi-Use Platforms: Costs, Benefits, and Lessons from Practice".

[3] Business needs are the things that a business must have to achieve its goals and objectives, so that the business can operate effectively, efficiently and make profit.

The application of the business analysis framework will allow pilot owners and/or investors to better understand the economic activities underlying the MUCL pilots and the factors influencing the efficiency of their combination. The business analysis through the collection of business-specific information allows to analyse the different business requirements, define the value proposition, identify opportunities for future development, identify TRL development needs, identify the different funding sources, and finally propose solutions that drive change in the functioning of the pilot and thereby optimize the design and operation of the pilot

1.3. Methodology: the Business Analysis Framework

A Business Analysis Framework was developed for application within the remit of Task 3.2 and is reported in Deliverable 3.2. The business analysis framework consists of six steps (see Figure 2).

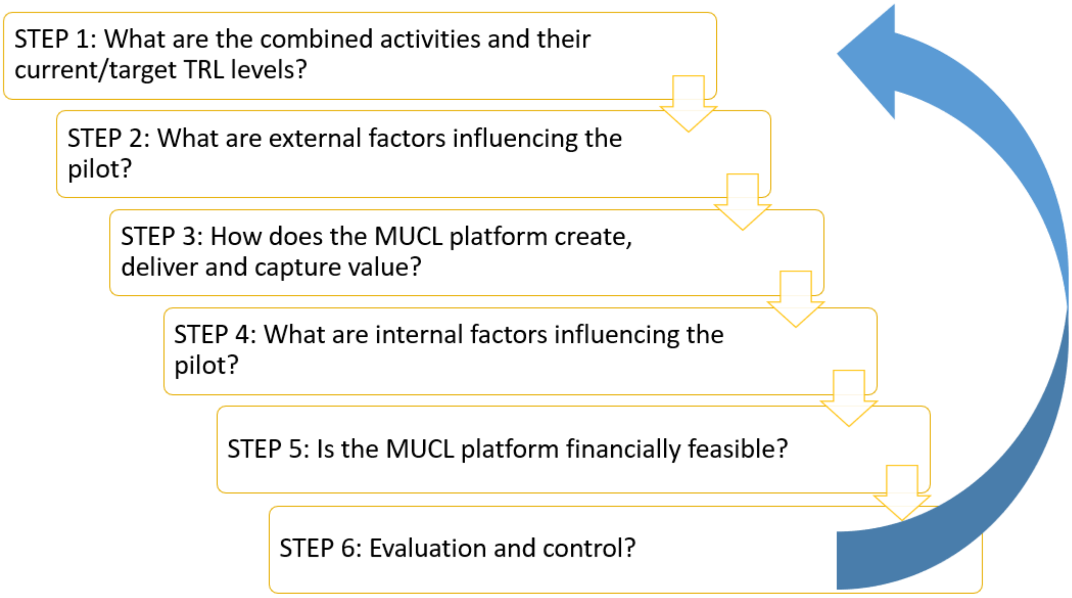
- STEP 1: Describing the MUCL project and its TRL level. The description should include the most up-to-date information on pilot owners, internal and external stakeholders of the pilot[4], combined activities, including the compatibility of activities and the expected synergies, the TRL of the MUCL platform, the strategic roadmap to reach TRL objectives, and the mission and vision of the pilot.

- STEP 2: Mapping the pilot context: PESTEL. The analysis allows pilot owners to identify external drivers and to anticipate their direct and/or indirect impacts on the pilots' operation. The context of the pilot is the environment in which the pilot operates and differs from one pilot to another. In contrast, external factors are events that occur outside of the project and have a direct and/or indirect impact on the pilot. The PESTEL analysis includes 6 different factors that are in line with the 5 pillars of the UNITED project. The factors are:

    1. Political: that determine how the government and/or political decisions influence the pilot;
    2. Economic: that determine how the economic performance of a country and/or region influence the pilot;
    3. Social: that is related to the social environment of the pilot;
    4. Technological: that are related to the technological advancement of the pilot;
    5. Environmental: that are related to the different sectors surrounding the pilot;
    6. Legal: that is associated with legal issues and legal barriers.

[4] Internal stakeholders are the companies and partners working directly within the pilot ; external stakeholders are the stakeholders influenced by the pilot activities such as the population, and/or local authorities, etc.

Figure 2 Business analysis framework: main steps and research questions.



- STEP 3: Business Model Canvas (BMC). The BMC aims to describe how the pilot creates, captures, and delivers value. It is a visual tool that provides a shared language for describing, visualizing, assessing, and innovating business models. It describes the pilots' business model through, what is called the 9 building blocks:

  1. Key partners: who are the key partners for each activity?
  2. Key activities: what are the main activities of the pilot?
  3. Key resources: what key resources does the value proposition require?
  4. Value proposition: what value does the pilot deliver to customers?
  5. Customer relationships: how the pilot interacts with its customers?
  6. Channels: what are the communication channels used by the pilot to reach its customers?
  7. Customer segment: what are the most important customers?
  8. Cost structure: what are the most important costs inherent to the business model?
  9. Revenue stream: how the pilot is generating revenue?

- STEP 4: SWOT analysis. This step aims to identify all internal and external factors influencing a pilot to develop a full awareness of all the factors involved in decision-making and to anticipate certain developments by identifying strategies to seize opportunities and/or overcome weaknesses. Strengths and weaknesses refer to the internal pilot characteristics, whereas opportunities and threats refer to the external factors that have already been identified during the PESTEL analysis (see STEP 2). During the SWOT analysis, the external factors will be classified as opportunities or threats.
- STEP 5: Financial analysis. This step will allow the pilot owner to study the financial feasibility of the pilot using the financial information provided by the project. It will help evaluate the pilots' financial performance and determine if it is feasible or not. Typically, this step is used to analyse whether the pilot is stable or not, or profitable enough to warrant a monetary investment. It is worth noting that for those pilots which are currently at a research stage, and not yet at the commercialisation stage, the financial analysis asses under which conditions the business model could become financially feasible.
- STEP 6: Evaluation and control. This is the final step of the business analysis framework. After acquiring the required information, this step will aim to evaluate if the pilot is in a commercial readiness level and to evaluate, using the information collected, if the pilot is going to reach its objective and propose corrective measures to be put in place.

1.4. Implementation in pilots

The implementation of the Business Analysis Framework started by collecting the needed information for the analysis. Different sources of information were mobilized. The first source of information was the previous deliverables of the UNITED project, in particular, D1.2 (UNITED, D1.2), D3.1 (UNITED, D3.1), and D7.2 (UNITED, D7.2). The previous deliverables provided information concerning the pilots' description including their goals, involved stakeholders, combined activities and expected synergies, the current TRL and targeted TRL, etc.

The second source of information was interviews with pilot leads and technology provides for each pilot. For that, a semi-structured questionnaire (Annex I), as well as financial template including all the possible costs and revenues categories (Annex II), were developed, and addressed to the concerned parties to provide the missing information that allows completing the business analysis cases for each pilot. The information needed was mainly for the PESTEL, SWOT, BMC, and financial analysis sections. It should be noted here that the information concerning financial information was challenging to obtain due to the confidentiality of the information. For that, the partner companies were reassured that the information will not be made public. The main objectives of the questionnaire were to a) verify and update information on pilot descriptions, and b) collect complementary information for the PESTEL, BMC, SWOT, and financial analysis.

Additionally, the impact of the COVID-19 pandemic on the different blue economy sectors, in particular the sectors involved in the UNITED project, was assessed. The work considered e.g. impacts on profits and employment, but also coping mechanisms and long-term changes to business strategies. The work was done by developing a questionnaire (see Annex IV) and conducting semi-structured interviews with partners from the different sectors for each pilot. The results of the questionnaire are reported in Annex V of this report.

Finally, an online workshop was organized in December 2021 between the different partners working Task 1.3 to discuss all the findings of each pilot and the conclusion of this deliverable (see Annex III for meeting agenda). The outcomes of the meetings are reported in the conclusion of this deliverable.

1.5. Integration of Business Analysis Within UNITED

The main aim of this report is to apply the Business Analysis Framework reported in Deliverable 3.2 of the UNITED project to the five pilots. The information will feed into different Work Packages (WPs) of the UNITED project, mainly into WP3 and WP8.

WP3 addresses the 'Economics of Multi-use Platforms'. The WP supports the economic assessment of multi-use combinations by providing and applying a multi-method economic assessment framework. In particular, Task 3.3 includes an assessment of the costs and benefits of multi-use compared to single-use alternatives. The work in Task 1.3 is the first step to understanding the costs and benefits of each pilot and to identifying factors influencing their costs and revenues. Another link exists with Task 3.4 which aims to build generic business models for the commercial rollout of Multi-Use Platforms, highlighting the transferability and upscaling potential of these pilots.

WP8 of UNITED addresses the 'Assessment and Validation'. The WP aims to evaluate the economic, social, and environmental acceptability needs validation and assessment frameworks of the pilots. WP8 includes a socio-economic assessment and validation of the pilots. The outcomes of Task 1.3 will feed directly in WP8, in particular, in Task 8.2, which focuses on the socio-economic assessment and validation. Task 1.3 will provide information on the social aspect, notably the social acceptability of each pilot, to be used in Task 8.2.

1.6. Structure of the report

This report aims to implement the UNITED Business Analysis Framework in the project pilots. The report is structured according to the five pilots and the business analysis steps (see Box 1). The six steps of the Business Analysis Framework are summarized in four steps:

1. Defining optimized business cases – that corresponds to STEP 1 of the Business Analysis Framework;
2. Identifying risks and barriers – that corresponds to STEP 2, 3, and 4 of the Business Analysis Framework;
3. Financial analysis – that corresponds to STEP 5 of the Business Analysis Framework;
4. Evaluation and control – that corresponds to STEP 6 of the Business Analysis Framework.

Box 1: *Outline of Business Analysis per pilot*

Sub-Section 1: Background
Sub-Section 2: Defining optimized business cases
- Sub-Section X.2.1: Mission and vision statement
- Sub-Section X.2.2: Objective of the pilot
- Sub-Section X.2.3: Pilot owners and stakeholders
- Sub-Section X.2.4: Technologies and services provided by the pilot
- Sub-Section X.2.5: Combined activities and expected synergies
- Sub-Section X.2.6: TRL level of the pilot
- Sub-Section X.2.7: Strategic roadmap to reach targeted TRL level

Sub-Section 3: Identifying risks and barriers
- Sub-Section X.3.1: PESTEL Analysis
- Sub-Section X.3.2: Business Model Canvas Analysis
- Sub-Section X.3.3: SWOT Analysis

Sub-Section 4: Financial analysis
Sub-Section 5: Evaluation and control
Sub-Section 6: Conclusion

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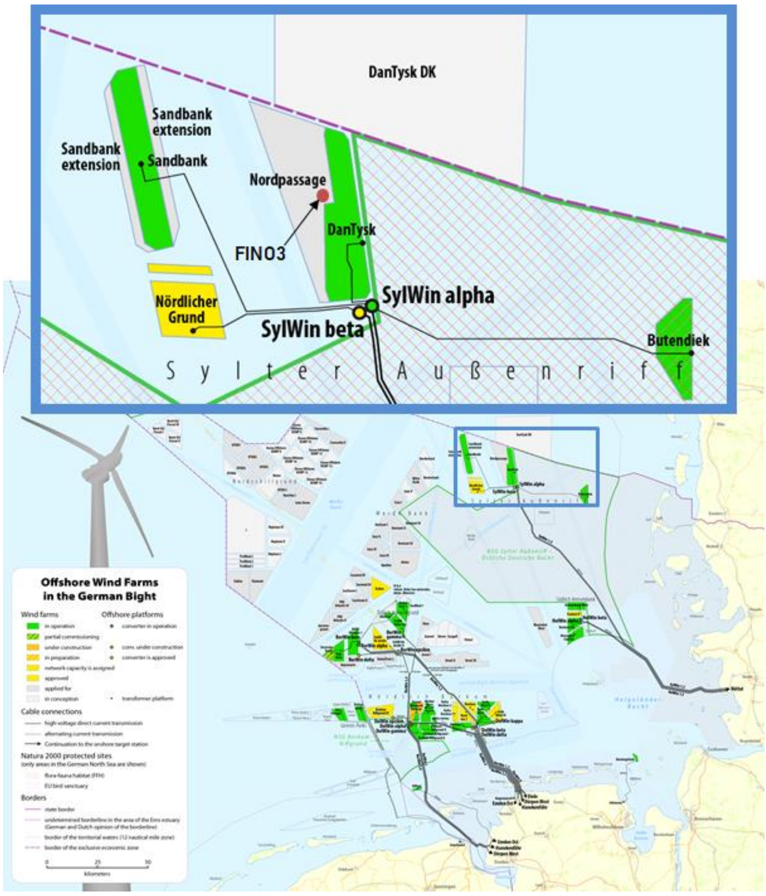
2. BUSINESS ANALYSIS OF THE GERMAN PILOT

2.1. Background

The German Pilot is located at the FINO 3 research platform in the North Sea (**Error! Reference source not found.**), German EEZ, about 45 nautical miles (80 kilometers) west of Sylt on the edge of the potential aptitude for wind turbines off the Schleswig-Holstein North Sea coast. The coordinates of the location are 55º 11,7'N, 007º 9,5', which is close to the offshore wind farms: Butendiek, DanTysk, and Sandbank. This "neighbourhood" influences also environmental planning aspects. For a detailed description of the German Pilot site, please follow up with deliverable D4.1 (UNITED, D7.2).

***Figure 3** Location of the German pilot in the North Sea, Germany*



2.2. Defining optimized business cases

2.2.1. Mission and vision statement

Mission statement

The mission of the German pilot is to develop, install, and operate a demonstration offshore aquaculture farm of mussels (Mytilus edulis) and macroalgae (Saccharina latissima) connected to an existing offshore structure to better understand the feasibility and risks of aquaculture in extremely exposed wind parks.

Vision statement

The vision of the German pilot is to contribute to the widespread establishment of offshore wind and aquaculture multi-use projects in the North Sea if they prove feasible.

2.2.2. Objective of the German pilot

The objective of the German pilot is to install and operate an offshore demonstration aquaculture farm of mussels (Mytilus edulis) and macroalgae (Saccharina latissimi) at the research platform FINO3. The aquaculture installation is not attached to FINO3 but is located in its safety zone and thus near. FINO3 does not generate wind energy, but its monopile construction has similar characteristics to offshore wind turbines. FINO3 is located 80km offshore west of the island Sylt in the German North Sea in the vicinity of the offshore wind parks DanTysk, Sandbank, and OSB Butendiek (UNITED D1.2). The pilot aims to demonstrate the economic, environmental, and societal benefits of combined offshore wind and aquaculture while reducing the technological, financial, health, safety, and environmental risks for both aquaculture and offshore platforms (UNITED D7.2). Furthermore, the legal situation of such a multi-use project will be analysed in terms of future transferability.

To reach these objectives, the following steps need to be undertaken (see also UNITED D7.2):

- Carrying out near-shore tests to determine which equipment and material are most resistant to, among others, biofouling, waves, tides, current, storms, salinity, and corrosion. These tests are performed at the Kieler Meeresfarm (KMF), an existing commercial aquaculture farm in the near-shore area of the Baltic Sea.
- Installing a demonstration mussel and macroalgae aquaculture system at the offshore site FINO3 in the North Sea, using the best-performing material and equipment from the tests at the near-shore site.
- Implementing an automated data collection and remote monitoring concept at the offshore site. This is necessary for any offshore facility to operate economically and safely due to costly transport of people and material and very limited to no accessibility due to harsh weather conditions.

2.2.3. Pilot owners and stakeholders

Different stakeholders are engaged in the activities of the German pilot, which can be grouped as internal stakeholders and external stakeholders (UNITED D3.1, D7.2). The internal stakeholders are directly involved in the German pilot and include the pilot lead and operator of the offshore-site R&D Centre University of Applied Sciences Kiel GmbH (from here on: FuE), the operator of the near-shore site and consultant Kieler Meeresfarm GmbH & Co. KG (from here on: KMF), and the engineering company 4HJena Engineering (from here on: 4HJena) responsible for automated data collection and remote monitoring solutions (see Table 2 for an overview).

Table 2 Internal stakeholders involved in the German Pilot (adapted from D3.1 of the UNITED project).

Stakeholder	Role	Interest	Contact
R&D Centre University of Applied Sciences Kiel GmbH (FuE)	Pilot lead, offshore-site operation	All research results	eva.strothotte@fh-kiel-gmbh.de
Kieler Meeresfarm GmbH & Co. KG (KMF)	Near-shore site operation, producer, consultant	All research results	info@kieler-meeresfarm.de
4HJena Engineering	Automated data collection and remote monitoring at offshore site	Research results on technical solutions	triest@4h-jena.de

External stakeholders are the Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency), shipping companies, helicopter companies, industrial divers, insurances, and other ongoing research projects conducted at FINO3 (UNITED D3.1, D7.2).

In addition, the project team engaged with interested actors from the offshore wind sector, because one aim of the German Pilot is to ensure the transferability of results from the planning stage by engaging offshore windfarm operators. In the context of this deliverable, we conducted a semi-structured interview with Northland Power[5] a developer and operator of offshore wind farms in the German North Sea.

2.2.4. Technologies and services provided by the German pilot

The research centre FuE is operating the offshore research platform FINO3. It is equipped with an airfield for helicopters, three generators for power supply and containers for measuring devices, servers, energy, workshop, storage, and pilot stay. The technical applications, infrastructure and logistics have been continuously tested and improved since the beginning of the construction of FINO3 in 2005. Studies on the installation, operation, and decommissioning of offshore installations have been conducted in different research projects and results are used for the UNITED pilot. Within UNITED, the best-performing set-up for a mussel and macroalgae longline aquaculture will be installed and tested at FINO3 (UNITED D7.2).

The near-shore aquaculture farm KMF is mainly active in the pre-operational phase of the German pilot, during which materials and equipment are tested. The tests focus in particular on anchors, longlines, collector lines, shackles, chains, buoys, sensors, cameras, biofouling as well as the logistics of installation, service and maintenance (UNITED D7.2).

The project partner 4HJena will provide technologies for automated data collection and remote monitoring at the offshore site FINO3 during the operational phase (UNITED D7.2).

2.2.5. Combined activities and expected synergies

The multi-use solution implemented in the German pilot is a demonstration aquaculture farm of blue mussel (Mytilus edulis) and macroalgae (Saccharina latissima). Both blue mussel and macroalgae cultivation were identified as suitable for the offshore location at FINO3 by a feasibility study for the German pilot carried out prior to the start of the UNITED project. It considered a range of biological, technological, and economic factors for five different aquaculture scenarios for multi-use at FINO3 (Geisler et al. 2018)[6]. Among these was a combined mussel long line cultivation with macroalgae, which was eventually chosen for the German pilot. Geisler et al. (2018) conclude that a mussel and macroalgae cultivation is suitable for the FINO3 site.

This choice of activities for the German pilot is supported by results showing that offshore wind farm operators prefer non-fed aquaculture of mussels and macroalgae to fed aquaculture of e.g. fish, because the former entails less frequent site visits and smaller-scale operations taking place within the offshore wind farm (Krost et al. 2011).

Synergies from this multi-use solution of offshore wind and aquaculture are expected in the following areas (UNITED D3.1):

[5] https://www.northlandpower.com

[6] The five options investigated were mussel long line cultivation (*Mytilus edulis*), macroalgae (*Saccharina latissima*), oysters (*Ostrea edulis*), trout in cages (*Oncorhynchus mykiss*) and Integrated Multi-Trophic Aquaculture (IMTA) a combination of mussel long line cultivation with macroalgae (*Mytilus edulis* with *Saccharina latissima*). While the IMTA scenario received the lowest overall score, this is because for each parameter the lowest score from the individual assessments of mussels and macroalgae was counted.

- Logistics;
- Transportation (ships, helicopters);
- Planning and maintenance work;
- Automated operation and monitoring;
- Improved social acceptance of aquaculture products and offshore multi-use.

2.1.6. TRL level of the pilot

The current technological readiness level (TRL) of the German Pilot is stated as TRL 5, which is defined as "Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)" (UNITED D7.2). In the case of the German pilot, the industrially relevant environment is the near-shore site in the Baltic Sea. While the single activities (the research platform FINO3 and the near-shore aquaculture farm KMF) are already operational and are thus categorized as TRL 9 (UNITED 3.2), their successful adaptation to and implementation in the challenging offshore environment requires complex logistical and technical adjustments.

2.1.7. Strategic roadmap to reach targeted TRL level

The German pilot is currently at technological readiness level (TRL) 5 and is supposed to reach TRL 7 with the input of UNITED, which is defined as "System prototype demonstration in operational environment" (UNITED D7.2). The aim of the German pilot is not to reach the commercialisation stage.

To reach TRL 7, and eventually move beyond it towards full commercialization, the following aspects need to be addressed (UNITED D3.1):

- Functionality of multi-use projects: Evidence on the effectiveness of offshore wind and aquaculture multi-use projects is needed, while reducing the risks for implementation and operation at affordable costs.
- Administration and government: Solutions for governance (e.g. obtaining permissions and licenses) that comply with legal standards need to be identified and described.
- Investors and sales plan: The decision-making process on investing into multi-use needs to be simplified with reliable offers for investors regarding financing models and business plans while reducing the overall economic risk.
- Standardized infrastructure: A complete infrastructure for operating a multi-use project needs to be created to reduce risks and operate efficiently: training certified offshore staff, optimizing the scheduling of logistics, transportation, and maintenance work, reducing energy need, etc.
- Technological development: Technologically feasible and affordable concepts for the offshore installation of semi-submerged longlines in high-energy offshore environments need to be tested and confirmed.
- Environment: Environmental data is required to investigate the impact of multi-use on the environment at the offshore site. If there are negative impacts, these must be known before upscaling.

2.3. Identifying risks and barriers

2.3.1. PESTEL Analysis

The PESTEL analysis was completed for a hypothetical commercial offshore wind power and aquaculture multi-use project, which does not yet exist in practice in the German North Sea. Several of these external factors are also relevant for the ongoing implementation of the German pilot. Information was sourced from UNITED deliverables published to date and a workshop with the project partners KMF and FuE held in September 2021. In addition, in the absence of a project partner from the wind energy sector, a supplementary semi-structured interview was conducted with the offshore wind power company Northland Power in September 2021.

Political conditions

- **Political support at EU level**. There is political support for offshore wind energy, aquaculture as well as multi-use of sea space at EU level (see e.g. Offshore Renewable Energy Strategy,[7] Sustainable Blue Economy Strategy,[8] Bioeconomy Strategy,[9] Common Fisheries Policy[10]).
- **Political support at national level.** The most recent German Maritime Spatial Plan (MSP) was published in September 2021 and allocates 15% of the German Exclusive Economic Zone (EEZ) to offshore wind energy. The MSP also sets out that the aquaculture sector should be expanded, and specifically mentions the multi-use of existing installations such as offshore wind farms for aquaculture[11].
- **Lack of regulatory and financial incentives.** Specific policy support in the form of regulatory or financial incentives for multi-use projects is lacking in Germany (e.g. subsidies for multi-use projects, multi-use requirements for offshore wind parks, easier access to permits for offshore windparks with multi-use component[12]).

Economic conditions

- **Existing markets for mussels and macroalgae.** There is an existing market for mussels as food (end-consumers and restaurants), mussel spat and macroalgae. The market potential depends on the quality of the harvested product, its processing, and the possibility of selling it locally.
- **Underdeveloped macroalgae market.** While macroalgae can be used in many sectors (cosmetics and pharmaceutical industry, restaurants, and retail, insulating material for construction, water remediation systems and sewage treatment plants, etc.) and there is political support for its use in the bioeconomy, the European market is still underdeveloped (Geisler et al. 2018).
- **Potential for new markets.** There is potential to create products from mussels besides food, such as mussel meal as animal feed, even though this is currently not competitive yet. In addition, if the mussel aquaculture's uptake of carbon dioxide could be certified, these certificated could be sold on the carbon market. Similarly, if a nutrient market was to develop in the future, mussel aquacultures could sell certificates issued for phosphorus and nitrogen removal.

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7 https://ec.europa.eu/energy/topics/renewable-energy/eu-strategy-offshore-renewable-energy_en

8 https://ec.europa.eu/oceans-and-fisheries/ocean/blue-economy/sustainable-blue-economy_de

9 https://op.europa.eu/en/publication-detail/-/publication/edace3e3-e189-11e8-b690-01aa75ed71a1/language-en/format-PDF/source-149755478

10 https://ec.europa.eu/oceans-and-fisheries/policy/common-fisheries-policy-cfp_de

11 https://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&jumpTo=bgbl121058_Anlageband.pdf#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl121058_Anlageband.pdf%27%5D__1640772692226

12 For comparison see the policy support in other European countries as described in the Belgian or Dutch UNITED pilots.

- Varying market price for aquaculture products. The development of a commercial offshore aquaculture in combination with wind farms in the North Sea region depends on, among others, the market price for mussels (Geisler et al. 2018). Aquaculture products can either be sold locally (as done by the KMF) or marketed on a larger scale on the German or European market. While mussels can be sold locally at higher prices, large-scale offshore aquaculture productions are more likely to market their products on national and international markets. To maximise profits on the international markets, advantage can be taken of seasonal and geographic fluctuations by flexibly selling products on the most profitable markets.
- Difficult access to finance. There is a lack of available finance for investments into offshore aquaculture and wind multi-use projects. Even though the cost of lending in Germany is low as of 2021, private investors and banks are reluctant to finance multi-use projects, because they are still at the research and experimentation stage and there is no commercial operation or proof (van den Burg et al. 2017). In addition, investors might be put off by the high cost: Investment cost of offshore equipment (cages, anchoring, long lines) can easily be doubled compared to coastal aquaculture, making it difficult to attract investors. Uncertain and lengthy licensing procedures add to the difficulty of finding investors for multi-use projects (Christensen et al. 2015). There is also a lack of public finance for multi-use projects.
- High costs for external services. Offshore multi-use projects depend on external service providers, such as charter of specialised ships or divers. The costs for these services are high and the offer is small.
- Consumer spending after Covid-19. The sale of mussels and macroalgae will be influenced by the economic recovery from the Covid-19 pandemic and the associated development of consumer spending on non-essential “luxury” goods.
- High insurance costs. Insurance of multi-use projects is difficult to obtain because it is unclear what parameters are needed by insurance companies to assess the risk and the insurance rate of multi-use projects. Most EU countries face uncertainty with respect to insurance and liability issues at multi-use sites, and the perceived complexity and unproven nature of technology leads to an over-cautious approach, which may result in prohibitively high insurance quotations (Christensen et al. 2015). The loss of aquaculture products to storms or other extreme weather events can likely not be insured, because force majeure is usually excluded from insurance policies or the costs for the insurance would be too high.
- Costly food safety analyses. Strict regulations on food safety analysis mean that regular testing of aquaculture products is expensive and time consuming. Mussel samples need to be tested weekly for microbial and hygienic limits, as well as for algae toxins. Once a year, an additional comprehensive analysis is carried out of the load of heavy metals and other environmental contaminants in the mussels (Geisler et al. 2018).

Social conditions

- Generally positive attitudes towards multi-use. Recent international studies point to a generally supportive attitude of the majority of stakeholders towards spatial and/or operational integration of marine aquaculture and offshore wind energy as a solution to increasing, and competing demands for limited ocean space. However, there are also general concerns about the intensification of ocean use (Michler-Cieluch and Kodeih 2008; Vollstedt 2011; Wever, Krause, and Buck 2015).

- Acceptance issues of offshore wind and aquaculture. While there is a rising demand for renewable energy, in parallel concerns are growing about the negative environmental impacts of renewable energy, including offshore wind installations (van den Burg et al. 2020; Geraint and Gianluca 2016; Gusatu et al. 2020). Also, the aquaculture industry is struggling with social acceptance issues, which is at least partially driven by negative examples from fish aquaculture, e.g. from salmon farming in Norway or Chile (Wever, Krause, and Buck 2015). However, many of the criticisms of fish aquaculture facilities do not apply to mussels and algae, because its environmental impacts are lower, the aquaculture doesn't require external feed and medication, and animal welfare considerations are easily met. Nonetheless, also mussel and macroalgae aquacultures face acceptance issues (Geisler et al. 2018).
- Lack of awareness of benefits. Consumers are often not aware that non-fed aquaculture (mussels, macroalgae aquaculture) is more sustainable than fed aquaculture (fish). There is also a general lack of awareness regarding the advantages of multi-use.
- Concerns about local benefits. In a case study conducted in the German North Sea area, some stakeholders voiced concern that large, possibly foreign investors would operate multi-use projects without generating any or only marginal benefits for the coastal region and local workforce (Wever, Krause, and Buck 2015).
- Development of consumer preferences. Consumer preferences for aquaculture products will influence the demand for mussels and macroalgae. Also, consumer preferences for buying local will influence demand, especially if products will be market regionally.
- Weak connections and trust between sectors. Implementing multi-use solutions will require building stronger connections and trust between the aquaculture sector and offshore wind energy sector.
- Conflicts between offshore wind and fisheries. There are ongoing conflicts between offshore wind parks and fishers, who feel threatened by the expansion of wind energy into their fishing grounds. Offshore mussel farming could potentially mitigate this conflict by reducing the perception that offshore wind parks are taking up too much sea area for themselves and potentially also by offering alternative employment options to local populations. However, studies carried out in the German North Sea revealed that some fisheries representatives perceive multi-use of offshore wind farms – including aquaculture – as lip service to appease those that lost their fishing grounds, and that local fishermen appear rather reluctant to the idea of engaging with offshore aquacultures (Michler-Cieluch, Krause, and Buck 2009; Wever, Krause, and Buck 2015).

Technological conditions

- Lack of technical knowledge, experience, and procedures. There is a lack of technical knowledge and experience with the multi-use of offshore wind and aquaculture, as well as a lack of standardized procedures to co-use aspects related to the multi-use project (e.g. sharing power supply, cable equipment or maintenance ships).
- Short service life of infrastructure at offshore location. The development of a commercial offshore aquaculture in combination with wind farms in the North Sea region depends on, among others, service life of infrastructure. Due to the high-energy location, the service life of the aquaculture installation is likely short (Geisler et al. 2018).

- High-energy offshore location. The offshore location of FINO3 in the North Sea is challenging for aquaculture installations, because of high waves and strong currents. Technological solutions for these conditions exist but have to be adapted to the specific needs and are very costly. . Especially mooring of aquaculture systems is challenging and failure could lead to damages of the monopiles or vessels nearby (UNITED D7.2).
- Remoteness requiring automation. The offshore location is characterised by its remoteness, which makes transportation costly and sometimes impossible due to weather conditions. This creates a high demand for automation and technical optimization of monitoring and maintenance. Technology for automation exists but has not been extensively tested in a multi-use setting and full automation is unlikely in the near future (even if theoretically possible[13]).
- Lack of qualified staff. There is a lack of qualified and certified staff that can operate in multi-use settings, and the training and certification processes for offshore staff are very expensive. The German pilot can benefit from the availability of trained and certified offshore staff at FINO3 (Geisler et al. 2018).

Environmental conditions

- Climate change risks. Climate change and the resulting increase in frequency and intensity of extreme weather events can lead to a loss of aquaculture products, as well as increased difficulties in operating the multi-use project (Geisler et al. 2018). Other factors like rising ocean temperature, or ocean acidification might have impacts on the aquaculture, but were not considered as a severe problem within a short- or midterm perspective by project partners.
- Untested growth rates of mussels and macroalgae at offshore location. There is insufficient biological data for the offshore location, e.g. time, scale and location of spat fall, growth rates of mussels and macroalgae. This makes it difficult to predict yields of offshore aquaculture. The development of a commercial offshore aquaculture in combination with wind farms in the North Sea region critically depends on the annual settlement success of juvenile mussels determining the mussel yield obtained per meter long line (Geisler et al. 2018). Blue mussels cultivated offshore in the German North Sea, for the most part, show high growth rates compared to those grown in nearshore sites, but more data is needed (Buck 2007).
- Low risk of pollution or infestation. The water quality offshore in the North Sea is good (e.g. less urban sewage than near-shore) and the risk of infestation of parasites is low or non-existent (Pogoda 2012). Also, compared to seabed growing areas, mussels grown in the water column are less contaminated by substances such as heavy metals.
- Degradation of fisheries driving aquaculture. Mussel and macroalgae aquaculture can provide a sustainable alternative to overfished fisheries, allowing fish stocks to recover. More generally, the environmental problems of many conventional food production systems might make mussel and macroalgae aquaculture more attractive, as it is energetically very efficient, requiring little land and inputs.
- Toxic algae blooms. Toxic algae blooms before the harvest can lead to contaminations of aquaculture products, which as a result can no longer be sold.
- Sufficient level of nutrients: Compared to the Baltic Sea (and to nearshore locations), the supply of nutrients in the German North Sea is lower, but still sufficient for growth of mussels and macroalgae at the offshore location. High concentrations of nutrients can even be harmful for aquaculture products and the risk of reaching these harmful levels are lower for offshore compared to nearshore sites (Geisler et al. 2018).

Legal conditions

[13] For more information on 'self-farming aquaculture' see this blog-entry from 2019: https://thefishsite.com/articles/self-farming-aquaculture-its-closer-than-you-think.

- **Difficult to obtain permits.** Obtaining permits for multi-use projects in Germany is a difficult and lengthy process, partially because there is a lack of dialogue between public institutions and uncertainty about the administrative offices responsible for issuing permits.
- **Unclear EIA requirements.** Permits for large-scale multi-use require environmental impact assessments (EIA), which are difficult and lengthy to conduct. Moreover, there is a lack of guidance for EIA requirements for multi-use activities (Christensen et al. 2015).
- **Unclear and fragmented regulation.** The regulation for multi-use projects at the German and European level is fragmented.
- **Lack of established safety assessment methods.** There is a lack of established safety assessment methods for multi-use projects.
- **Strict security regulations in wind parks.** Strict security regulation concerning safety distances in wind parks discourage setting up multi-use projects.[14]
- **Wind farm operators effectively decide about multi-use.** The Seeanlagenverordnung (German Federal Marine Facilities Ordinance)[15] allows for the development of aquaculture at already existing wind power installations, as long as the aquaculture site does not become an obstacle for general maintenance. This gives the offshore wind farm operators a de-facto veto right against any development deemed hindering or detrimental to their activities in the area, leaving the ultimate decision about multi-use in the hand of the wind farm concession holder (Geisler et al. 2018).
- **Unclear security of tenure**. Most offshore wind farms are licensed for around 25 years, after which all infrastructure has to be completely removed. If an offshore aquaculture farm is installed at a wind farm which is to be decommissioned, there is uncertainty about the ability of it to continue its activity (e.g. regarding legal status of activities, the share of decommissioning costs).
- **Introduction of pathogens/diseases**. There are regulations concerning the introduction of aquaculture species and associated pathogens and diseases, which need to be adhered to.

2.3.2. Business Model Canvas Analysis

The **aquaculture** Business Model Canvas was completed for the existing and commercially operating near-shore Kieler Meeresfarm (KMF), based on the workshop with the project partners KMF and FuE held in September 2021 and existing deliverables (see Figure 4). Differences with an offshore aquaculture of mussel and macroalgae are indicated where necessary. The **wind power** Business Model Canvas was completed for a fictional wind power company, drawing on the interview with Northland power conducted in September 2021 (see Figure 5). Based on the two Business Model Canvasses, similarities and differences between the business models of offshore wind and aquaculture are identified, which gives insights into the feasibility of a multi-use projects involving the two sectors.

Figure 4 Business Model Canvas analysis –Aquaculture activity of German pilot

Business Model Canvas				
Key partners	Key activities	Value propositions	Customer relationships	Customer segments
• Sub-contractor for	• Regular site visits		• Mostly through	

[14] For an overview of different aspects of safety distances see Mehdi (2017).

[15] The Seeanlagenverordnung has expired and been replaced by the Seeanlagengesetz on January 1, 2017.

services (divers, mooring, etc.) • Food testing authority • Provider of spat and algae • Public administration (environment, shipping, etc.) • Research partners • Educational institutions	for monitoring, maintenance, and harvesting • Food quality testing • Sale and delivery of products • Participation in research activities • Tours, lectures	• Fresh, local mussels • Local macroalgae • Innovative project offering possibilities to carry out research • Educational opportunities	personal contact	• Individual consumers (retail) • Gastronomy • Macroalgae industry • Research • Education (adult education, schools)
	Key resources • Staff and expertise • Sea use rights and aquaculture permit • Vessels, equipment • Spat • Land-based facilities for processing and storage		**Channels** • Word of mouth • Social media	

Cost structure[16]	**Revenue streams**
• Installation • Operation and maintenance • Monitoring • Food quality tests	• Main revenue stream from selling products to individual costumers (currently 50% of mussel revenue, set to increase) and to

[16] In an offshore aquaculture, costs for transportation, installation (especially mooring) and maintenance would go up significantly. In order to be profitable, it would need to be much larger to benefit from economies of scale (i.e. relatively less costs for permits, monitoring and food safety tests) and automate processes in order to reduce staff costs and the need for transportation.

• Rental of land-based facilities • Transportation • Usage fee for sea area, permits • Permit fees • Staff costs (salaries, training, certification) • Advertisement • Insurance • Contribution to research projects	gastronomy (currently 50% of mussel revenue, set to decrease) • Minor revenue streams from sale of macroalgae and education activities • Steady and significant revenue stream from research activities

Figure 5 Business Model Canvas analysis – hypothetical offshore wind farm of German pilot

Business Model Canvas				
Key partners	Key activities	Value propositions	**Customer relationships**	**Customer segments**
• Subcontractors for installation and maintenance • Component supplier • Investors/ banks • Insurance • Research and innovation partners	• Operation and maintenance of offshore wind park, both from land and at sea (daily trips or multi-day shifts out at sea) • Transport to offshore wind park • Environmental monitoring • Transmission of produced energy to shore	• Renewable electricity	• Mediated by electricity provider	• Electricity consumers (mainly energy distributor, but potentially also consumers looking for renewable energy)/ /energy markets)
	Key resources		**Channels**	
	• Staff and expertise			

	• Sea use rights and permit • Vessels, equipment			

Cost structure • Site analyses • Installation costs, including material • Land based infrastructure • Operation and maintenance • Studies (environmental, biological etc.) • Monitoring • Usage fee for sea area • Staff • Insurance • Permit fees	**Revenue streams** • Electricity market

The Business Model Canvasses show that there are similarities between the activities of offshore wind farms and aquacultures, which allow for synergies that could reduce costs. Realising these synergies would require coordinating means of communication, operations and maintenance timetables, training requirements and procedures (e.g. emergency responses). There is potential for synergies, and thus costs reductions, from sharing:

- Transportation (ships, helicopters) for routine monitoring and maintenance trips – which would also reduce environmental impact of transportation;
- Offshore maintenance work;
- Onshore and offshore storage spaces and workshops;
- Environmental monitoring data and surveillance;
- Certified offshore staff and training; and
- Insurance premiums.

In addition to benefits for both parties of the multi-use, there are some advantages of multi-use which only accrue to the aquaculture business. First, the offshore location would allow the aquaculture to make use of economies of scale which it could not exploit in the nearshore area. In addition, the monitoring and surveillance program (type of sensors, possible parameters, duration of measurements) will not be limited by the availability of batteries, as the aquaculture farm can be supplied with power from the platform. It would also be possible for the aquaculture farm to benefit from equipment present on the wind turbine fundaments, e.g. cranes. It would even be technically feasible to use the turbine's monopile for mooring the longlines if this is taken into account in the design of the wind turbine from the beginning. In general, realising the benefits of multi-use is easier if both activities are planned together from the outset.

From the perspective of the wind farm operator interviewed in the context of this deliverable, multi-use with an aquaculture installation could pose challenges. There are concerns that the presence of the aquaculture could disrupt monitoring and maintenance activities on the wind turbines, or that mooring failures could result in damage to maintenance and repair vessels or turbine foundations. The presence of aquaculture structures within the wind park could also render navigation more difficult, especially if the structures would be directly anchored at the wind turbine fundaments. To circumvent these challenges, the aquaculture could be installed not within the wind park, but in the security-zone surrounding it (500 m in Germany), leaving marked entry points for maintenance and repair vessels. Fishing and navigation are forbidden in the security zone and would thus not interfere with the aquaculture installation.

There are differences in annual revenues and costs between offshore wind and aquaculture and it is yet unclear whether cost savings would be sufficient to incentivize offshore wind operators to participate in multi-use projects, especially given the additional challenges. More detailed analyses of the financial benefit of multi-use need to be undertaken to determine whether there is a financial incentive for the offshore wind sector to participate in multi-use.

However, even in the absence of a financial benefit or political incentives and requirements for multi-use (e.g. easier to obtain permits, multi-use requirement in new offshore wind parks, subsidies), there are positive externalities which could motivate the participation by the offshore wind sector in multi-use. For example, multi-use could improve the social and environmental image of the offshore energy, because of the generated ecosystem services, job creation, and co-use of increasingly limited sea space. This is an important aspect for an industry struggling with social acceptance issues.

2.3.3. SWOT Analysis

The SWOT analysis was completed for hypothetical offshore wind power and aquaculture multi-use project, but some aspects are also relevant for the ongoing German pilot. The SWOT analysis reveals that there are inherent strengths to offshore wind and aquaculture multi-use, as well as external opportunities that it could benefit from. However, there are also significant weaknesses and threats that need to be addressed. Information was sourced from UNITED deliverables published to date, the workshop with the project partners KMF and FuE in September 2021, and the interview with Northland Power conducted also in September 2021. For an overview see Figure 6.

Strengths

From a financial perspective, the main strength of a multi-use project would be synergies resulting in cost savings, e.g. through the development of a flexible, collective transportation scheme; the sharing of high-priced facilities; and rationalization of operating processes. The multi-use project could also improve the reputation of both the aquaculture and wind energy sector, which struggle with acceptance issues, and ease spatial conflicts about the distribution of sea space. From an environmental perspective, a strength of this set-up would be possible positive impacts of the aquaculture on the marine environment through the filtration of seawater and the removal of nutrients. The aquaculture products as well as the renewable energy derived from the multi-use site could receive certain eco label or small spatial footprint certifications. (However, the certification of aquaculture products could be compromised due to combination of aquaculture-shellfish with a wind park in an "industrial" production setting (S.W.K. van den Burg et al. 2017).) Also seed mussels (spat) may be produced at the offshore location: While spat from near-shore areas in the North Sea is often contaminated with toxic substances, relatively uncontaminated spat can be produced at the offshore location (Geisler et al. 2018). Offshore wind and aquaculture multi-use also offers opportunities to produce large volumes of food and thus alleviate pressure on fish stocks and land-based production systems.

Weaknesses

From a technical perspective, the harsh offshore environment poses a challenge, especially given the lack of experience with offshore aquaculture. Waves, wind, or currents could damage equipment or lead to injury of staff. There is a risk of mooring failure of the aquaculture installation, which could result in damage to the wind park, obstruction of operations and loss of harvest. Weather conditions might also cause delays in the harvesting and delivery schedules, leading to strained relationships with customers. Moreover, biofouling, corrosion, and scour need to be managed (Losada and Guanche 2013). The offshore location moreover requires a high level of automation, which relies on yet untested systems. Due to the overall complexity of a multi-use offshore wind and aquaculture project, delay could arise. Another weakness is that the operations of the multi-use partners could interfere, and problems could arise from ambiguous assignment of rights and duties. There could also be an imbalance in the financial benefits resulting from synergies (i.e. a greater financial benefit for the aquaculture), which could lead to diverging levels of interest or involvement among the partners. A high level of investment that is required for the installation of an offshore aquaculture, while there are only few sources of financing available[17].

Opportunities

There are several opportunities for a multi-use project of offshore wind and aquaculture. In general, the blue economy sector is growing, that is specifically true for aquaculture and offshore wind. There is also political support for multi-use both at the EU and national level. Positive externalities of mussel and macroalgae aquaculture (nutrient reduction, carbon sequestration) might open finance possibilities in the future. Additionally, there might be the potential for setting up local cooperative ownership structures of multi-use projects, which might strengthen social acceptance and local involvement.

Threats

There is still uncertainty about biological feasibility of offshore aquaculture, as the growth rate of mussels and macroalgae is uncertain. An offshore wind and aquaculture multi-use project might have negative cumulative environmental impacts, for example, disturbance of the marine environment due to increased vessel traffic connected to the multi-use. There is also a risk of unwanted introduction of pathogens, diseases, and non-native (fouling) species when operating offshore structures by moving material and equipment as well as ships from one region to another without any measures. The success of the aquaculture might be hindered by unforeseen contaminations due to algae bloom. There could also be social acceptance issues with either the multi-use project, or aquaculture or offshore wind specifically. In addition, there is a shortage of staff and sub-contractors for installation, maintenance, and operation of offshore platforms; insurance costs might be very high; and multi-use projects are threatened by their unclear legal status, a lack of clarify on how to conduct EIAs and obtain permits.

[17] While mussels do not require external feed and as filter-feeding organisms remove nutrients from their environment, they do excrete nitrogen in the form of ammonium or concentrate nutrients, organic particles, or toxins through pseudofaeces formation which could accumulate underneath the aquaculture structures (Geisler et al. 2018). However, given the strong currents in the offshore area as well as the relatively small size of the German pilot, emissions from mussel and seaweed aquaculture are unlikely to pose a problem.

Figure 6 SWOT analysis – German pilot

Strengths	Weaknesses
– Cost savings from synergies – Improved reputation and acceptance of offshore wind and aquaculture – Mitigation of spatial conflicts – Positive environmental impact through nutrient removal – Potential for certifications of products – Possibility to produce uncontaminated mussel spat – Alleviate pressure on fish stocks and land-based production systems	– Lack experience with offshore aquaculture – Challenging offshore environment – High demand for automation – Delays due to complexity of multi-use – Potentially interfering operations – Ambiguous assignment of rights and duties between partners – High investment and lack of finance – Uneven financial benefit from multi-use
Opportunities	**Threats**
– Fast-growing blue economy – Political support for multi-use at EU and national level – Finance possibilities opened up by positive social and environmental externalities – Potential for setting up local cooperative ownership structures	– Uncertainty about biological feasibility – Unknown cumulative environmental impacts – Contamination from algal blooms – Shortage of staff and sub-contractors – Social acceptance issues – High insurance costs – Unclear legal status, lack of clarity on permit and EIA procedures

2.4. Financial analysis

2.1.1. Data collection and availability

The German pilot is currently installing a demonstration offshore aquaculture of blue mussels and macroalgae at the FINO3 research platform in the German North Sea. The aquaculture is not operational yet and it is not the aim to reach the commercialisation stage during the UNITED project. It is thus not possible to conduct a business analysis of a commercially operating offshore wind power and aquaculture multi-use project based on the available project data.

However, prior to the start of the UNITED project, a feasibility study on installing a blue mussel aquaculture at the FINO3 research platform was carried out by the R&D Centre University of Applied Sciences Kiel GmbH (FuE) which now leads the German pilot (Geisler et al. 2018) and GMA (Gesellschaft für Marine Aquakultur). This feasibility study contains a business model based on real-world data for offshore activities from FuE, which is currently being implemented by the German pilot. In section 4.1, the original business model from Geisler et al. (2018) is presented; insights from the ongoing UNITED project have not yet been considered.

In addition, in section 4.2 presents a business model for a theoretical blue mussel aquaculture at the Nordergründe offshore wind park, which was carried out by the "MytiMoney" study group as part of the Coastal Futures research project in 2008 (Bela H. Buck et al. 2017; Bela H. Buck, Ebeling, and Michler-Cieluch 2010). This project has never been realized in practice.

In the following the two business models are presented and compared. While it is not possible to draw definite conclusions about the operation a commercial wind power and aquaculture multi-use project, the two business models offer valuable insights into the cost structure and profitability of offshore mussel aquaculture projects. The offshore cultivation of macroalgae was not considered[18]. There is almost no access to real-world financial data from the offshore wind sector. Instead of a detailed business analysis of an offshore wind company, below some indications from the literature on the investment, maintenance and operational costs for the offshore wind sector are presented.

Blue mussel aquaculture at the FINO3 research platform

The economic analysis by Geisler et al. (2018) was part of a feasibility study on offshore aquaculture of blue mussels (Mytilus edulis) at the existing research platform FINO3, located 80 km offshore in the German North Sea. It was carried out prior to the UNITED project and the German pilot is the implementation of the business plan. The size of the mussel farm in the economic analysis by Geisler et al. (2018) is planned with 300m of Mussel longline assuming a harvest of 2t/100m per year. A four-year life cycle of the project was assumed. The life cycle and size of the German pilot are not representative of a commercial offshore wind and aquaculture project. The business model presented here therefore only gives an indication of the cost structure of such a project but does not allow any definite conclusions on its profitability. The analysis is updated with latest information provided by the pilot owner on costs about seaweed farming, which were originally not included in feasibility study by Geisler et al. (2018). Additional information about seaweed farming is drawn from Watson & Dring (2011) and North Sea Farmers (2021).

The business model of the German pilot by Geisler et al. (2018) operates at a loss, because the project duration is only four years, and the size of the aquaculture is small. The German pilot puts this business model into practice because it is a demonstration project which represents the step before upscaling to a commercial economically feasible project. The feasibility study notes that making a profit would be possible with an increased size and longer use of the offshore aquaculture (requiring more durable materials) to offset the high installation, operation and maintenance costs, as also suggested by other studies (Bela H. Buck, Ebeling, and Michler-Cieluch 2010; Jansen et al. 2016; Krost et al. 2011). In the German pilot, shipping and personnel costs are the most significant cost factors. They would be less decisive for the profitability of larger offshore aquacultures but remain important costs factors.

Geisler et al. (2018) also underline that the numbers must be considered with caution, because the market price for mussels, as well as the yield may fluctuate strongly from year to year. The project partners FuE and KMF confirm this experience, especially during the Covid-19 pandemic when restaurants closed. The business model above also does not consider insurance costs (ca. 5% of investment cost, if not located at FINO3) and monitoring costs (ca. 5% of annual project costs, if not located at FINO3). If a similar project was designed for another site, these costs would need to be considered. In addition, in the feasibility study significant costs for processing and packaging, as well as for frequent laboratory tests are mentioned, but they are not included in the calculation.

To increase the profit margin and thus the competitiveness of offshore aquaculture, the feasibility study suggest 1. certification for ecosystem-friendly production, which would give access to new markets and allow to charge higher prices, 2. diversifying production, e.g. producing mussel spat or marketing locally at higher prices, and 3. developing automated monitoring, maintenance and harvesting solutions to further reduce logistics costs (Geisler et al. 2018). These opportunities are explored during the UNITED project.

Blue mussel aquaculture at the offshore wind farm Nordergründe

The hypothetical study was carried out by the study group ''MytiMoney'' as part of the research project Coastal Futures in 2008 (Bela H. Buck et al. 2017; Bela H. Buck, Ebeling, and Michler-Cieluch 2010). It is based on a theoretical longline aquaculture of blue mussels *(Mytilus edulis)* at the offshore wind farm Nordergründe in the German North Sea, located 31.5 km from the shore. The study assumed the installation of four mussel plots of 49 ha with

[18] Neither of the business models considers the offshore cultivation of macroalgae. economic data about the cultivation of macroalgae at a near-shore site is available from the project partner Kieler Meeresfarm, but has not been considered in this deliverable.

71 longlines of 700 m each, amounting to 284 longlines in total, and a project life cycle of four years. Here the results of the 'basic scenario' with a new vessel and new land facility and the cultivation of mussels for consumption are reported.[19]

Table 3 Financial analysis of blue mussel aquaculture at wind park Nordergründe, adapted from Buck et al. 2017 and Buck, Ebeling, and Michler-Cieluch 2010

Cost/ revenue categories		Cost/revenue (in € for 4 years)	Comments
Investment cost		**8 842 000 €**	
	Mussel plots	3 342 000 €	The investment cost per meter of longline is assumed to be 15.80€ (including collectors, mooring constructions, connecting pieces and the complete buoyancy). It is assumed that the investment costs are 835,500 € per single mussel plot every four years.20 The case study assumed four mussel plots. The operating life expectancy is assumed to be four years for longlines and collectors, six years for buoyancy, and ten years for anchors.
	New vessel	4 000 000 €	Cost of a new vessel (45m class, 430 BRZ, 500 KW) including all necessary equipment for longline cultivation
	Land-based facility	1 500 000 €	
Fixed costs		**3 560 817 €**	
	Depreciation	3 022 540 €	Depreciation on vessel, land facility and longlines
	Licenses	1 000 €	Licensing costs for a single mussel plot at the offshore site Nordergründe are based upon the scale of charges and fees of the State of Lower Saxony. Following the fees for mussel license areas, only the bureaucratic work load will be charged.
	Motor overhaul	154 000 €	This case assumes a complete motor overhaul after 10 years with a cost of 385,000€
	Interest on fixed capital	232 951 €	7% (of 3,327,867 €)

[19] The MytiMoney project also assessed the cultivation of mussels for seed, as well as the use of existing capacities of near-shore mussel farmers.

[20] Our own calculations show that the investment cost per mussel plot is 785 260€, if the cost per meter of longline is 15.80€ (71* 700*15.80). Regardless, here the numbers from the "MytiMoney" group are reported.

	Miscellaneous costs	151 127 € (for 4 years)	Miscellaneous costs include insurance premiums, administrative costs 5% of depreciation
Variable (operating) costs		**1 358 186 €**	
	Maintenance and repair	302 254 €	10% of yearly depreciation
	Interest on operating capital	88 853 €	7% (of 1,269,333 €)
	Personnel	479 952 €	It was assumed that two full positions and two seasonal employees are needed for 70 days offshore per year (280 in total) at a cost of 3,333 Euro/ month.
	Fuel	336 000 €	Fuel was assumed to cost 0.55€ per liter, 84,000 € per year
	Miscellaneous costs	151 127 €	5% of yearly depreciation
Revenues		**9 140 000 €**	
	Revenues from selling mussels	9 140 000 €	Assumes a price of 1€/kg and a harvest of 2,380,000kg/ year One mussel plot has 49 ha (700m x 700m), on which 71 longlines are installed. Each longline carries 1765 m of collector harness, amounting to 118,925 m per plot. The biomass of mussels per meter of collector is assumed to be 10kg, giving an annual production of 16.75 metric tons per single longline (production value 16,750€) and 1,190 metric tons (production value 1,190,000€) per mussel plot. While the study site has four mussel plots, only two plots can be harvested annually starting in year two, giving six harvests over the project duration of four years. This amounts to 3,280,000€ a year starting from the second year.
Balance (revenues - investment costs - variable costs - fixed costs)		**-4 247 004 €**	*Own calculation, not provided by case study*
Net returns (variable costs - fixed costs - revenues)		**4 594 996 €**	**Here investment costs are not considered, only the variable and fixed costs and revenues over four years.**
Net present value (NPV)		**5 667 073 €**	
Internal rate of return (IRR)		**14.73%**	

The "MytiMoney" project found that the base scenario reported above with a baseline production of 2380 tons of consumption mussels per year is clearly beyond the break-even point, if investment costs are not considered (Bela H. Buck et al. 2017; Bela H. Buck, Ebeling, and Michler-Cieluch 2010). They moreover conclude that profits are likely, because the IRR level of 14.73% should in most cases be higher than the costs of capital. If investment costs are considered, the set-up would also operate at as loss after four years. The authors caution that the lack of practical experience of culturing mussels in exposed environments precludes estimating effects of economic risks on the business model.

Offshore wind power

Limited data is available for the offshore wind industry, here the average global installation costs, as well as operation and maintenance costs for offshore wind power from a recent report by the International Renewable Energy Agency (IRENA 2021) are reported.

Installation costs: The total installed costs for offshore wind power (which includes the cost of designing, fabricating and building a wind farm) fell from USD 4 706 per kW in 2010 to USD 3 185 per kW in 2020. These reductions result from reduced investment costs, which fell by 18%, and efficiency gains due to, for example, larger turbines. It should be noted that these are average costs, which often differ regionally and per specific site. In Germany the average installed cost in 2020 was higher at USD 4 143 per kW. Between 2010 and 2020, the average offshore wind project size increased from 136 MW to 301 MW, and currently projects with capacities exceeding 1 GW are being deployed (IRENA 2021). Assuming a 300 MW offshore wind farm, its average total installed cost in Germany would have been USD 1 242 900 000 in 2020 (own calculation).

Operation and maintenance costs: The costs for installation and maintenance of offshore wind farms per KW are higher than for onshore wind. This is mainly due to costly access to the sites, which is influenced by weather conditions and the availability of skilled personnel and specialized vessels. There is limited data available on operation and maintenance costs, but they have been falling. For 2018, representative ranges for current projects fell between USD 70 per kW per year to USD 129 per kW per year (IEA et al., 2018; Ørsted, 2019; Stehly et al., 2018 in IRENA 2021). Once again assuming a 300 MW offshore wind farm, the annual cost of operation and maintenance would have been between USD 21 000 000 and USD 38 700 000 in 2018 (own calculation).

2.1.2. Results

Both business models for offshore multi-use aquacultures of blue mussel (Mytilus edulis) in the German North Sea would operate at a loss when only considering a project duration of four years (see Table 4 for a comparison). Given the considerable investment costs, an offshore wind and aquaculture multi-use project can only be profitable in the medium to long-term. Besides the life cycle such a multi-use project, size is critical for profitability. Offshore aquaculture is only profitable beyond a certain size due to economies of scale, the so-called 'break-even point'. The comparison shows that the small set-up at FINO3 with a yearly harvest of 12 750 kg and a price per kg of 2 € could not operate at a profit, whereas the larger theoretical set-up at Nordergründe wind park with a yearly harvest of 2 380 000 kg and a price per kg of only 1 € would be beyond the break-even point, if investment costs are not considered. Where exactly the break-even point is located depends on investment and operating costs, as well as the market price of mussels[21]. To confidently assess the financial feasibility of a commercial offshore wind power and aquaculture multi-use in the German North Sea, more data on costs from pilot projects such as currently carried out in UNITED, as well as updated data on market prices of mussels are needed[22].

Table 4 Comparative overview of business models

	Feasibility study for the German pilot at FINO3	Theoretical study of blue mussel aquaculture at Nordergründe

[21] Besides the differences in size and price, it should be noted that FINO3 is located 80 km offshore, Nordergründe only 31,5 km, which influences transportation costs. Moreover, the two studies considered different cost categories: The feasibility study for the German pilot (Geisler et al. 2018) considered for example decommissioning costs and marketing for FINO3, whereas the « MytiMoney » group included depreciation and interest on capital in their business model for the Nordergründe case study.

[22] Since the publication of the feasibility study (Geisler et al. 2018), the price for mussels has developed differently than foreseen as a result of the Covid-19 pandemic and the associated restrictions and changes in consumer behavior. In addition, prices for other materials and services might have increased as a result of the pandemic.

Harvest per year	12 750 kg	2 380 000 kg
Price per kg	2 €	1 €
Revenues for 4 years	76 500 €	9 140 000 €
Investment costs for 4 years	420 301 €	8 84 ,000 €
Operating costs for 4 years	935 826 €	4 919 003 €
Balance after 4 years	-1 279 628 €	-4 247 004 €
Net return after 4 years	-859 326 €	4 594 996 €

The two cases presented here assume the use of existing offshore platforms (the research platform FINO3 and the Nordergründe offshore wind park) and thus consider some of the benefits of multi-use in their calculations (e.g. the availability of electricity supply from the platform, mooring support, sharing transportation). One objective of the German pilot is to develop, test and analyze these synergy effects during the installation, operation and decommissioning of the aquaculture farm. There are estimates that up to 5% of annual project costs can be saved for the aquaculture business from synergy effects (Kite-Powell 2017). However, neither the feasibility study for the German pilot nor the theoretical case study for the Nordergründe offshore wind park considers the financial benefits accruing to offshore wind power companies from multi-use. Given the large differences in investment, operation and maintenance costs between offshore wind and aquaculture, it is unlikely that the financial benefits from multi-use for the offshore wind sector are significant, but more data is needed to confidently assess them.

2.5. Evaluation and Control

The objective of the German pilot is to install an offshore demonstration aquaculture farm of mussels (*Mytilus edulis*) and macroalgae (*Saccharina latissima*) at the research platform FINO3. As of the end of 2021, the tests at the near-shore site are nearing completion and the first installation of aquaculture infrastructure at the offshore site is planned for early 2022. This business analysis is based on the status quo of the on-going German pilot, already published UNITED deliverables, expert interviews as well as scientific literature. More data and insights will be obtained during the further implementation of the German pilot.

The research activities conducted as part of the UNITED project focus primarily on the technical and environmental aspects of offshore wind and aquaculture multi-use, such as the high forces (wind, waves, currents) as well as biofouling, scour, salinity, etc. impacting equipment and material; complex logistics for installation, maintenance and monitoring of the aquaculture; the need for automation due to the remote location; as well as uncertainties about growth rates of mussels and macroalgae at the offshore location in the North Sea. These challenges need to be overcome by the German pilot to set up an offshore demonstration aquaculture farm at FINO3 and reach technological readiness level (TRL) 7, as planned.

However, if the demonstration pilot should be advanced to commercial scale, several additional social, economic, legal, and political challenges need to be addressed to go beyond TRL 7. These are, among others, the high investments costs, and a concurrent lack of finance for offshore multi-use projects, a lack of certainty about regulations and permits for multi-use projects, potentially high insurance costs, as well as social acceptance issues. While it is not the objective of the German pilot to install a commercial offshore wind and aquaculture farm, some of these aspects are nonetheless considered early on to fulfil the vision of contributing to the widespread establishment of multi-use projects in the German North Sea.

An offshore wind and aquaculture multi-use project would only be financially feasible based on the available data from the German pilot if the aquaculture was larger and the project duration was longer than four years. Cost reductions from synergies between offshore wind and aquaculture are likely significant for the aquaculture, but the size of the financial advantage could not be fully assessed considering the available data. The transfer of these findings to a commercial aquaculture farm within an offshore wind farm will give further insights into costs and potential savings from synergy effects. While this goes beyond the scope of the UNITED project, the German pilot can serve as a base for future investigations.

Even if all the potential synergies were realisable in practice, the financial advantage from multi-use would likely be small for an offshore wind company. It is thus unlikely that the financial benefits of multi-use alone are sufficient to motivate the offshore wind sectors to participate in multi-use projects, especially because they might be concerned about negative impacts on their operations. It is thus important to emphasise the non-financial benefits of multi-use for the offshore wind sector.

2.6. Conclusion

The aim of the German pilot is to install an offshore demonstration aquaculture farm with mussels (*Mytilus edulis*) and macroalgae (*Saccharina latissimi*) at the research platform FINO3, located 80 km offshore in the German North Sea. The aim of the German pilot is not to reach full commercialisation. Based on the information provided by the German pilot in previous UNITED deliverables, as well as external literature and expert interviews, this analysis presents an overview of the internal and external factors that would influence a (hypothetical) commercially operating offshore wind and aquaculture multi-use project in the German North Sea and considers its financial feasibility.

Considering external factors, such a project could take advantage of general political support at the national and European level; existing markets for mussels and macroalgae; additional business opportunities to be developed in the future; a generally positive attitude towards multi-use; as well as promising environmental conditions at the offshore location. However, there are also several external challenges to the successful implementation of offshore aquaculture and wind multi-use projects. Firstly, there is a lack of political incentives or requirements for multi-use in offshore wind parks in Germany. The investment costs are high, but obtaining finance is difficult. Projects might also face social acceptance issues, as well as be impeded by insufficient trust and connection between the wind and offshore sectors. There is also a lack of technical knowledge and experience in implementing aquaculture in offshore locations, which are characterised by remoteness and extreme weather events, the latter of which are intensifying due to climate change. Lastly, there is uncertainty about regulations, environmental impact assessments, security standards and procedures for obtaining permits for multi-use projects in Germany. In addition, locally unknown growth rates of mussels and seaweed at offshore locations, as well as fluctuating market prices for aquaculture products need to be considered.

Considering internal factors influencing offshore wind and aquaculture multi-use projects, the analysis of the business models has shown that there are opportunities for cost savings from sharing transportation, monitoring and maintenance work, land-based and offshore facilities, staff and training, as well as insurance premiums. To what extend these synergies could be realized in practice is yet to be determined. It seems likely however, that the financial benefits derived from these synergies would be more significant for the aquaculture farm than the offshore wind sector, resulting in a potentially uneven motivation for multi-use. In addition, some benefits would only accrue to the aquaculture, whereas from the perspective of the wind farm operator, multi-use may even have disadvantages. These differences point to the importance of highlighting non-financial benefits of multi-use for the offshore wind sector, such as improved reputations of mitigation or conflicts with fisheries. This is especially important in the absence of political incentives or requirements for multi-use in Germany.

To assess the financial feasibility of such a multi-use project, this analysis drew on a feasibility study carried out for the German pilot, as well as a theoretical case study for a wind and aquaculture multi-use project at the Nordergründe wind park in the German North Sea. While there are differences in the results, they show that offshore aquacultures require significant investment and are likely only profitable in the medium to long-term and for installations above a certain size which can profit from economies of scale. Further research is needed to determine the costs and revenues of offshore wind and aquaculture multi-use projects, especially the cost savings and/ or increases because of the multi-use for both the aquaculture and the offshore wind sector. The German pilot is still under construction and continuously gained information will feed into the upcoming UNITED reports on the economic aspects of multi-use.

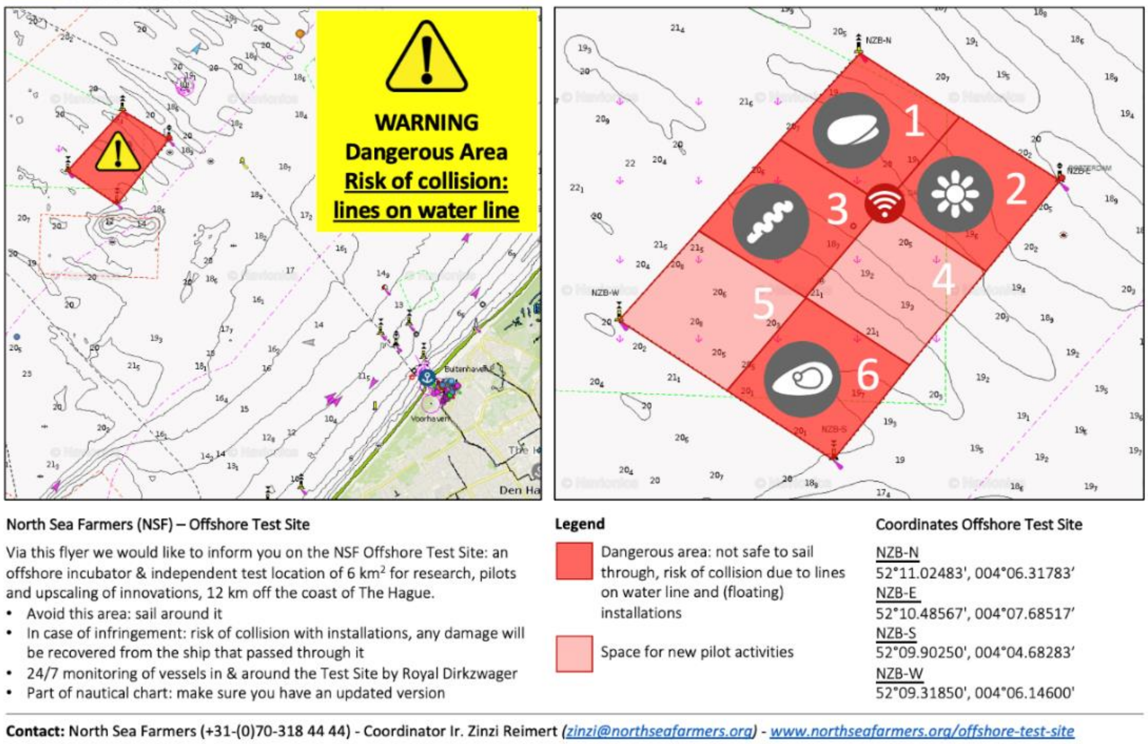
For the moment, the research activities conducted within the UNITED project in the German pilot focus on technical and environmental aspects, because offshore aquaculture in the German North Sea are a novel approach and no reference values exist so far. This business analysis highlighted the importance of considering also social, political, economic, and legal aspects in order to eventually reach the commercialisation phase of offshore wind and aquaculture multi-use projects.

3. BUSINESS ANALYSIS OF THE DUTCH PILOT

3.1. Background

The test site is located in the North Sea, 12 kilometres offshore, of the coast of Scheveningen, The Hague (see Figure 7). An offshore site of 6km^2 (3km x 2km) of the North Sea with six research plots of 1km^2 each. The sectors involved are energy and aquaculture (UNITED, D7.2).

Figure 7 Overview of the Dutch pilot test site. Plots 2 & 3 include the UNITED pilots of solar panels and seaweed farm respectively – the view is towards the north



3.2. Defining optimized business cases

3.2.1. Mission and vision statements

Mission statement

The pilot's mission is to contribute to the 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.

Vision statement

The vision of this pilot is that five years from now, commercial multi-use be realized in the North Sea. Companies will cooperate to combine offshore wind, nature, aquaculture, and/or floating solar. The pilot has contributed to a better understanding of multi-use and has been a showcase of multi-use.

3.2.2. Objective of the Dutch pilot

The Dutch Pilot aims to help industries develop large-scale offshore solar farms through UNITED and address important bottlenecks that impede such implementations. It will also help OWF owners develop large-scale offshore seaweed farms in existing wind parks and develop new OWFs offering integrated wind/aquaculture activities in the tender phase.

3.2.3. Pilot owners and stakeholders

Different stakeholders are engaged in the activities of the Dutch Pilot. Two groups of stakeholders could be identified: stakeholders and external stakeholders (UNITED, D3.1). The internal stakeholders are directly involved in the Dutch Pilot and/or in the UNITED consortium and include (see Table 5):

- Research institutes: Deltares, TNO;
- Businesses: North sea farmers, Oceans of Energy, The seaweed company; and
- Offshore Industry: Ventolines.

Table 5 Internal stakeholders involved in the Dutch pilot (adopted from D3.1 of the UNITED Project).

Stakeholder	Role	Interest	Contact
North sea farmers	Pilot Lead	All research results	eef@northseafarmers.org
Oceans of Energy	Company floating solar	Towards commercial floating solar energy, uses project for testing and demonstration of certain aspects to higher TRL level	brigitte.vlaswinkel@oceansof-energy.blue
The Seaweed Company	Commercial seaweed company	Towards commercial large-scale offshore seaweed cultivation	Joost.wouters@theseaweed-company.com
TNO	Support research on floating solar energy offshore	Research	Ton.veltkamp@tno.nl
Ventolines	Service provider of onshore wind and solar and offshore wind projects	Role in future development	arnoutvandenbosch@ventolines.nl
Deltares	Support technical questions	Research results	Roderick.hoekstra@deltares.nl

3.2.4. Technologies and services provided by the Dutch pilot

The main services provided by the Dutch pilot are the production of renewable energy and local aquaculture products.

The Dutch pilot is linked to an existing Offshore Test Site that is operated by North Sea Farmers, one of the project partners. The Dutch Pilot has two main systems that are being tested, the seaweed farm in plot 3 and the solar farm in plot 2 (UNITED, D7.2).

Plot 2 is where testing of offshore floating solar farms takes place. It is operated by the solar farm company, Oceans of energy, also a partner of UNITED. The main goal is to eventually work towards a safe and successful installation of floating solar farms within offshore (multi-use) wind farms.

In plot 3, The Seaweed Company (project partner) is testing two seaweed cultivation systems. One system is placed in line with the tidal currents and the other is oriented perpendicular to this current. This should show which orientation has the highest yield, i.e., light availability might differ in both orientations. In addition, load sensors have been placed to get a better understanding of the loads in the system since there is still a lack of knowledge on the influence of the seaweed drag concerning the loads. These Cultivator systems will be tested for two growing seasons (UNITED, D7.2).

3.1.5. Combined activities and expected synergies

On the test site (comprising multiple plots), a combination of seaweed, floating solar (400m^2), mussel cultivation, nature restoration, and offshore wind will be tested. As such, the pilot will provide a real-world scalable version for commercial exploitation on OWFs.

The following synergies are expected (UNITED, D3.1):

- Cost reduction due to the combination of activities;
- The wave dampening effect of floating solar infrastructure 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-powered sensors (e.g. temperature, light, turbidity, algae, nutrients, etc.) that can 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.

3.2.6. TRL level of the Dutch pilot

The Dutch level's current technology readiness level (TRL) is between 6 and 7. The pilot includes facilities in two plots (2&3): a seaweed Pilot and a solar farm Pilot, i.e. system prototype demonstration in an operational environment. Both the solar farm and the seaweed prototype includes various elements with a lower TRL (UNITED D3.2, D7.2).

3.2.7. Strategic roadmap to reach targeted TRL level

The pilot aims to reach a TRL between 7 and 8 by the end of the UNITED project and 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 (UNITED, D3.2).

Several research questions will be investigated concerning the planned combined activities' design, deployment, and monitoring. Prospective activities include (UNITED, D3.2):

- 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 behaviour of a cable from the floating solar array to the seabed and the buoy.
- Combined environmental monitoring, including the effects of structures on marine life.
- Wave dampening modelling is based on various configurations of structures (seaweed, floating platforms, combinations).
- Basin testing of combined seaweed and floating solar structures.

3.3. Identifying risks and barriers

3.3.1. PESTEL analysis

This sub-section presents the external factors influencing the Dutch pilot. The information is based on the interview held with the Dutch pilot leader, North Sea Farmers, the workshop organised for November 2021 with some relevant stakeholders, and information from other deliverables (mainly UNITED, D1.2).

Political conditions

- The Dutch government support the development of multi-use through its Community of Practice North Sea Sustainable Blue Economy
- There is a **lack of procedures & regulations** as multi-use in offshore wind farms is a new business. First steps are taken towards a uniform approach, but this still must be developed further.
- **Market entry difficulties.** Difficulties related to market entry can emerge from a changing political climate in offshore renewables, or renewables at large become less important.

Economic conditions

- **High costs.** High *maintenance* (offshore wind energy and aquaculture sites), *insurance* (mainly due to lack of experience in MUCL projects and due to the inherent risk associated with multi-use of the same platform) and *decommissioning* of multi-use platform "MUCL" (potential costs after the end of the multi-use) costs.
- **Insurance compliance.** Limits related to the scalability of aquaculture activities to comply with insurance requirements due to the proximity of the two industries.
- **Revenue losses and increased costs due to the COVID 19 pandemic.** Decreased orders for seaweed products due to closed catering and restaurants and missed harvest because of travel restrictions during the lockdown. Adding to that, raised costs and services (for example, increased container costs from 1 500 to ~10 000 $).
- **Lack of robust techno-economic analysis** examining the economic viability of multi-use combinations.

Social conditions

- **Lack of public awareness** about the implications of multi-use
- Low individual financial power and overall capacity to join MUP from local collaborators.
- **Conflicts of interest** between users of the sea (i.e. Different users of the sea (i.e. External tourist agencies, other energy producers, etc.).
- Demonstration and acceptance are required from stakeholders: the focus should be to make them see and convince them that this "innovative" multi-use of the EU seas is a new chance for existing stakeholder groups and not a threat.
- **Lack of dialogue** between public institutions and difficulties in identifying the administrative offices responsible for issuing permits.

Technological conditions

- **Lack of infrastructure** for shore-side electricity generation for the multi-use activities and the risk of anchoring vessels damaging power supply cables.
- High vibration from offshore wind turbines can cause damage to the infrastructure.
- **Safety issues** related to the deployment of the different operational activities (seeding, growing, harvesting, and processing)
- **Lack of proof of concept** that can demonstrate the techno-economic feasibility of the multi-use

Environmental conditions

- Damage due to catastrophic environmental events (storms/earthquakes)
- Lack of detailed environmental impact study to determine the impacts of construction and installation operations and maintenance on the physical environment because of offshore projects (and associated activities) combined with impacts from other marine activities or users in the sea.
- Lack of knowledge of the surrounding waters – through baselines surveys and monitoring –to ensure enough reaction time is available for industries and other interested parties to respond to environmental changes.
- Separate environmental impact assessment processes (permitting) for each (hybrid) technology and lack guidance on cumulative impact assessment.

Legal conditions

- Unclear and fragmented regulation for MUPs on a national level and European regulation level.
- Uncertainty about the security regulation discourages setting up an MUP (MU is currently allowed in several Dutch offshore wind farms areas under strict conditions).
- The wider regulation framework is considered not very beneficial for solar/energy farms as, it is argued, it is illegal to feed energy from floating solar farms into the grid of an offshore wind farm.
- Possibilities to get certified require early cooperation with private and public standard-setting agencies.

3.1.2. Business Model Canvas

The Dutch pilot has three activities: offshore wind farms, floating solar panels, and net-substrate-based seaweed cultivation. The information related to the nine building blocks of the Business Model Canvas analysis of the three activities is presented below.

The following matrix (Figure 8) presents the information obtained for the nine building blocks of the business model canvas of the wind energy company. The information was collected by interviewing with the Dutch pilot leader, North Sea Farmers.

Figure 8 Business Model Canvas analysis – Offshore wind farm activity of Dutch Pilot

Business Model Canvas				
Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
• Supply industry for offshore • Oceans of Energy • The Seaweed companies • North Sea farmers • Government • Tennet[23] • NGOs	• Install and operate offshore wind farm **Key Resources** • Human capital • Knowhow • Network	• Production of renewable energy at sea. • Multi-use is done to make efficient use of space and allow other sectors to operate at sea.	• Connection to the grid **Channels** • Sales via 'normal' channels for electricity, i.e. EPEX	• Energy companies
Cost Structure • Installation cost • Operation and maintenance cost			**Revenue Stream** • Sales of electricity	

The following matrix (Figure 9) presents the information obtained for the nine building blocks of the business model canvas of the Aquaculture company. This information was collected by interviewing the Dutch pilot leader, North Sea Farmers.

Figure 9 Business Model Canvas analysis – Aquaculture activity of Dutch Pilot

Business Model Canvas				
Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
• Oceans of Energy • North Sea farmers • Owner of wind farm • Government	• Installation and maintenence of seaweed farm • Seaweed harvesting • Sales of seaweed products	• Produce sustainable and circular raw materials from the North Sea • Promoting nature development on the seabed	• Direct relationship with business-to-business customers	• Restaurants (Food ingredients) • Famers (fertilizer, animal feed...) • Pharmaceutical companies

[23] TenneT is a transmission system operator in the Netherlands and in a large part of Germany. TenneT B.V. is the national electricity transmission system operator of the Netherlands, headquartered in Arnhem

• NGOs	**Key Resources** • Human Capital • Know-how • Existing customer relationships		**Channels** • Direct contact with customers	• Bioplastics producers

Cost Structure • Cost of Engineering, Procurement, Construction, and Installation (EPCI) of offshore seaweed farm including renewals • Cost of Operation and Maintenance of offshore seaweed farm including processing	**Revenue Stream** • Sales of seaweed end products • CO_2 certificates • Government subsidies

The following matrix (Figure 10) presents the information obtained for the nine building blocks of the business model canvas of the Oceans of Energy company. This information was collected by interviewing the Dutch pilot leader, North Sea Farmers.

Figure 10 *Business Model Canvas analysis – Floating solar activity of Dutch Pilot*

Business Model Canvas

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
• The Seaweed Company • North Sea farmers • Owner of wind farm • Government • NGOs	• Installation and maintenance of floating solar panels **Key Resources** • Human Capital • Knowhow	• Production of renewable energy at sea • Provide electricity when there is little wind • The wave dampening effect on a seaweed farm • Local provision of electricity	• Indirect, no close relationship with electricity users **Channels** • Regular electric sales channels including EPEX	• Energy companies • Seaweed Company benefitting from wave dampening effect • Seaweed company benefitting from the local supply of electricity

Cost Structure • Installation costs of floating solar panels • Maintenance costs	**Revenue Stream** • Revenues of sales of electricity • Compensation from Seaweed Company and energy company for the wave dampening effect

The business model canvas matrixes (Figures 8, 9, & 10) show similarities and differences between the activities of the Dutch pilot.

Concerning similarities, it could be noted that similarities between the combined activities of the Dutch pilot led to several synergies related to reducing costs due to the use of the same boat for maintenance/harvest (reducing costs and environmental impact), reducing needed space at sea for energy/aquaculture, the wave damping effect of floating solar infrastructure, which is potentially beneficial for the safety of seaweed cultivation on the pilot (or other activities).

Concerning differences, several differences exist in the activities of the Dutch pilot. The differences are at the level of some of the building blocks. Hence, except for floating solar panels and wind energy with similar customer segments, Aquaculture propositions and targeted customers are different. Furthermore, the cost and revenue structure of activities are different. These differences are seen as a source of enrichment for the pilot, especially when targeting different customer segments that allow the diversity of customers and hence the diversity of revenue streams.

From here, it could be concluded that the Dutch pilot is creating, capturing, and delivering value from all combined activities.

3.3.3. SWOT analysis

The swot analysis of the Dutch pilot is shown in the following matrix (Figure 11).

Strengths

One of the main strengths of the Dutch pilot is the strong cooperation between all partners. Furthermore, the offshore pilot allows experimentation and testing in realistic conditions, making a solid showcase.

Weaknesses

The Dutch pilot's main weakness is the high production cost that is challenging the business case for large-scale seaweed farming and floating solar.

Opportunities

The Dutch pilot has a lot of opportunities that the pilot can take advantage of, such as a) making use of the unused wind farm area for new sustainable production systems (seaweed/solar), b) the growing market demand for green energy and cultivated seaweeds, c) providing an opportunity to become less dependent on other continents for energy and raw material resources and d) the solid political will to develop multi-use.

Threats

The Dutch pilot's threats are a) competition for funds with other sustainable activities such as hydrogen, etc., b) unknown detrimental effects of large scale solar or seaweed farming, and c) the lack of compensating subsidy scheme for multi-use sea-weed aquaculture

Figure 11 SWOT analysis – Dutch Pilot

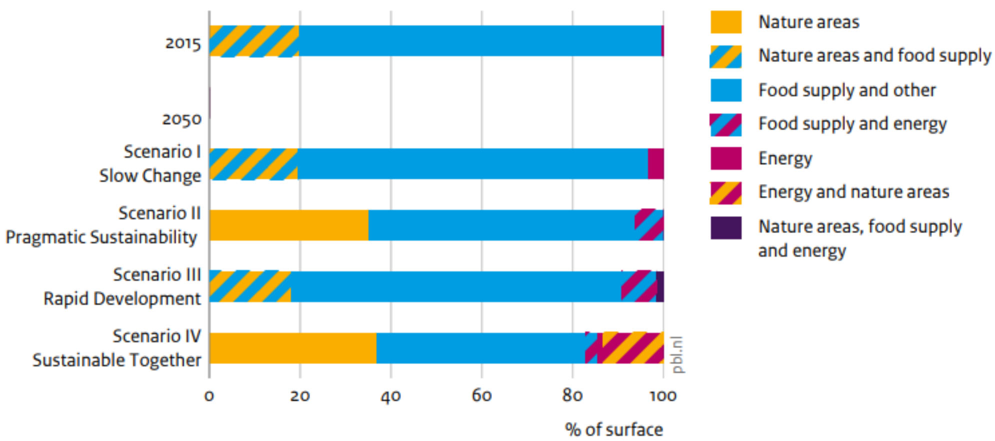
Strengths: - Cooperation between partners - Network of partners in the sector - Opportunity to experiment in realistic conditions but with limited risk in the Offshore Test Site	**Weaknesses:** – Cost of production challenging the business case for large-scale seaweed farming and floating solar – Technological challenges for operating offshore and reducing the cost price
Opportunities: - Unused wind farm area can be used for new sustainable production systems (seaweed/solar) - Market demand for green energy - Market demand for cultivated seaweeds - Opportunity to become less dependent on other continents for energy and raw material resources - Strong political will to develop multi-use	**Threats:** - Competition for funds with other sustainable activities such as hydrogen, etc. - Unknown detrimental effects of large scale solar or seaweed farming - Lack of compensating subsidy scheme for multi-use seaweed aquaculture

3.4. Financial analysis

Limited information is available on the specific financial details of the operators within the Dutch Pilot, namely Oceans of Energy and The Seaweed Company, due to the confidential nature and limited capacity of the SMEs to disclose operational financial information. However, key areas for fiscal savings and potential synergies between wind farm operators and seaweed cultivation in the form of mariculture and floating solar energy production have been outlined in the SWOT and business model canvas. Furthermore, the primary sources of revenue and streams for revenue generation for both sectors have been identified, likewise, primary fixed and variable costs, are correlated with this information with what is available through literature and sector forecasts can provide a generalized overview for financial analysis.

The outlook of OECD (2016) on the future state of the world's oceans for 2030 and beyond, with the ever-increasing pressures placed on maritime environments and the conversion of natural environments for economic activities, there is a strong need to limit the expansion of activities and increase the density thereof. Therefore, the pressure is foreseen to be placed on the multi-use market and it is expected to grow due to the limitation of new natural spaces being converted to economic activities. Many regional knowledge institutes are generating outlines for the expansion of multi-use activities concerning Seaweed (van den Burg, 2019), Blue Biotechnology and Seabed Mining (Johnson et al., 2018), Fisheries, Tourism, and Nature Conservation (Kyvelou et al., 2021). Specifically, regarding the Dutch maritime agenda on the prospective vision of the North Sea in the coming decades, nature conservation is a driving factor in restricting economic activities to multi-use and co-location to ensure that the expanding maritime economic sectors find synergies and do not consume the natural landscape (Figure 12).

Figure 12 Surface occupied by the maritime sectors



Source: Future of the North Sea. The North Sea in 2030 and 2050: a scenario study (Matthijsen et al., 2018)

The global production of farmed aquatic plants, such as seaweeds has grown tremendously from 1995 (i.e. 13.5 million tonnes) to 2016 (i.e. over 30 million tonnes). Around the globe the demand for seaweed hence its production is growing due to its health benefits such as providing numerous vitamins and minerals, containing a variety of protective antioxidants, and iodine and tyrosine which support thyroid functions. The varied uses of potential seaweed grown offshore, therefore, depend on the strains being cultivated and vary depending on the quality and potential end-user. A study done by FAO[24] showed that the development of a small seaweed farm depends on the size of such an endeavour with the price decreasing as the scale grows. Furthermore, local legislation, environmental conditions, and regulations dictating the types of structures required for installation, such as anchoring systems, have a significant impact on cost. These total costs can vary between 159.88 € (for a 320 Line farm) and 233.95 €[25] (for a 480 Line farm). Specific to the North Sea, WUR has conducted a study (van den Burg et al., 2016)

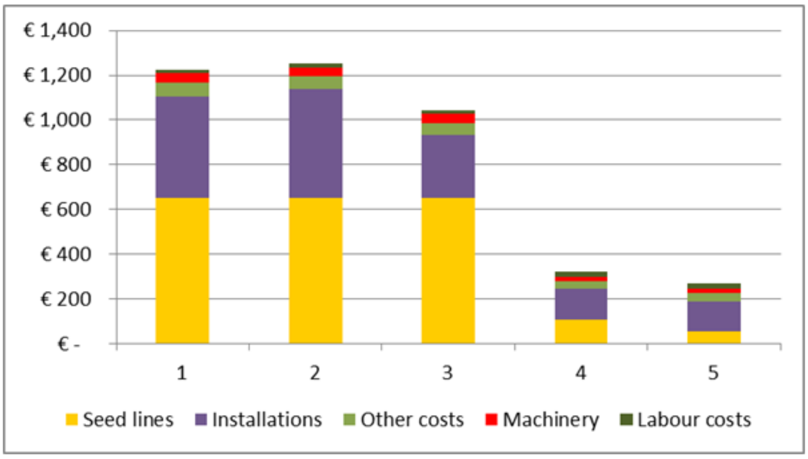
[24] https://www.fao.org/3/AC287E/AC287E03.htm

[25] Costs were given in USD and converted to EUR using USD/EUR 0.86 conversion rate

on the economic feasibility of seaweed production in the North Sea. The fixed cost (that includes the installation of seaweed production) is estimated at 119 031 € per ha (including elements that do not need yearly replacement such as base-lines, buoys, mooring, and other equipment), the labour cost is estimated at 360 € per ha, the harvesting cost at 2466 € per ha, the material cost at 11903 € per ha, the maintenance cost at 595 € per ha, and insurance cost at 603 € per ha.

A joint study (Groenendijk et al., 2016) of five applied research institutes, ECN, TNO, WUR-DLO, Marin, addressed several grow out scenarios for commercial cultivation of seaweed in the Dutch portion of the North Sea. They have compared the total estimated costs to produce seaweed with the economic revenue of the seaweed products. Production costs, likewise, cited by FAO, are strongly scale dependent. For the cultivation of Saccharina latissimi, five scenarios have been addressed with costs varying from 1.230 € per ton FW (= 9.400 € per ton DW) to 270 € per ton FW (= 2.050 € per ton DW) as reflected in the figure below from the cited report.

*Figure 13- Cost structure of large scale Saccharina latissama production in five different scenarios (in €/ton FW) **Source IMARES C055/16***



For the production of Ulva sp. the total costs of production ranged from 920 € per ton FW (= 4.400 € per ton DW) to 570 € per ton FW (= 2.700 € per ton DW). The potential profits of the production chains depend heavily on the degree of use of the seaweed, whether it is processed to extract proteins consumption, processed through bio digestion for biofuels, or other end-products. Therefore, the profit structure is difficult to accurately assess for the activities within the Dutch pilot, however the active seaweed partner, The SeaWeed Company, has provided a short summary of production costs for production lines as seen in the following summary for a cost breakdown (OPEX) (Table 6):

Table 6 OPEX cost breakdown of seaweed production in Dutch Waters as realized by UNITED SME partner The Seaweed Company

Cultivator system (2 spar buoys - 3/4 nets of 50m in between) - # of systems in brackets	**y1 (5)**	**y3 (20)**	**y10 (500)**
Seeding	€ 40.060	€ 207.180	€ 3.669.318
Deployment	€ 75.901	€ 188.104	€ 3.786.323
Monitor&Maintain	€ 90.079	€ 312.005	€ 2.205.917
Harvest	€ 107.499	€ 292.964	€ 6.819.179
Clean&Store	€ 25.600	€ 88.100	€ 1.765.000
Grand Total	**€ 339.139**	**€ 1.088.352**	**€ 18.245.737**
Cost price per kg wet (Eur /Kg)	€ 11,30	€ 4,03	€ 1,52

In May of 2021, a report by Golroodbari et al. (2021) has been published on the feasibility and economics of integrating a floating solar farm in the context of Dutch coastal waters addressing the potential revenue streams for energy production. The energy market system is complex, and many factors influence the energy price, notably the winter of 2021 has seen a European-wide energy crisis, notably seeing energy and gas prices skyrocket in The

Netherlands. To have a better calculation of revenue potential in the face of considerable fluctuations, the average annual energy prices based on the Amsterdam Power Exchange (APX) market, now part of the European Power Exchange (EPEX) can be used, and the average values are 52.97.8 € per MWh and 39.96.4 € per MWh for peak and off-peak prices, respectively, for the years 2010-2018. Of note in the Netherlands is that the cost of the grid connection of offshore wind farms and energy production is considered a social cost, therefore the government is willing to pay to facilitate the generation of offshore energy. In the Netherlands, there are currently no subsidies specifically designed for offshore floating solar systems, however, there have been subsidies granted for renewable energy production in the past. The Golroodbari et. al. (2021) study's economic analysis showed that the profitability of integrating floating solar within wind turbine parks is dependent on two major factors: the limited increase in energy production relative to wind turbine parks and the costs of the solar system. The primary recommendation to increase viability is to increase the amount of solar power delivered to the grid while decreasing the currently inhibitive combined costs of the floating solar installation construction, installation, and maintenance.

3.5. Evaluation and Control

The Dutch pilot has two main objectives:

- To help industries develop large-scale offshore solar farms through UNITED and address important bottlenecks that impede such implementations; and
- To help OWF owners develop large-scale offshore seaweed farms in existing wind parks and develop new OWFs offering integrated wind/aquaculture activities in the tender phase.

The Dutch pilot is highly influenced by many external/internal factors. Several economic, political, social, technological, and legal factors were identified as negatively influencing the Dutch pilot.

The main influencing factors are related to:

- Political factors: there is a lack of procedures & regulation as multi-use in offshore wind farms is a new business. First steps are taken towards a uniform approach, but this still must be developed further.
- Environmental factors: where the risk of increased pollution events (mainly excessive nutrient load and other substances) due to the installation of aquaculture cages may negatively influence the Dutch pilot.
- Economic factors: the pilot is facing high costs of installation, insurance, maintenance, and decommissioning. Also, the revenues of the pilot are highly influenced by the political decisions of the Dutch government. This was observed during the COVID-19 pandemic where the lockdown negatively influenced the sales of the pilot and led to the decrease in sales of the products and the missed two harvests of seaweed because of travel limitations.
- Technical factors: safety issues related to the deployment of the different operational activities (seeding, growing, harvesting, and processing) could negatively influence the Dutch pilot.

Regardless of the negative influence, the pilot is managing to create, capture, and deliver value. This could be seen from the business model canvas of the pilot

Finally, it is still early to evaluate if the pilot is going to reach its objective or not. The pilot is still in the development phase and didn't reach the targeted TRL yet. However, the pilot can start by taking advantage of all its strength and opportunities so that it can develop strategies to overcome the threats.

3.6. Conclusion

The Dutch pilot aims to contribute to the 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 test site is located in the Dutch part of the North Sea, 12 kilometers offshore, of the coast of The Hague.

The business analysis of the Dutch pilot presents a general overview of the pilot from a business and financial perspective and all the external/internal factors influencing it. As the research activities in the pilot continue, the business-related results represent only the current situation. The results are based on already published UNITED deliverables, expert interviews, workshops, and scientific literature. Generally, many positive aspects can be associated with the multi-use project. These included financial benefits stemming from the reduced costs (e.g. using some bought for maintenance and/or harvest) when pursuing multi-use instead of single-use projects, even though the financial benefits would need more quantitative data evidence. But there are also other opportunities and benefits apart from the financial side. These can include environmental and societal aspects (e.g. solar panels' potential in reducing the intensity of waves through the wave dampening effect, which is potentially beneficial for the safety of seaweed cultivation on the plot).

Nevertheless, there are several threats and weaknesses associated with the multi-use project. Most of them refer to technical, political, and environmental aspects resulting from the novelty of the multi-use approach and the absence of proof of concept.

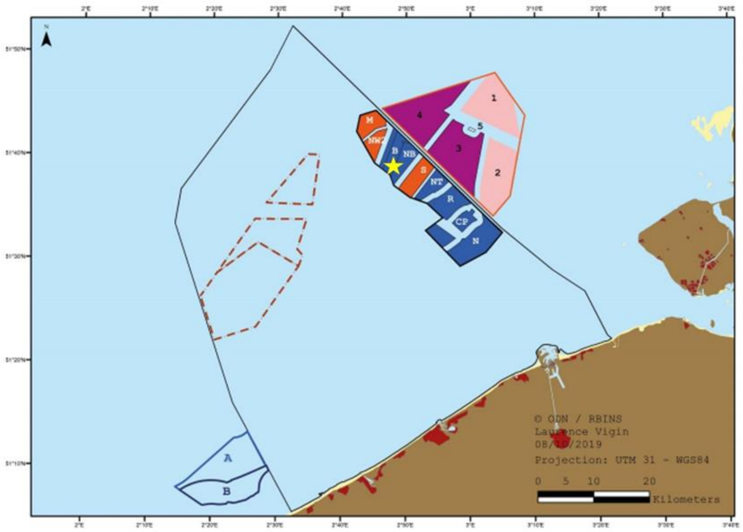
To conclude, more investigation is still needed. More proof of concept needs to be shown, especially from a financial aspect, to determine the feasibility of multi-use. This will be done in the next phases of UNITED.

4. BUSINESS ANALYSIS OF THE BELGIAN PILOT

4.1. Background

The Pilot is situated in the Belgian part of the North Sea (BPNS), more specifically in the offshore wind farm of Belwind, operated by Parkwind (Figure 14), and combines three different activities: offshore wind energy, European flat oyster (*Ostrea edulis*) aquaculture and reef restoration, and seaweed (*Saccharina latissima*) cultivation (UNITED, D7.2).

Figure 14 Belgian part of the North Sea with realised and planned offshore wind farm concessions – the approximate position of the Pilot site is indicated by the yellow star – Figure taken from the WinMon report



4.2. Defining optimized business cases

4.2.1. Mission and vision statements

Mission statement

The pilot aims to enhance the conceptual design and implementation methods of marine aquaculture activities in OWFs and specifically flat oyster culture and oyster reef restoration as well as seaweed culture.

Vision statement

Belgian offshore wind farms offer a unique environment to interactively restore oyster reefs and develop aquaculture. The hard substrate used as scour protection around wind turbine foundations may be the perfect substrate for oyster larvae to settle on and initiate natural oyster reefs. In addition, bottom fishing is not allowed in wind farms and therefore oyster reefs would thus not be damaged by these activities.

It is believed that aquaculture activities should be developed hand in hand with restoration efforts, as the two activities enhance each other: in the short term, aquaculture can provide the initial stocking material to help develop natural reefs and, in the long term, once the natural oyster reefs are established, the latter can provide oyster larvae to the aquaculture sector that set naturally on spat collectors.

The "safe" environment of the OWF is equally interesting for another extractive aquaculture activity, being the culture of seaweed. The environmental characteristics such as lower temperature, lower turbidity, and less fouling may offset the negative impact of strong currents and waves. This way, OWF can evolve to locations where ecosystem services are fully exploited by, amongst others, removing excess nutrients upon harvesting the oysters and seaweed and enhancing biodiversity.

4.2.2. Objective of the Belgian pilot

The Belgian pilot has two main objectives. The primary objective is to evaluate OWFs as a suitable location for restoring native flat oyster reefs in combination with culturing flat oysters and seaweed for human consumption (UNITED, D1.2). To reach the primary objective, different activities need to be undertaken such as:

- Identifying suitable zones for the restoration of flat oyster reefs in offshore wind farms;
- Demonstrating the feasibility of developing scour protection material that meets technical requirements while fostering the development of small oyster reefs, which might ultimately form a network of small oyster patches spanning several square miles;
- Developing a longline for the production of flat oysters in open sea conditions;
- Developing a longline for the production of seaweed in open sea conditions;
- Identifying spat collectors and grow-out systems for offshore cultivation of flat oysters;
- Identifying net types and seaweed strains suited for grow-out in the Belgian part of the North Sea
- Developing a monitoring scheme to monitor flat oyster growth in the function of the change in the environmental parameters;
- Optimising the flow of communication and planning between the different activities to enhance the installation and data collection efficiency; and
- Identifying the existing synergies between (oyster reef) restoration, aquaculture, and the production of wind energy.

The secondary objective of the Belgian pilot is to compare the growth of sugar kelp cultivated offshore and nearshore (UNITED, D1.2). To this end, a longline system has been designed to attach seeded algal material. Morphological and nutritional characteristics are known to be influenced by the dynamics of the environment and may offer opportunities to culture seaweed for specific purposes. Activities in the pilot are divided into three different phases (UNITED, D1.2)[26]:

[26] Note: The objective of this section is not to repeat information already mentioned in previous deliverables of the UNITED project. For additional information on each operational phase, the reader can always refer to D1.2 of the UNITED project: "Report on the state-of-the-art implementation of an integrated pilot approach".

- Pre-operational phase: testing of different aquaculture systems nearshore. In this phase, different aquaculture systems will be tested at a nearshore site. The nearshore site will be used for testing different types of aquaculture equipment for flat oyster and sugar kelp and testing nature-inclusive[27] scour protection. The best performing set-up will be selected and applied in the operational phase at the offshore site – the Belgian pilot is located in the Belgian part of the North Sea, more specifically in the Offshore Wind Farm (OWF) of Belwind.
- Operational phase: testing of selected aquaculture system offshore. The operational site is chosen based on the specific requirements for flat oyster and sugar kelp growth. The oyster restoration structures for the Belgian pilot were installed in the summer of 2021, while the aquaculture longlines will be installed in the spring of 2022.; and
- Post-operational phase: decommissioning of the pilot. This concerns the removal of all the structures installed at sea, including the screw anchors, longlines, buoys, aquaculture systems, restoration tables with oysters, and seaweed nets.

Flat oyster aquaculture and restoration and seaweed cultivation are being tested in the pre-operational phase at the Westdiep nearshore site, five kilometres off the coast of Nieuwpoort. Results of these tests have been used for the design and adjustment of the aquaculture systems planned for the offshore operational phase, at the Belwind OWF site, located 49 km from shore in the North Sea[28]. Following the German pilot procedure, the aquaculture system's technical components will be purchased off the shelf and then mixed and matched to the environment at the final site. Implementation will be done in collaboration with a specialised company that has installed these anchors and longlines in different places in the world, also for commercial purposes.

4.2.3. Pilot owners and stakeholders

Different stakeholders are engaged in the activities of the Belgian pilot. Two groups of stakeholders could be identified: the internal stakeholders and the external stakeholders (UNITED, D3.1). The internal stakeholders are directly involved in the Belgian pilot and/or in the UNITED consortium and include (see Table 7):

- Scientific institutes: Ghent University, and Royal Belgian Institute of Natural Sciences (RBINS);
- Businesses: Colruyt Group and Brevisco; and
- Offshore Industry: Parkwind, and Jan De Nul Group.

Table 7 Internal stakeholders involved in the Belgian Pilot (adopted from D3.1 of the UNITED Project).

Stakeholder	Role	Interest	Contact
Ghent University	Pilot Lead	All research results	Nancy.nevejan@ugent.be; Andclerc.declercq@ugent.be
Jan De Nul Group	Responsible for technical functioning offshore, designing structures offshore, designing restoration structures or other solutions	Results on technical solutions	project.united@jandenul.com
Brevisco	Responsible for technical functioning nearshore	Results on aquaculture production	Stephanie@brevisco.be

[27] Nature-inclusive design refers to options that can be integrated in or added to the design of an offshore wind infrastructure to create suitable habitat for native species.
[28] https://parkwind.eu/projects/belwind

Parkwind	The operator of the offshore wind farm, insurance	Applicability of multi-use of space	Dirk.Vandercammen@Parkwind.eu elisabete.pintodasilva@parkwind.eu
Colruyt Group	Life Cycle Analysis, economics	Possibility of producing oysters and upscaling feasibility	laura.pilgrim@colruyt.com
RBINS	Biological studies, ecological implications	Research results	Sdegraer@naturalsciences.be tkerkhove@naturalsciences.be

The external stakeholders are not directly involved in the activities of the pilot. They are considered potential users of project outcomes. The external stakeholders include Non-Governmental Organisations (NGOs) like the World Wide Fund for Nature (WWF) and Natuurpunt, authorities like the Management Unit of the Mathematical Model of the North Sea (MUMM), governmental bodies such as the Ministry of the North Sea and Directorate-General of the European Union Commission (DG Environment), business groups like the ship owners for fisheries, Blue Cluster, and Belgian Offshore Platform, and scientific institutes such as Flanders Marine Institute and the European Marine Biological Resource Centre Belgium.

4.2.4. Technologies and services provided by the Belgian pilot

The main services provided by the Belgian pilot are the production of renewable energy, the production of local aquaculture products, and the delivery of ecosystem services. The OWF of Belwind is operated by Parkwind and comprises a total of 56 wind turbines with an overall installed capacity of 171 MW. The production of local aquaculture products and seaweed cultivation will be done in the same location (UNITED, D3.1). The design of the offshore longline for flat oyster and sugar kelp will be designed by numerical analysis using an in-house tool, "MoorDyn-UGent", which is based on a lumped mass approach developed by the MTD-UGent team (UNITED, D1.2).

Oyster spat collection and grow-out of the oyster system is being developed by the UGent Laboratory for Aquaculture and Artemia Reference Centre, while the investigation of the best growth options for sugar kelp is done by the Phycology Research group of UGent. Several scour protection materials are being tested with the help and experience of Jan De Nul (a partner of UNITED). The key significance lies within the choice of the right material and the conceptual design of the construction in an offshore environment. Another important aspect to pinpoint are systems for disease monitoring, which will be a joint task of UGent Laboratory for Aquaculture and Artemia Reference Center and RBINS teams. Moreover, the optimization and scheduling of logistics, such as distribution and harvesting, transportation as well as maintenance work, needs to be planned in detail (UNITED, D1.2).

4.2.5. Combined activities and expected synergies

The Belgian pilot combines three different activities: offshore wind energy, European flat oyster (Ostrea edulis) aquaculture and reef restoration, and seaweed (Saccharina latissima) cultivation.

One of the goals of the pilot is to identify synergies between the different activities and develop a business model as the output of the project. The synergies expected are (UNITED, D1.2):

- Synergies in the relocation of ships for the maintenance and surveillance of wind turbines, restoration, and aquaculture activities;
- Synergies in the use of service vessels and their crew: used for installation and decommissioning of aquaculture and restoration infrastructure;
- Synergies in the use of port facilities;
- Synergies between oyster aquaculture activities and oyster restoration efforts; and
- Synergies between OWF infrastructure and oyster restoration efforts.

Finally, the Belgian part of the North Sea is mainly characterised by a sandy bottom, with a few gravel beds. These hard-substrate gravel beds are strongly degraded, threatening their associated biodiversity. The introduction of the OWFs in this part of the North Sea is creating an artificial habitat for hard-substrate biodiversity. This allows the reintroduction of native species such as the flat oyster and the restoration of the associated biodiversity.

4.2.6. TRL level of the Belgian pilot

The current technology readiness level (TRL) of the Belgian pilot is between 5 and 6 which could be defined as: "Technology validated and demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)" (UNITED D3.2 and D7.2). The individual TRL level of OWFs operated by Parkwind is TRL 9. The other activities are currently being tested in the pre-operational phase of the pilot.

4.2.7. Strategic roadmap to reach targeted TRL level

The Belgian pilot has the potential to reach TRL 5 to 6 by the end of the UNITED project. To achieve that, several technical and other aspects and research questions that the pilot needs to address, including (UNITED, D3.1):

- Identifying and delivering basic biological material;
- Understanding biosecurity measures concerning the imports and production of seaweed spores and flat oysters;
- Identifying the optimal offshore gear (grow-out systems, longlines, scouring materials, seed collectors, holding systems, restoration structures);
- Optimizing the communication and timing between the different activities to improve the efficiency of the installation and data collection;
- Developing a business case and financial analysis of the integrated offshore wind and aquaculture activities;
- Monitoring of oyster growth and oyster spat, biodiversity changes on added substrates, fouling organisms, and seaweed growth, and quality differences between nearshore and offshore cultivation;
- Extracting data on water quality variables (chlorophyll-a, suspended solids, temperature, irradiation) from remote sensing, nearby buoys, and OWF monitoring campaigns;
- Developing a predictive model for the recovery of flat oysters in the Belgian part of the North Sea;
- Developing a predictive model for the growth of flat oysters in aquaculture systems in the Belgian part of the North Sea;
- Scoring the ecosystem services of oyster reef restoration; and
- Identifying suitable areas for oyster reef restoration in offshore wind farms.

4.3. Identifying risks and barriers

4.3.1. PESTEL analysis

The development of the Belgian pilot is influenced by several external factors. Information concerning the external factors was collected by conducting interviews with partners working directly within the pilot, , Colruyt and Parkwind.

Political conditions

- **Political support.** The Belgian political decision-makers are pushing to have other activities in OWF to have more aquaculture activities and to take advantage of the existing space. For that, there is an upcoming political tendency to advocate the multi-use of marine space. This is seen in the new Belgian Maritime Spatial Plan (MSP 2020-2026) that requires the new offshore wind farms to include other activities including extractive aquaculture, passive fisheries, and other renewable energy activities (UNITED, D1.2).

Economic conditions

- **High costs.** High installation (including equipment and vessels), maintenance, insurance, and decommissioning costs (UNITED, D1.2).
- **Increase in prices of the products and services due to the COVID-19 pandemic**. Adding to that, during the COVID-19 lockdown a lot of restaurants and catering services were obliged to close which had an impact on the sales of oysters and seaweed.
- **Existing market for renewable energy**. High social demand for implementing more renewable energy such as OWFs. This high demand is positively reflected in the activity of the pilot.
- **Existing market for locally produced products**. After the COVID-19 pandemic, consumers have new preferences to buy more locally produced products.

Social conditions

- The local community is now more aware of the need to have more sustainable products and clean/green energy.
- **Developing preference for locally produced products.** Consumers prefer to buy more locally produced products.
- The pilot has high social acceptability due to the local and sustainable aspects it gives to the final consumers.

Technological conditions

- A numerical tool "MoorDyn-UGent" for the design of the offshore longline for flat oyster and sugar kelp is available (UNITED, D1.2).
- Development of monitoring activities will be done in the upcoming years. The development includes automation of the monitoring activities of the pilot and will improve the work of the pilot and allow cost reduction[29].
- Technology improvement allows having a greater distance between turbines[30]. The greater distance between the turbines gives more space for aquaculture activity and optimizes the installation of aquaculture lines[31].

Environmental conditions

- Climate change. Climate change likely increases the frequency of storms and bad weather[32]. An increase in the frequency of storms will make it difficult to develop the pilot activities and to plan trips of maintenance and monitoring.
- Ocean acidification. An increase in the levels of ocean acidification might lead to the deterioration of the habitats which will harm the oysters and seaweeds activities.
- Attraction of birds by the aquaculture installations increases the risk of collision and bird mortality.

[29] The cost reduction is due to fewer boat trips to collect monitoring samples.
[30] The new turbines are larger, so the distance between the turbines must be greater.
[31] Currently, in the BE pilot, the lines installed for the aquaculture activity are short lines. With the larger OWF and with greater distance between turbines (the improved technology), longer aquaculture lines will be installed. This will facilitate the cultivation of seaweed and oysters.
[32] https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_11.pdf

Legal conditions

- **Difficult to obtain permits**. Approval from the concession holder is required. This regulation might change in the future with the introduction of the new Belgian Marine Spatial Planning that recommends having aquaculture activities within the OWFs[33].
- **EIA requirements.** The development of OWFs and aquaculture activities requires an Environmental Impact Assessment (EIA) trajectory as commercial exploitation in the future will have to conduct an EIA.
- **EC Directive requirements.** The EC Directive 2006/88/EC on animal health requirements for aquaculture animals and products thereof, and the prevention and control of certain diseases in aquatic animals require companies operating in aquaculture activities to conduct food testing before putting it on the market for final consumers. This directive was transposed into Belgian law by the authorities.

4.3.2. Business Model Canvas

The Belgian pilot has four activities: offshore wind farm, flat oyster aquaculture, reef restoration, and seaweed cultivation. Here the flat oyster aquaculture and reef restoration, and seaweed cultivation are taken together in one Business Model Canvas as they are closely related in almost all the building blocks. The information related to the nine building blocks of the Business Model Canvas analysis of the three activities is presented below respectively.

The following matrix (Figure 15) presents the information obtained for the nine building blocks of the business model canvas on the offshore wind farm. The information was collected by interviewing the OWF operator, Parkwind.

[33] Note: the new MSP recommends and encourages multi-use activities in OWFs, yet it is not clear yet how it will be applied.

Figure 15 Business Model Canvas analysis – Offshore wind farm of Belgian pilot

Business Model Canvas				
Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
• Grid owner; • Cable supplier; • Foundation supplier; • Wind turbines supplier; • Grid infrastructure supplier; • Cable installation supplier; • Foundation installation supplier; • Transport/vessel supplier	• Production of offshore wind energy	• Clean/green energy for final consumer	• Sharing information with society via the Belgian Offshore Platform that shows how much electricity was produced. Pilot activities are not directly communicated with the final consumer.	• Off-takers[34] that buy the electricity from the pilot and resell it to final consumers
	Key Resources		Channels	
	• Company engineers; • Collaboration with off-takers; • Good relationships with maintenance suppliers		• Direct communication with off-taker	
Cost Structure			Revenue Streams	
• Installation cost; • Operation and maintenance cost; • Decommissioning cost			• Selling electricity to off-takers; • Offering grid balancing services; • Subsidies from the government.	

The following matrix (Figure 16) presents the information obtained for the nine building blocks of two activities: flat oyster aquaculture and reef restoration, and seaweed cultivation35. The information was collected by interviewing Colruyt.

[34] The off-takers buys the electricity produced by the OWF and sell it to final consumers.

[35] The flat oyster aquaculture and reef restoration (orange font), and seaweed cultivation (green font) are represented in one matrix (note: blue font represent the similarities between activities).

Fure 16 Business Model Canvas analysis –Flat oyster aquaculture and reef restoration (in yellow), and seaweed cultivation activities (in green) of Belgian pilot (in blue – the common information for both activities)

Business Model Canvas

Key Partners

- Suppliers of oyster spat,
- Suppliers of starting material for seaweed,
- Concession holder,
- Companies owning/operating boats,
- Processer and packager,
- Food distributing and selling,
- Waste treatment,
- Suppliers of materials for installation & maintenance,
- Supplier of boats,
- Supplier of processing and packaging lines

Key Activities

- R & D and concept design,
- Installation,
- Maintenance,
- Harvest,
- Decommissioning & Monitoring,
- Processing,
- Packaging,
- Distribution & Transportation,
- Marketing,
- Sales B2B & B2C

Key Resources

- The wind farm owns the concession and allows the aquaculture to install lines,
- Operational business in house,
- Own processing lines and distributions,
- Own boats,
- Short-chain,
- Monitoring & Automating,
- Qualified staff

Value Propositions

- Local oyster production,
- Local seaweed production,
- Nutritional value of seaweed (pharmaceuticals),
- Alternative protein sources,
- Ecosystem services (valuation of ecosystem services will be done in future deliverables of UNITED),
- Lower environmental impacts,
- The reverse of eutrophication,
- CO2 sequestration,
- Possible Bio certification

Customer Relationships

- Marketing channels,
- Feedback system,
- Personal contact

Channels

- Restaurant website,
- Folders of retailers,
- Social media,
- Staff in shops and restaurants,
- Local products promotion,
- Education of consumers
- Both B2B & B2C

Customer Segments

- Micro segment (luxury and new product),
- Macro segment (as an ingredient in the food)

Cost Structure

- Oyster spat,
- Starting material for seaweed
- Insurance cost,
- Maintenance cost,
- Concession cost,
- Material installation cost,
- Processing & Packaging,
- Personnel at sea,
- Cost on the boat (90% of total),
- Cost of onshore building
- Decommissioning cost

Revenue Streams

- Sales of seaweed for other purposes (e.g., feed, biomass, pharmaceuticals),
- Sales of food products & by-products
- Monetarization of ecosystem services
- Subsidies from government

To know how the Belgian pilot creates, captures, and delivers value, it is recommended to compare the similarities and differences between the three activities. From the above matrixes (Figures 15 & 16) and previous deliverables, it could be noted that similarities between the different activities of the Belgian pilot lead to several synergies that are related to a) cost reduction, in particular in the monitoring cost (monitoring of wind turbines, and restoration and aquaculture activities), and the transportation cost (the combination of several activities in one location allows the use of the same service vessels and their crew); b) the use of the same port facilities; and c) the use of the same infrastructure by the OWF and the aquaculture activity.

Hence, the combination of activities leads to benefits for the different parties engaged in the pilot. The benefits are translated into monetary gains resulting from the economies made in the transport vessels, the decommissioning cost, and the monitoring activity. Considering the differences, the Business Model Canvas matrix of the pilot is composed of different key activities with different value propositions to the final consumer and targeting different customer segments.

4.1.3. SWOT analysis

The following matrix (Figure 17) presents the SWOT analysis of the Belgian pilot.

Strengths

One of the main strengths of the Belgian pilot is the cost reduction for each activity due to the existing synergies between the different activities, for oyster production and seaweed cultivation. Furthermore, the combination of several activities leads to various and robust sources of revenue. Other strengths for the pilot also exist, such as a) strong marketing story concerning the sustainability, b) improvement in ecosystem services – this can bring extra sources of revenue because of an enhancement in the biodiversity, or an increase in the tourism activities for example – and c) the various partners with expertise in engineering, sustainability, and offshore wind energy.

Weaknesses

There are several **weaknesses** such as a) the dependence on the occurrence of storms, b) the high cost of transportation due to the location of the pilot – far from the coast -, c) high maintenance and insurance costs, and d) no revenues from ecosystem services.

Opportunities

The **opportunities** for the Belgian pilot are various and could be divided into three main categories: political, technological, and social. For the political, the Belgian pilot has an opportunity to develop more activities in the same location where it operates. This is due to the new Belgian marine spatial plan that requires that the new zone for energy production needs to be coupled with other/extra activities. For the technological opportunities, the Belgian pilot can take advantage of the new developments in antifouling techniques, and the developments happening in the automation of activities at sea, for monitoring activities. This will help the pilot to better operate and reduce its costs. Finally, for the social opportunities, there is now a new trend to buy more local products. This trend might lead to an increase in the sales of the pilot. Furthermore, the pilot can valorise the by-products with pharmaceutical companies as they are rich in protein.

Threats

The **threats** facing the Belgian pilot can be divided into political, market dependency, and others. For the political threats, the EC Directive (2006/88/EC) on animal health requirements for aquaculture animals and products thereof, and the prevention and control of certain diseases in aquatic animals[36] require extensive food quality testing which is very costly. Also, upscaling of aquaculture activities from scientific projects to commercial projects needs the acquisition of a permit and going through the EIA procedure. As for the market aspect, the market for flat oysters is relatively limited, in comparison to the market for Japanese oysters, and is mostly concentrated during the end of the year, which poses challenges for processing. The seaweed market is very new in Europe, and consumers may not be familiar with such products. As for the dependency aspect, the pilot is dependent on various factors such as a) on concession holders; b) on the boat operator or processor if not in the house; c) on delivery of oyster spat or starting seaweed material; and d) on good weather, as it is not possible to do maintenance or

[36] Transposed into Belgian law by the FAVV, EIS, and FOD.

harvest when weather is not good enough or too unpredictable. Regarding other threats, climate change such as the increasing occurrence of big storms, acidification, increase in sea surface temperature. There are inherent safety and security risks at sea. In addition, there is uncertainty about the future of (monetarization of) ecosystem services. One final threat is the disease outbreak in oysters and seaweed. Both can get sick because of viruses and bacteria which influence the quality of the products for several years.

Figure 17 SWOT analysis – Belgian Pilot

Strengths:

- Synergies between different activities could reduce cost of each activity individually
- Combination of multiple activities means multiple streams of revenues, which can make the pilot more robust
- Strong marketing story in relation to sustainability
- Ecosystem services might bring in extra money
- Partners with expertise in engineering, sustainability, offshore, aquaculture, product quality, market insights

Weaknesses:

- Harvest and structures itself are dependent on the occurrence of (big) storms
- The wind parks are relatively far from the coast, which increases the cost per boat trip and fuel use
- Oysters are high-maintenance products due to need for anti-fouling
- High insurance cost because of new activity and because of combination with wind energy
- Currently no revenues from ecosystem services like restoration of oyster reefs

Opportunities:

- New Belgian Marine Spatial Plan: new zone for energy production has strict condition that it needs to be coupled with extra activity
- New developments in antifouling techniques
- New developments in automation of activities at sea
- New developments in robust, offshore materials
- Strong tendency to buy locally
- Strong tendency to buy more sustainable products
- Shift towards alternative protein sources
- It is prohibited for fisheries and other vessels to enter the wind parks, which makes it a suitable zone for restoration and aquaculture
- Success of Belgian hatcheries and oyster reef restoration to ensure qualitative spat of oysters

Threats:

- Disease outbreak – oysters getting sick because of viruses and bacteria's.
- Offshore location is highly dynamic environment, which poses a risk for loss of product or materials
- Regulations (FAVV, MER): Environmental Impact Assessment could pose limitations; FAVV: required quality testing is very extensive, sampling has high cost
- Market for flat oyster is relatively limited in comparison to market for Japanese oyster
- Market for flat oyster is mostly concentrated during the end of the year, which poses challenges for processing
- Market for seaweed is very new
- Dependency on concession holders
- Dependency on boat operator or processor if not in-house
- Weather dependency: not possible to do maintenance or harvest when weather is not good enough or too unpredictable (weather poses a risk to the structures)
- Dependency on delivery of oyster spat or starting material for seaweed
- Climate change: increasing occurrence of (big) storms, acidification, & increase in sea surface temperature
- Uncertainty of the future of (monetarization of) ecosystem services
- Inherent safety and security risks at sea

4.4. Financial analysis

To present, little information exists on the different costs and revenues of the Belgian pilot activities. This subsection presents the evidence collected on costs and benefits from different sources (e.g. interview with partners involved in the pilot, and literature). The baseline to which the costs and revenues are compared is the single use of OWF. In fact, without the presence of the OWF the aquaculture and seaweed activities would not exist. They benefit from the existing infrastructure to install their activity. From the above sections, notably the Buiseness Model Canvas, a better understanding of the different costs and revenues categories for each activity is given.

For the OWF, from the BMC, the costs are divided into two main categories: a) installation cost, and b) operation and maintenance cost. The installation cost refers to the cost of constructing and putting in place the OWF. This needs to mobilize many workers, as well as different types of vessels. The number of workers and vessels mobilized depends on the type of activity (e.g. installing the foundation, installing cables, etc.), and can vary between 280 to 300 Full Time Employee (FTE) per day. The cost of vessels ranges between 5 000 € per day and 100 000 € per day depending on the vessel (e.g. small or large vessel), and the type of activity[37]. Additionally, evidence exists in the literature that provides information on the costs to install and operate an OWF, for example, IRENA (2019) estimated the cost of installing a 9 MW OWF at 30 million Euros (approximately 3 333 € per Kw); another study[38] estimated the cost to range 3 435 € per Kw and 4 293 € per Kw[39] for the year 2016. Finally, Synder and Kaiser (2009) compiled data on the costs of an offshore wind farm built in Europe and estimated the installation cost for OWF to range between 1 255 € per Kw and 6 011 € per Kw[40] for the year 2008. For the operation and maintenance costs, which corresponds to the cost to operate the OWF, Fingersh et al. (2006) estimated the cost to operate an OWF, with a 3 MW installed capacity, at 18 4615 € per year.

The revenues of the OWF are mainly related to selling electricity produced by the OWF to off-takers. The revenues received for the Belwind OWF is roughly 30 € per MWh with a governmental subsidy equal to 107 € per MWh (note: the figures are fixed by the Belgian regulations[41]). Knowing that the electricity production of the Belwind OWF is almost 550 GWh per year (approximately 550 000 MWh per year), the revenues of the OWF could be roughly estimated at 75 million Euros per year.

Besides the cost of putting in place OWF, the Belgian pilot is facing other costs related to the installation and harvest of seaweed and oysters. Different cost categories exist including the installation of longlines, the cost to install nets, personnel costs, etc. Estimates and evidence exist in the literature. Concerning the starting material of seaweed, according to a study done by FAO[42], the investment needed to start a small seaweed farm depends on the size of the seaweed farm. The cost depends on different materials considered necessary to start the seaweed farm. The total cost varies between 159.88 € (for a 320 Line farm) and 233.95 €[43] (for a 480 Line farm). Also, van den Burg et al. (2016) investigated the economic feasibility of seaweed production in the North Sea and estimated the costs related to fixed cost at 119 031 € per ha, the labour cost at 360 € per ha, the harvesting cost at 2 466 € per ha, the material cost at 1 1903 € per ha, the maintenance cost at 595 € per ha, and the insurance cost at 603 € per ha.

According to the information collected from the UNITED partners, the annual revenues from oyster sales is estimated at 149 400 € per plot per year considering that only a part of one oyster plot is harvested because of the thinning process; the revenues for the seaweed activity is estimated at 64 000 € per plot per year.

From the information collected and presented in this section, cost savings and monetary gains are only noted for the aquaculture and seaweed activities. The cost savings are translated by the use of the same vessels used to do the installation and maintenance work for the OWF. For the OWF, the cost savings are very minimal and do not

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[37] The information concerning the number of employees and vessels mobilized was communicated by ParkWind – partner responsible of installing the OWF of BE pilot.

[38] https://www.windpowermonthly.com/article/1380738/global-costs-analysis-year-offshore-wind-costs-fell

[39] The figures in the study were given in USD and were converted to EUR using USD/EUR 0.86 conversion rate.

[40] The figures were estimated in USD and were converted to EUR using USD/EUR 0.86 conversion rate.

[41] https://cms.law/en/int/expert-guides/cms-expert-guide-to-offshore-wind-in-northern-europe/belgium

[42] https://www.fao.org/3/AC287E/AC287E03.htm

[43] Costs were given in USD and converted to EUR using USD/EUR 0.86 conversion rate

have any real monetary gain from the combination of activities. There are no significant direct impacts on costs or revenues that were identified.

From the information presented in this section, it is still difficult to evaluate the financial performance of the pilot and compute financial metrics such as the NPV and the ROI. Further investigation on the different costs and revenues of each activity of the pilot is still needed. This will be done in a future deliverable (Deliverable 3.3 of the UNITED project).

4.5. Evaluation and Control

The Belgian pilot has two main objectives:

- To evaluate if the OWFs location is suitable for restoring native flat oyster reefs in combination with culturing flat oyster and seaweed for human consumption; and
- To compare the growth of sugar kelp grown offshore and nearshore.

The Belgian pilot is still in the establishment process and did not reach its full functioning capacity. This means the pilot still needs a couple of years to reach the maximum production capacity. For that reason, its capacity to reach the two fixed objectives should be re-evaluated once the pilot reaches its full capacity of functioning.

Nevertheless, the establishment of the pilot is highly influenced by many external/internal factors. These factors are various and may have positive and/or negative impacts on the development of the pilot.

On the first hand, regarding the positive factors, the pilot is positively influenced by the political factors where the new Belgian Marine Spatial Plan requires the new OWFs to include other activities including extractive aquaculture, passive fisheries, and other renewable energy activities. This is seen as insurance for the development of several activities in offshore wind farms, in particular activities related to aquaculture. Also, pushing to have more aquaculture activities within the OWF, by the political decision-makers, is an opportunity for the Belgian pilot to develop its activity.

Adding to the political factors, technological development and improvement will positively influence the development of the pilot. This is true for the aquaculture activity where a) the technology improvement in OWFs and having bigger turbines allows to have more space to install larger lines for aquaculture activities, and b) the automation of monitoring for aquaculture activities leads to cost reduction and gain in time to detect any anomaly. Concerning the environmental factors, they also have a positive influence on the Belgian pilot, especially for habitat creation and restoration. Finally, on the social acceptance, the new consumer trends to consume local products allows an increase in the sales of the pilot and increases the social acceptance of such activities. These factors (political, technological, environmental, and social) are seen as opportunities for the pilot which the pilot needs to take advantage of.

On the second hand, even though the Belgian pilot has several opportunities to develop, several threats exist. These factors are related to:

- Environmental factors: where climate change influence negatively the development of the pilot. Especially with the increase in the frequency of storms and ocean acidification which leads to habitat deterioration and loss of biodiversity.
- Economic factors: the pilot is facing high costs of installation, insurance, maintenance, and decommissioning. Also, the sales of the pilot are highly influenced by the political decisions of the Belgian government. This was observed during the COVID-19 pandemic where the lockdown negatively influenced the sales of the pilot and led to a decrease in sales of the products.
- Legal factors: where the pilot is facing several European and national regulations related to food safety and food quality – which led to an increase in the costs for the pilot.

Financial data is still limited. Further investigation is still needed to determine the feasibility and the financial performance of the pilot. However, from the available data, it was clear that the financial benefits for multi-use cases are relatively small. While they present relatively large benefits for the aquaculture and seaweed activities, the financial benefits do not exist for the OWF which faces a large cost to put in place and operate OWF. Non-financial benefits such as Corporate Social Responsibility might be the reason why OWF engages in multi-use activities.

Finally, it is still difficult to evaluate if the pilot is going to reach its objective or not. As mentioned earlier the pilot is still in the development phase and not fully operational. Yet, the pilot can start by taking advantage of all its strength and opportunities so that it can develop strategies to overcome the threats. Indeed, some of the threats, like environmental threats, are difficult to overcome.

4.6. Conclusion

The business analysis of the Belgian pilot presented a general overview of the pilot, and all the external/internal factors influencing it. The pilot is located in the Belgian part of the North Sea and combines three activities: off-shore wind energy, European flat oyster (*Ostrea edulis*) aquaculture and restoration, and seaweed (*Saccharina latissima*) cultivation.

From the business analysis, it was clear that the pilot is influenced by external factors. This influence could be:

- Positive influence: where technological advancement for example can facilitate the work of the pilot, for the monitoring activities, and leads to cost reduction in the operational costs. Also, the political factors requiring the development of other activities inside the offshore wind farms are seen as insurance for the pilot's existence – the pilot can take advantage of this opportunity to develop more activities that could be related to energy activities or aquaculture activities.
- Negative influence: especially related to the environmental change and to the difficulty in predicting the weather. This makes it more difficult to plan future activities inside the pilot, especially activities related to aquaculture.

Limited information still exists on the financial performance of the pilot. However, from the limited information, it was clear that different factors (e.g. legal, social) motivate the OWF to engage in multi-use activities. To end this case study, more investigations are still needed on the financial aspects of the pilot to determine the feasibility of the pilot and all the benefits and costs of the pilot. This will be done in future deliverables.

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5. BUSINESS ANALYSIS OF THE DANISH PILOT

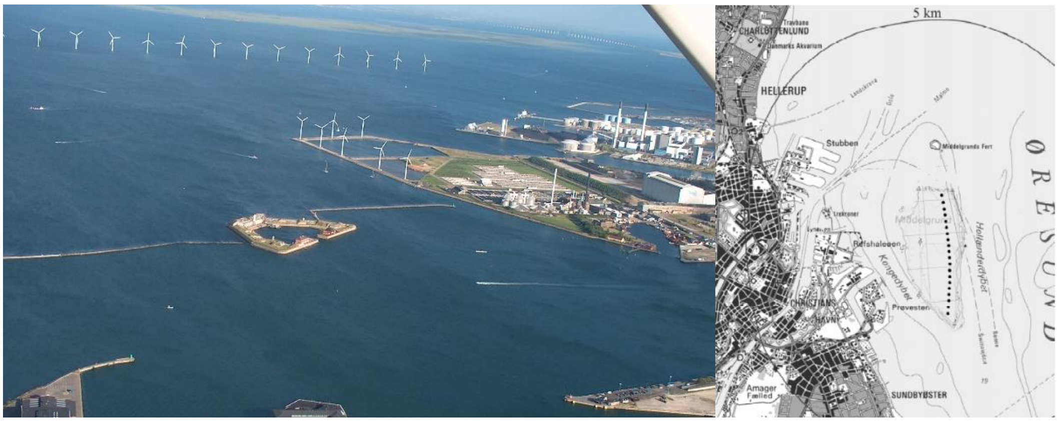
5.1. Background

The Danish pilot was developed in the year 2000 at the reef south of the Middelgrunden island. The pilot is established 3.5 km outside of Copenhagen harbour and combines two main activities: the **production of offshore wind energy**, and **tourism activities** related to visiting the offshore wind farm (Figure 18) (UNITED, D7.2).

Middelgrunden was established on a natural reef with 3 to 6 meters of water depth, 3.5km outside of Copenhagen harbour, in the fall of 2000. It is visible from Copenhagen city and surrounding beaches and tourist points of high value, like The Little Mermaid and the Round Tower. The offshore wind farm consists of twenty 2 MW turbines from Bonus Energy, now Siemens Gamesa Windpower, and is owned 50% by HOFOR (Copenhagen local energy and water supply) and 50% by the Middelgrunden Wind Turbine Cooperative with 8,553 members. It is the largest wind farm in the world based on cooperative ownership.

The wind farm consists of 20 turbines, each with a rated capacity of 2 MW. The maximum height of the wingtip is 102 meters. The electricity production is anticipated to be about 100 GWh a year. The turbines are erected on standard gravity foundations, which are placed on a firm seabed after the upper layer of soft sediment has been removed.

Figure 18 Location of Middelgrunden wind farm outside of Copenhagen harbour, Baltic Sea



5.2. Defining optimized business cases

5.2.1. Mission and vision statements

Mission statement

The pilot mission is to promote the understanding of the role that offshore renewable energies can play in the Danish energy system, by promoting multi-use activities in which tourists have an active role in renewable energy projects.

Vision statement

To make the iconic Middelgrunden Wind Farm (which was voted, in the year 2020, as the second most iconic landmark of Copenhagen by the Citizens of Copenhagen) even more present in the city of Copenhagen.

5.2.2. Objective of the Danish pilot

The key objective of the Danish pilot is to expand the existing tourism activities and the creation of new attractions that results from shared sea space, joint on-and offshore infrastructure, and operational activities (UNITED, D1.2). Expansion of tourism activities is going to be done by opening opportunities to attract new target groups, and eventually to be part of the tourism offer in Copenhagen and its region.

The work currently being done by the pilot consists of:

- Expanding tourism activities to more local and international groups through the development of virtual visits;
- Expanding the multi-use activities in the area, by engaging with divers' associations to welcome them in the area; and
- Working on introducing more boat companies and having them promote the visit to the turbines.

5.2.3. Pilot owners and stakeholders

Unlike the other pilots, the Danish pilot is already in place and not in the process of construction. It was first established in the year 2000 south of the Middelgrunden island by the common effort from different groups, mainly:

- a group of wind energy enthusiasts who, in 1996, had built the wind energy cooperative of Lynetten,
- the Copenhagen utility, and
- the municipality of Copenhagen.

The touristic activities started as an open house event for the shareholders of the Middelgrunden. It all started when the shareholders of the cooperative had the opportunity, with their families, to visit the turbines. These activities were organized by the board of the cooperative and were expanded to other stakeholders interested in visiting offshore wind turbines. The people visiting the pilot cover a range from technology developers and the supply chain to researchers and academia.

The ownership of Middelgrunden Wind Farm is divided into two bodies: 1) HOFOR, a Danish energy company – owned by the Copenhagen municipality - that owns the 10 northern turbines; and 2) Middelgrunden Wind Cooperative, a cooperative that represents about 8 500 shareholders and who together owns the 10 southern turbines of the offshore wind farm.

Table 8 Roles of HOFOR, Middelgrunden Wind Cooperative, and SPOK ApS in the Danish Pilot

Company/institution	Role in the pilot	Main interest to join in the pilot	Contact person
HOFOR	Owner of 10 wind turbines of the Middelgrunden Wind Farm	Offshore wind energy	n/a
Middelgrunden Wind Cooperative	Owner of 10 southern turbines of the Middelgrunden Wind Farm; On behalf of 8500 shareholders	Offshore wind energy, people engagement	H.C. Sørensen
SPOK ApS	In charge of visiting programme of Middelgrunden Wind Farm	Energy interest, people engagement	julia.fernandez.chozas@gmail.com spok.consult@gmail.com

Table 9 shows the external stakeholders (UNITED, D3.1) – they are also regarded as potential users of the results of the project.

Table 9 External stakeholders for 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

5.2.4. Technologies and services provided by the Danish pilot

The pilot is established on a natural reef with 3 to 6 meters of water depth, 3.5 km outside of Copenhagen harbour. It combines the production of electricity and tourism activities – the tourism activities are related to visiting the offshore wind farm.

There are 20 wind turbines (each has a capacity of 2 MW) in the offshore wind farm, and the total installed capacity is 40 MW. The pilot produces about 100 GWh/year of electricity, which corresponds to almost 3% of the electricity demand of Copenhagen (UNITED, D1.2).

The tourism activities provided by the pilot include a dedicated lecture on the wind farm, the functioning of a wind turbine, the Danish Energy Programme and wind energy strategy, and all relevant topics associated with wind energy. Lectures are tailored-made according to the audience. After the lecture, the tour continues in the form of a boat trip - by a fisherman's boat or fast boat- up to the turbine, which the tourists can visit from the inside. Overall, the cooperative organizes 30 to 40 boat trips every year. Furthermore, every two years, the cooperative organizes an open house day, and 150 to 200 people climb turbines during these open days.

5.2.5. Combined activities and expected synergies

The pilot combines two activities: a) production of offshore wind energy, and b) tourism activity – boat tours including a lecture on the functioning of the wind farm. Both activities are highly compatible (they are not excluded from one another). In the future, further activities will be added such as (UNITED, D1.2):

- Diving;
- Leisure fishing;
- Educational tours for locals – to increase local knowledge about the importance of green energy;
- Shared onshore facilities – such as offshore-related information centres; and
- Boat tours to offshore wind farms combined with angling or restaurant facilities.

Currently, the synergies due to the combination of the offshore wind farm and tourism activities are mainly on cost reduction. More synergies will be identified with the development of the project (UNITED, D1.2).

5.2.6. TRL level of the Danish pilot

The current TRL of the Danish pilot is 6: *"Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies"* (UNITED, D7.2). It aims to reach TRL 8: "*System complete and qualified"* by the end of the project and ought to make it feasible to continue the activity while providing societal and environmental benefits to the region (UNITED, D3.1).

The combination of offshore wind energy with tourism activity is expected to have a good effect on the Danish pilot to scale up and reach TRL 8. The Middelgrunden Windfarm is one of only a few wind farms where visitors can see the turbine closely and climb the nacelle. As demonstrated in the MUSES and other projects, the combination of offshore wind turbines and tourism can generate long-term benefits for local communities by encouraging innovation and entrepreneurship and generating job growth. Particularly rural areas in need of economic boosts through tourism can benefit from this. The expansion of tourism related to the offshore wind farm in the Copenhagen area and beyond will help the Danish pilot to reach the targeted TRL (UNITED, D3.1).

5.2.7. Strategic roadmap to reach targeted TRL level

As described before, the Danish pilot is working now on expanding tourism activities, expanding multi-use activities[44], and introducing more boat companies to promote visits to offshore wind turbines, which contributes to the development of the TRL level.

To reach its TRL level, the pilot needs to address two main issues:

- The first issue is related to the safe access to the wind turbine foundation. This issue is related to the boat companies, to whom the Middelgrunden cooperative can rent the boats to transport visitors from the harbour to the turbine foundation. Furthermore, the cooperative is trying to convince the boat companies to promote the boat tours on their own.
- The second issue is related to insurance. To present it is not clear who is responsible, insurance-wise, for the different steps that form a wind turbine tour.

5.3. Identifying risks and barriers

5.3.1. PESTEL analysis

This sub-section presents the external factors influencing the Danish pilot. The information was collected by interviewing the pilot leads of the Danish pilot, SPOK ApS. The information presented in this section shows that the Danish pilot and the development of future activities in the pilot are influenced by a lot of external factors. The most important factors influencing the pilot are a) the political, where a government decision might enhance or restrain the tourism activity – one of the main activities of the pilot and which in its turn influence the economic factors – and b) the legal factors, where the non-renewal of the lease of the location where the pilot operates might lead to no future activities (in both tourism and offshore energy). Furthermore, it could be seen, that the Danish pilot has opportunities to develop by adding other activities such as harnessing wave energy and putting in place floating solar PV – this might increase the attractivity of the pilot and attracts more tourists who might be interested in the different blue energy field.

[44] The pilot is aiming to add more tourism activities including diving, fishing, etc.

The following of this sub-section shows in detail the external factors influencing the Danish pilot.

Political conditions

- **Political support.** The Danish pilot is situated in Copenhagen (Denmark) and, therefore, is mainly influenced by the Danish political decisions regarding energy policies (e.g. wind energy and other renewable energy), and other environmental policies (e.g. policies related to marine spatial planning for example). The Danish political commitment to wind energy helped Denmark in positioning itself as a wind energy exporter. Worldwide visitors come to Denmark to hear about wind energy solutions, and often, as part of their visits, they also visit the Middelgrunden Wind farm – either as part of a client's tour or voluntarily to enlarge their knowledge. These visits/tours of wind farms are most of the time organized by a public-private partnership association[45] from Denmark.
- **Uncertainty about empowerment after end-of-use.** Currently, there are ongoing discussions on the opportunities of re-powering[46] the wind farm when it reaches its end of life in the year 2025. Depending on the final decision, there might be a different approach, in the future, for visiting the wind farm.

Economic conditions

- **Absence of incentives**. There are no government subsidies in place from which the Danish pilot can take advantage.
- **The existing international market.** Denmark is positioned as a wind energy exporter. Visitors from all over the world visit Denmark to hear about wind energy solutions, and often, they visit the Middelgrunden Wind farm – either as part of a client's tour or voluntarily to enlarge their knowledge.
- **Electricity market prices uncertainty**. The Danish pilot is highly influenced by the price of electricity. Electricity produced from the Danish pilot is sold on the Nord pool energy market – a highly volatile market where prices change each hour. It is not feasible for the pilot if the price of electricity reaches low levels – there will be no profit and it will be hard to maintain the same level of operations.
- **Reduction of visitors due to COVID-19.** Due to the COVID-19 pandemic and restrictions, the number of tourists decreased in Denmark which reduced majorly the pilot activities.

Social conditions

- **Existing social acceptance.** Before building the wind farm, the process took 2 years of continuous discussions and presentations with citizens to hear about project characteristics, pros and cons of the project, possible visual impact, and other effects – a big effort for involving the public in this process was made. After that, the pilot has always been very welcomed by all kinds of groups, such as academia, industry, families, etc. The social acceptance of the pilot led to choosing the Middelgrunden Wind Farm as the second most iconic landmark of Copenhagen, showing how citizens perceived it.

Technological conditions

[45] The association *State of Green* play a big role in organizing these visits.

[46] Re-powering is a term that means updating the existing gear and equipment of wind turbine. This could be done by replacing older wind turbines with new ones, or by swapping out the parts in the original turbines with new, more efficient technologies.

- **Positive innovation environment.** The use of wind energy is becoming more and more common, and the new re-powering might affect the wind farm and associated multi-use activities. The cooperative is now studying the possibility of using the area where the pilot is located for a) harnessing wave energy, b) installing floating solar PV[47] platforms, and c) storing electricity with a battery.
- **End of lifetime wind turbines (2025).** The Danish pilot was constructed in the year 2000, which indicates that the turbines are now 21 years old. A lot of equipment, like the gearboxes, the control system, and the power electronic system needs to be updated. However, this only could be done if the price of electricity – produced by the wind farm – is not too low. If the price is too low, there is no interest in repowering the turbines – it is not feasible.

Environmental conditions

- **Heavy metal contaminated site**. The cooperative studied the possibility of adding one activity for the pilot, which is aquaculture. It was found that aquaculture activity is not possible as the site is contaminated by heavy metals – after having been used as a dump site up to 1975.

Legal conditions

- **Competitive disadvantage due to EU tender rules.** The EU rules and legislations are restricting the establishment of projects similar to the Danish pilot – this means a project established with a cooperative approach (in combination with a utility partly owned by the public). Nowadays, projects like this need to go out in a tender, and a cooperative does not have the resources to compete in a tender as a utility or energy company does. Furthermore, before the project is approved, a cooperative cannot have the same financial capabilities as after project approval – a cooperative cannot show it is robust enough until the project has been granted.
- **Uncertainty about future lease contracts.** Finally, the site where the pilot operates is leased from the Danish government. The lease ends in 2025 (after 25 years of the installation of the pilot). The cooperative is looking to renew the lease for the location. Yet, this is the first time such a request will be sent to the Danish government and there is no procedure for this.

5.3.2. Business Model Canvas

The Danish pilot combines two main activities: the offshore wind farm, and tourism activities. The following of this section will present the 9 building blocks of the business model canvas for each activity and will compare differences and similarities to show how the pilot creates, captures, and delivers value. The information for both activities of the Danish pilot was collected by interviewing the pilot lead, SPOK ApS. The following matrix (Figure 19) shows the information acquired for the 9 building blocks for the offshore wind farm.

Figure 19 Business Model Canvas Matrix – Offshore Wind Farm activity of Danish Pilot

Business Model Canvas				
Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
• Public authorities (e.g. Danish government) • Windfarm shareholders;	• Electricity production;	• The OWF produces 3% of clean energy for Copenhagen	• There is no direct interaction between the cooperative and final consumer –	• Macro segment – all customers willing to buy clean/green energy – the wind farm sells electricity to energy

[47] Solar Photovoltaic

• Local intermediaries (e.g., local councils); • State of Green association			the electricity is sold on the Nord Pool electricity market	networks/distributors on the Nord electricity market and in their turn, they sell electricity to the final consumer.
	Key Resources		Channels • Website – Nord Pool Energy Market[48]	

Cost Structure	Revenue Streams
• Fixed cost – maintenance cost (15 € MWh) • Variable cost – operation cost (10 – 12 € MWh)	• Selling electricity

For this activity, information regarding some building blocks is not identified or not present. This is the case for the customer relationship[49] and key resources building blocks.

The following matrix (Figure 20) shows the information acquired for the 9 building blocks of the tourism activity:

Figure 20 Business Model Canvas Matrix – Tourism activity of Danish pilot

Business Model Canvas				
Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer segments
• Boat providers; • Copenhagen sport divers; • Insurance company; • Local intermediaries (e.g., tourist boards); • Local museums, exhibitions, and information centers	• Boat tours including a high-level professional presentation on Middelgrunden Wind Turbine Co-operative and wind energy; • Educational tours on blue energy; • Diving, leisure fishing, latest policies on wind energy	• Knowledge related to the offshore wind farm and green energy; • No other alternative that can provide the same services	• Tourism activities being warmly welcomed by the citizens and visitors; • Smooth personal contact without complaining	• Students; • Companies; • Visitors; • Shareholders
	Key Resources		Channels	

48 https://www.nordpoolgroup.com/Market-data1/#/nordic/table

49 Electricity is sold on the nord pool market. There is no interaction between the pilot and the final consumer of electricity.

	• Vessels and guides		• Website; • Email; • Mouth to ear – rely on previous visitors to give recommendations to visit the OWF.	

Cost Structure	Revenue Streams
• Boats; • Guides; • VAT	• Revenue to the boats and guides service provider if there is a tourism activity

The business model canvas matrixes (Figures 19 & 20) show similarities and differences in both activities of the Danish pilot. On the first hand, concerning the similarities, it could be noted that similarities between the two activities of the Danish pilot led to several synergies related to cost reduction due to the use of the same vessel to do the maintenance work for the OWF and the tourism activity tours. To present, this is the only synergy identified. Hence, the combination of these two activities leads to benefits for both parties. The economies realised are translated into monetary gains (note: due to confidentiality of information, the monetary gains could not be measured).

On the other hand, a lot of differences exist in the activities of the Danish pilot. The differences are at the level of all building blocks. Hence, the pilot combines different key activities, with different value propositions and is targeting different customer segments. Furthermore, the cost and revenue structure of both activities are different. These differences are seen as a source of enrichment for the pilot especially when targeting different customer segments that allow the diversity of customers and hence the diversity of revenue streams.

From here, it could be concluded that the Danish pilot is creating, capturing, and delivering value from both activities

5.3.3. SWOT analysis

The following matrix (Figure 21) shows the SWOT analysis for the Danish pilot.

Strengths

The main (and only) **strength** of the Danish pilot is that no other places are doing the same activity and providing the same services as the ones provided by the Danish pilot.

Weaknesses

There is one main **weakness** translated in the dependence on boat providers – tours and visits of the turbine will be suspended if no boats are available.

Opportunities

The Danish pilot has a lot of **opportunities** which the pilot can take advantage of such as a) introducing incentives for repowering offshore wind – this gives safer feasibility for the pilot and allow it to update the old equipment -, b) faster development of introducing battery storage system in the individual turbine that could improve the feasibility, and c) introduction of new technologies to produce more offshore electricity such as floating solar PV platform and wave energy harness

Threats

The **threats** facing the Danish pilots are a) political rules against the prolongation of the sea lease – which could lead to stopping the work on the project, b) political decisions restraining the tourism activity, and c) climate conditions related to the dependence on weather conditions – no tours and visits are possible in bad weather conditions.

From the above information, it could be noted that the Danish pilot has a lot of opportunities to take into consideration if it is seeking to develop. However, these opportunities are limited by the threats for which the pilot needs to develop strategies to overcome them. Most of these threats are related to the political decisions of the Danish government. Hence, one of the strategies could be to negotiate with the government so the pilot can overcome these threats.

Figure 21 SWOT analysis – Danish pilot

Strengths: – No other places or pilots are offering the same activity - unique boat tours and lectures on the Middelgrunden Wind Farm	**Weaknesses:** – Dependence on the boat providers
Opportunities: - Introducing incentives for repowering offshore wind giving a safer feasibility - A faster development of introducing battery storage system in the individual turbine improving feasibility - Introducing new technologies such as floating solar PV platform and wave energy harness	**Threats:** - Political rules against prolongation of the sea lease would end the work in the project - No tourism activities due to Covid restrictions - Dependence on weather conditions

5.4. Financial analysis

To present, little information exists that allows the conduct of financial analysis and feasibility study for the Danish pilot. However, the existing information allows a better understanding of the costs and revenues structure for each activity. The baseline to which the comparison of costs and benefits could be done is the single-use activity of OWF. The OWF is the main activity of the pilot where without this activity the pilot does not exist.

OWF comprises two main categories of costs a) **installation cost**, and b) **operation and maintenance costs** (see Figure 19). Considering the installation cost, evidence exists from the literature. A study[50] showed that the installation cost for OWF vary between 3 435 € per Kw and 4 293 € per Kw[51] for the year 2016. Another study[52] showed that this cost is slightly lower for the year 2020 and estimated at 2 737 € per Kw[53]. Synder and Kaiser (2009) compiled data on the costs of offshore wind farms built in Europe from a variety of public sources and estimated the installation cost of OWF to range between 1 255 € per Kw and 6 011 € per Kw for the year 2008[54]. Looking at the Middlegrunden wind farm (the Danish pilot) Synder and Kaiser (2009) estimated the installation cost at 45.52 million Euros for a 40 MW installed capacity (approximately 1 138 € per Kw – if compared to other studies, the estimation done for the Danish pilot comes in the same order of magnitude).

For the operation and maintenance costs, evidence exists in the report, notably in the BMC (see Figure 19). The operation and maintenance cost comprises the fixed cost which was estimated at 10 €/MWh and the variable cost which was estimated to vary between 10 € MWh and 12 € MWh. Additionally, evidence exists in the literature on the operation and maintenance cost of OWF. Fingersh et al. (2006) modelled the cost of a single offshore wind turbine with an installed capacity of 3 MW and estimated the operation and maintenance cost at 184 615 € per year

The revenues for the OWF are generated by selling electricity to the final consumer (see Figure 19). The electricity is sold on the Nord pool energy market[55] that defines electricity price each hour. Revenues of the pilot from electricity production depend on wind energy production and the price defined by the market. This value is difficult to estimate – wind energy production depends on air velocity. Other costs that are related to the costs of boats (e.g. renting the boat and paying the fuel), guides, and VAT exist. However, it is difficult to extract information from the literature to estimate these costs.

Considering the tourism activity, the activity comprises costs and revenues for boats, guides, and VAT. Information concerning the different cost categories was challenging to acquire. According to an expert opinion, the turnover for the boats was estimated at 24 500 DKK for the year 2020 and at 8 800 DKK for the guides.

From the information collected and presented in this section, cost savings and monetary gains are only noted for tourism activities. The cost savings are translated by the use of the same vessel to do maintenance for OWF and tourism activities at the same time. For the OWF, there is no significant cost saving.

Finally, from the information presented in this section, it is difficult to evaluate the financial performance of the pilot to determine its feasibility of the pilot. Hence, at this stage, calculation of the financial metrics such as the Return on Investment (ROI), the Net Present Value (NPV), the debt-to-asset ratio, and the return on equity is very difficult and cannot be done. Further investigation on the different costs and revenues of each activity of the pilot is still needed. This will be done in a future deliverable (Deliverable 3.3 of the UNITED project).

5.5. Evaluation and Control

The main objective of the Danish pilot is to expand the existing tourism activities and to create new attractions that might result from shared sea space, joint on-and offshore infrastructure, and operation activities (UNITED, D1.2). The expansion of tourism activities is going to be done by opening opportunities to attract new target

[50] https://www.windpowermonthly.com/article/1380738/global-costs-analysis-year-offshore-wind-costs-fell
[51] The figures in the study were given in USD and were converted to EUR using USD/EUR 0.86 conversion rate.
[52] https://www.statista.com/statistics/506756/weighted-average-installed-cost-for-offshore-wind-power-worldwide/
[53] The figure was given in USD and was converted to EUR using USD/EUR 0.86 conversion rate.
[54] The figures were estimated in USD and were converted to EUR using USD/EUR 0.86 conversion rate.
[55] https://www.nordpoolgroup.com/

groups, and eventually to be part of the tourism offer in Copenhagen and its region. The expansion of the tourism activities will lead to additional revenues for the pilot due to the increase in the number of tourisms. An indicator to measure the progress in the expansion of tourism activity could be the comparison of revenues as well as the number of tourists between the different periods (before and after adding additional activities).

To reach its objective, the Danish pilot is offering several alternatives related to tourism activities such as diving, leisure fishing, educational boat tours for locals, and other tourists interested in wind energy. Nevertheless, the objectives are highly influenced by external factors (e.g. political, economic, social, technological). The objective here is not to enter in detail each factor, but to show what are the positive and/or negative external factors influencing the pilot.

On the first hand, regarding the positive factors, the pilot is positively influenced by the technological development happening. There is an opportunity for the pilot to add other energy-related activities such as floating solar PV and harnessing wave energy. This will allow the pilot to produce more energy and attract more visitors/tourists interested in green/blue energy. Furthermore, the pilot is not facing any social acceptability problems. On the contrary, people living in Copenhagen highly appreciate the presence of the pilot. This was demonstrated by voting the pilot as the second iconic tourist attraction of Copenhagen. The high acceptability of the pilot gives it an advantage in development and overcoming some threats.

On the other hand, the pilot is facing several negative external factors that are forming a threat to its existence. These threats are mainly due to:

- Political and legal factors. The pilot is highly influenced by the political decisions of the Danish government. This has been seen in the COVID-19 pandemic where travel restrictions decreased the tourism activity in Copenhagen and hence limited the activities of the pilot. Furthermore, on the legal basis, if the Danish government don't approve the renewal of the lease for the Danish pilot marine space, the work in the pilot will stop entirely; and
- Technological: the Danish pilot was constructed in the year 2000 (21 years ago). A lot of equipment needs to be updated. This only could be done if the price of electricity generated by the wind farm is not too low.

Furthermore, other negative internal factors are influencing the pilot such as the dependence on the boat providers.

To avoid these threats (negative external factors) the pilot should develop different strategies so it can take advantage of the existing opportunities. One of these strategies could be based on the strength that the pilot activities are unique and on the social acceptance of the pilot.

Regardless of the threats, the pilot is managing to create, capture, and deliver value. This could be seen from the Business Model Canvas of the pilot. It could be noticed that the pilot has different a) key partners, b) key activities, and c) is targeting different customer segments through different channels.

Financial data is still limited, and not available, further investigations are still needed. However, from the available data, financial benefits for multi-use are relatively small and companies might be motivated by other factors to engage in multi-use activities, notably for the OWF where the financial gains are relatively too small and not significant if compared to the costs. Other non-financial benefits might be motivating companies to do multi-use activities. Non-financial benefits could be related to environmental or other social benefits.

Finally, to reach its objective and the targeted TRL, the pilot should consider different ways forward. First, the pilot must rely on and take advantage of its only strength: "*No other places or pilots are doing the same activity*" to overcome the threats and the weaknesses that it is facing, and, notably, to increase and diversify its tourism activities. The increase in tourism activity could be done by partnering with a large majority of boat owners to decrease the probability of dependence on specific boats. Second, to overcome the threats, the cooperative should rely on the social acceptability of the pilot. The focus on boat companies, especially the companies handling the service teams for the wind turbines, will increase in the future the multi-use activities related to OWF and tourism. Encouraging boat companies to be more engaged in the multi-use activities can benefit both activities (OWF, and tourism) translated in transport cost reduction.

By relying on these two factors, the Danish pilot might ensure its continuity and overcome the threats and reach the targeted TRL level by the end of the project.

5.6. Conclusion

The business analysis of the Danish pilot presented a general overview of the pilot, and all the external/internal factors influencing it. The pilot is located outside of Copenhagen and combines two main activities: offshore wind energy and tourism activities. The purpose of this conclusion is not to repeat elements already mentioned in the sections above, but to highlight the main elements influencing the pilot.

From the business analysis, it was clear that the pilot is highly influenced by external factors. This influence could be:

- Positive influence: where technological advancement can lead to a development in the pilot activities, to the development of energy production and eventually the development of tourism activities – the development of energy activities might attract more tourists interested in learning about solar energy, wave energy, and wind energy. Other positive influences are related to social acceptance of the pilot which facilitates the development of the pilot activities and might ensure its continuity.
- Negative influence: related to political and legal factors where a no renewal of lease to the location of the pilot lead to an immediate end of the work of the pilot – which could be, at the same time, a loss to a lot of transport (boat) companies and other tourist guides working within the pilot.

Financial information is still limited. However, the case study showed that non-financial benefits might be motivating the companies to enter multi-use activities. The OWF might be benefiting from the tourism activities to expand its energy production activity. To end this case study, more investigations are still needed on the financial aspects of the pilot to determine its feasibility of the pilot. This will be done in future deliverables.

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6. BUSINESS ANALYSIS OF THE GREEK PILOT

6.1. Background

The Greek Pilot, denoted as the PATROKLOS Pilot site, is situated in the 59th km of Athens-Sounio Ave., Palaia Fokaia, Attiki, Greece, in the wider area of Cape Sounio (Figure 22). The wider area is protected by NATURA 2000 and the Treaty of Barcelona due to several significant characteristics that this Pilot site has to offer. The area is a characteristic example of Mediterranean landscape. It includes an area declared a National Park since 1971 and is regarded as an archaeological site of great importance, furthermore 68% of the area is accessible and declared public. During the Classical and Hellenistic periods, the Cape, and the ancient harbour city of Sounion were of prime geostrategic im-portance located on the main maritime route surveying all traffic and enemy fleets towards the metropolis of Athens and the silver mines of Lavreotiki. Until today there are visible important remains of the sanctuaries of Athena and Poseidon, the fortification circuit, and the settlement of the promontory, and of a naval base. The naval base built originally by the Athenians in the 5th century BC lies in the north-western part of the cape and was incorporated in the fortress. It consisted of two rock-cut slipways intended to house light patrol ships (UNITED, D7.2)

Figure 22 Left and Middle: Proposed Pilot space, the yellow square depicts aquaculture unit (source: Google Earth). Right: Aquaculture unit and islet Patroklos on the opposite - Mediterranean Sea, Greece

6.2. Defining optimized business cases

6.2.1. Mission and vision statements

Mission statement

The mission of the Greek pilot is to explore how to combine aquaculture and tourism activities. Specifically, it will investigate the potential of including an aquaculture farm in scuba diving tours, thereby turning the aquaculture farm into a touristic asset, providing economic opportunities, and alleviating local opposition to aquaculture. The scuba diving is led by Planet Blue, a 2-person local scuba diving company; the aquaculture farm is run by Kastelorizo Aquaculture, a 100+ person aquaculture and restaurant company.

Vision statement

The Greek Pilot aims to create a novel, attractive scuba diving offer for tourists to visit the aquaculture site. In doing so, it aims to increase profits by adding new revenue streams and opportunities to reduce costs for the diving and aquaculture companies, as well as increase knowledge and public perceptions of aquaculture.

6.2.2. Objective of the Greek pilot

Regarding the aquaculture business, the long term goal coming from the combination of activities is to build community acceptance, to introduce the scuba diving tours to the site as an opportunity for locals and tourists to familiarize themselves with the aquaculture's operations and to recognize this new type of leisure activity as a way to increase the touristic interest in the wider area, attracting tourists that would also enhance the local touristic businesses (local restaurants, hotels, shops, etc.). From a business perspective, the aquaculture business would be very interested to create a framework in which the touristic activities would produce income coming from the expeditions. The aquaculture is also a part of a group, which includes a chain of restaurants that obtain fish for their dishes, coming from the aquaculture production. The aquaculture business would aim to advertise and promote these restaurants through touristic expeditions to the site, by familiarizing the guests with the aquaculture production, highlighting the benefits of consuming fish bred in aquaculture in terms of health safety and environmental protection. Regarding the scuba-diving centre, the long-term goal is to permanently add the aquaculture visits as one of the attractions suggested to their customers, as these visits would increase the tourists' interest. The scuba diving expeditions to aquaculture sites are something quite original and could be considered a competitive advantage to the scuba diving business. In addition, there is the potential to advertise to tourists together (e.g. advertise diving in Kastelorizo restaurants and vice versa).

6.2.3. Pilot owners and stakeholders

WINGS ITC Solutions is the lead of the Greek pilot and a supporting partner in the multi-use project. Their technology and Aquaculture monitoring and management system will help synchronize aquaculture operation and tourism activities at the site.

The project partner **KASTELORIZO AQUACULTURE**[56] operates an aquaculture farm on floating facilities in the marine area near the Natura 2000 islet Patroklos, which is located 850 meters from the shore of the mainland. In addition, they operate an aquaculture farm on Crete. They produce fish and shellfish and sell them in Greece and abroad, including in its seven own restaurants. Their fish and shellfish farming unit is already established and in operation (i.e. TRL = 9).

The project partner **Planet Blue**[57] is a local diving center based in Lavrio, Greece, 60km south of Athens and not far from Patroklos. They offer diving tours for groups and individuals. Planet Blue also has a business providing Remote Operating Vehicles (ROVs) to aquacultures, including mapping the underwater landscape of aquaculture sites or conducting inspections or repairs of aquaculture infrastructure placed in great depths. In addition, Planet Blue offers diving expeditions for cleaning up waste in the aquaculture area. Both the diving activities and the ROV services are already established and in operation (i.e. TRL 9) (see Table 10 for a summary for the internal stakeholders).

Table 10 Internal stakeholders involved in the Greek Pilot (adopted from D3.1 of the UNITED Project).

Stakeholder	Role	Interest	Contact
WINGS ITC Solutions	Pilot Lead	Service provider. Results on technical solutions	idrigopoulou@wings-ict-solutions.eu elabrakopoulou@wings-ict-solutions.eu
KASTELORIZO AQUACULTURE	Aquaculture farm	Results on aquaculture production. Social acceptability.	-
Planet Blue	Diving tours and ROV services	Increased business opportunities from combined activities.	info@planetblue.gr

6.2.4. Technologies and services provided by the Greek pilot

The main services provided by the Greek pilot is production of local aquaculture products, touristic activities, and the delivery of ecosystem services. To investigate the TRL level and proof of concept for the commercial demonstration of this specific multiuse, monitoring would be done through cameras that have been installed at the cages to monitor fish behaviour, to be able to track any stress indicators during the scuba-diving expeditions. Furthermore, environmental parameters are also being monitored at the aquaculture site, with the use of multi-probe sensors, also installed by WINGS. The monitoring of the Temperature, Dissolved Oxygen, Current, pH, Turbidity, Chlorophyll, Nitrate, and Ammonium are being monitored, not only to be able to establish the environmental footprint of the aquaculture site but also to track any disturbance to environmental parameters from the multi-

[56] The company has the full-time equivalent of 98 employees and an annual turnover of 5.4 million Euros (2020).
[57] Planet Blue has the full time equivalent of two employees and an annual gross turnover of 110 thousand Euro.

use (e.g. Ammonium rise might be an indicator of stress in fish). Regarding the cameras and sensors, these have already been installed on the site to start receiving data regarding environmental parameters and fish behaviour. Video footage is also being used for other experimental functions of the cloud platform, such as disease detection and biomass estimation, which are mainly used for the overall optimization of the fish farm. Nevertheless, in order to succeed reaching the TRL8, there have been efforts to create optimal installations in the site based on the lessons learnt from the initial installations efforts (UNITED, D1.2).

6.2.5. Combined activities and expected synergies

The multi-use solution implemented in the Greek pilot is a combination of aquaculture and tourism. First, scuba diving tours will visit the aquaculture site, where waste from the feed is attracting an abundance of wild fish. Potentially, boat tours may be organised to show visitors how the aquaculture farm works, listen to on-board lectures by aqua-culture experts, and taste products from the aquaculture.

The following synergies can be expected from this multi-use activity (UNITED, D1.2):

- New touristic activity (scuba diving at an aquaculture site, potentially linked to restaurants);
- Business development aimed at cost minimisation by sharing the existing aquaculture/diving equipment (ROVs, diving gear, and expertise), as well as advertising and potentially other costs (such as shared licence and regulation costs);
- Increased local acceptance of the aquaculture farm near Patroklos by residents, as well as increased wider societal acceptance of aquaculture;
- Facilitation of growth of local tourism and business through offering an attractive and original recreational activity; and
- Alignment of management and planning decisions to optimise developments for both pilot partners, such as extending the aquaculture farm in such a way that it does not intervene with current touristic and recreational activities.

6.2.6. TRL level of the Greek pilot

The current TRL of the Greek pilot multi-use case is 3-5 (i.e. the multi-use case has been conceptualised and the individual elements have been proven, but the multi-use case needs testing and demonstration in the relevant environment; UNITED D3.2 and D7.2). Both Kastelorizo and Planet Blue have mature, existing businesses. The innovative element is the combination of their two businesses into a multi-use case[58].

6.2.7. Strategic roadmap to reach targeted TRL level

The Greek multi-use pilot aims to reach TRL 7/8 (demonstration in an operational environment, also referred to as pre-or first of a kind commercial demonstration) by the end of the project. This would include developing and testing a business case, as well real-life testing of scuba-diving visits in the demo site, as well as assessing other areas for collaboration (including reducing shared costs, growing new markets, other).

During the operational phase, touristic expeditions are already taking place at the aquaculture site, with groups of eight people (six tourists, a scuba-diving instructor, and the vessel skipper) visiting the site and diving, following an underwater path that has initially been created by the scuba diving team to safely guide the involved participants to the underwater tour[59]. This path has been created with the use of an ROV (Remote Operating Vehicle)

[58] In addition to the multi-use case, the Greek demo site is also a testing site for enhancing the aquaculture farm with technological tools that allow for the synchronization of aquaculture and touristic activities with the help of the supporting partner WINGS ICT Solutions. We do not focus on this element in the business analysis, instead of focusing on the development of the multi-use case where touristic activities combine scuba-diving and aquaculture offered by Planet Blue and Kastelorizo Aquaculture are developed.

[59] As of December 2021, two paths have been developed, with a plan to expand this to four.

that is owned by the scuba-diving centre. The ROV has been used as part of other activities taking place in the site, such as infrastructure inspections (for anchors that are placed in great depths and for cage nets)[60].

The following challenges/open questions have been identified in collaboration with the pilot lead and the involved companies, which need to be assessed and overcome to reach TRL 8 (UNITED, D3.1):

- Need to investigate and demonstrate that the aquaculture site is attractive to scuba divers;
- To maximise cost savings (related to sharing infrastructure and any joint activities e.g. advertising) will need to investigate how these can be coordinated;
- Unclear legal context and complicated licensing procedures
- The aquaculture farm has obtained an exploitation permit for 10 years, but it is unclear whether legislation allows or prohibits additional use of the same site for touristic activities. It is to be investigated if the multi-use case adds or reduces administrative and regulatory challenges or costs.
- Potential disruption of farming activities by scuba diving tours[61];
- Potential to improve community perception of aquaculture – supported by scuba diving guides educating visitors on the activity and on correctly and wrongly held beliefs of aquaculture; and
- Any environmental issues related to multi-use (e.g. impact on stress levels of fish)[62]

Further, concerning the testing of enhanced monitoring tools at the site, the following challenges/open questions have been identified:

- Need to create cameras and sensors installations that would be low cost and environmentally friendly in the long run, with solar panels feeding with the necessary energy, replacing any existing electricity power needs; and
- All devices transmitting data to the cloud should be independent of wired connections with modems (any wired connection in the aquaculture site has been proven to be sensitive and easily disturbed by the operating vessels).

6.3. Identifying risks and barriers

6.3.1. PESTEL analysis

This section presents an evaluation of the external conditions surrounding the pilot. This is done using the PESTEL analysis approach. Information concerning the external factors was collected by conducting interviews and email exchanges with partners working directly within the pilot, WINGS, Blue Planet and KASTELORIZO.

Political conditions

[60] The aquaculture site anchorage ropes, which run from the more than 40 anchor blocks, create a complicated net that poses a risk to the ROVs, potentially limiting Planet Blue's ability to inspect the blocks.
[61] In piloting stages, this has not proved a problem. Planet Blue has communicated to the aquaculture farm before they visit and visits have not lead to disruptions.
[62] As dives occur outside the fish farm nets, fish are not expected to become stressed by the diving visits.

- **Uncoherent national regulatory framework**. Multi-use is currently not included in Greek maritime spatial planning, reportedly due to favouring of "exclusive" maritime activities such as aquaculture (Kyvelou and Ierapetritis 2021). However, existing sites combining aquaculture and diving activities offer potential multi-use examples.
- EU support for researching multi-use (as evidenced by UNITED); potential for continued research support.
- EU European Maritime, Fisheries and Aquaculture Fund provides financial support to the EU aquaculture sector; each EU country has the decision-making power as to how it spends that money. Potential for support.

Economic conditions

- Infrastructure depends on aquaculture economic conditions (i.e. the aquaculture sites).
- **Coronavirus crisis** (and related travel restrictions) impacts both multi-use partners, due to Kasterlorizo's reliance on restaurants (and therefore tourism) and Planet Blue's reliance on local and foreign divers.
- Tight economic conditions increase **need to reduce costs** (which could spur multi-use)

Social conditions

- **Negative local views**. Social acceptance of mussel and fish aquaculture is often somewhat negative, due to perceived space competition and local environmental impacts (Krovel et al 2019). Potential of diving to address this issue and increase social acceptability of aquaculture.
- Some existing examples of multi-use occurring at private scale (e.g. Western Rhodes (namely, the Blutopia marine park) (Kyvelou and Ierapetritis 2021)

Technological conditions

- Offshore monitoring of aquaculture sites could be supported by diving, and/or by IT solutions
- Potential for technological exchange between the multi-use partners

Environmental conditions

- Aquaculture impacts could affect local **water quality** and diving, therefore mutual interest in managing environmental impacts.
- **Increased ecosystem services**. Aquaculture can attract fauna (which is often scarce in other sites due to overfishing in the Mediterranean), supporting diving increased recreational value and increasing biodiversity in the area.
- **Climate change**, increasingly frequent extreme weather events (warming, storms, etc.) – potentially poses a risk for both aquaculture and tourism

Legal conditions

- **Difficult to obtain permits**. Currently uncertain legal structures for multiuse (and use of marine space in Greece, in general).
- **Lack of an integrative Marine Spatial Planning framework**. Instead of an all-sector MSP approach, Greece has terrestrial spatial plans (at the regional level). Most of the national spatial planning is occurring at the sectoral level, e.g. a sectoral plan for aquaculture was made in 2011. (European MSP Platform 2021) "For example, the sectorial Special Spatial Planning Framework for Aquaculture (2011) combined with other provisions (such as the Law 2742,1999 issued in compliance to the ESDP) promotes zoning of the sea allocated to aquaculture (allocated zones to aquaculture, AZA, in Greek POAY) with the aim to avoid any interference with potential conflicting activities, thus receiving a lot of criticism by various stakeholders, including SSF, the tourism industry, and the local authorities especially in highly touristic areas and areas with sensible marine and coastal ecosystems". (Kyvelou and Ierapetritis 2021)
- **Multi-use not mentioned in current MSP documents in Greece**. (Kyvelou and Ierapetritis 2021)
- Regulatory challenges to get aquaculture licenses
- Relaxed regulatory framework for scuba diving operations increases the potential for the sector to engage in multiuse activities.

6.3.2. Business Model Canvas

In this section, we present one BMC each for the two companies. We identify potential synergies related to multiuse by highlighting them in green. The following matrix (Figure 23) presents the information obtained for the nine building blocks of the business model canvas on the aquaculture operator. The information was collected from questionnaires, material provided by the companies and by conducting an interview with the pilot lead.

Figure 23 Business model canvas analysis – Aquaculture activity of Greek pilot (in Kastelorizo)

Business Model Canvas

Key Partners

- WINGS, other technical suppliers (e.g. monitoring, remote management)
- Planet Blue
- Distributors
- Fish Feed partners
- Spawn providers
- Kastelorizo restaurants
- Tourism offices

Key Activities

- Fish farming (feeding, breeding etc)
- Maintain, monitor aquaculture infrastructure (including boat trips)
- Run restaurants
- Advertise/sell seafood (including inventory)

Key Resources

- Aquaculture sites and equipment
- 10 year aquaculture exploitation license for the site
- Staff and expertise
- Boats?
- Aquaculture license
- Restaurants and equipment

Value Propositions

- Fresh mussels
- Fresh fish
- Frozen mussels and fish
- Local products
- Cooked seafood
- Other
- Low impact on environment
- Local experience

Customer Relationships

- In-person service
- Supermarket relationships?
- Export relationships?

Channels

- Internal
- Wholesale market
- Word of mouth
- Advertising
- Local press and local businesses social media
- Potential to combine channels (e.g. website, advertising etc)

Customer Segments

- Restaurant customers at own restaurants
- Wholesale: supermarkets
- Export of fresh fish
- Tourists (domestic/international)

Cost Structure

- (nearly) fixed costs: maintenance of aquaculture site, equipment, boat, rent on restaurants
- Costs with aquaculture site (harvest, monitoring, feeding – including specialized divers?)
- Sensors, cameras, solar panels maintenance
- Cloud platform services monthly/yearly fee
- Salaries, training costs
- Advertising
- Low infrastructure maintenance costs and stock loss due to early inspection from divers
- Own contribution to research projects
- Regulatory costs

Revenue Stream

- Revenue from restaurants
- Revenue from selling fresh/frozen seafood to supermarkets
- Revenue from exporting fresh fish
- Revenue from Scuba diving activity

The following matrix (Figure 24) presents the information obtained for the nine building blocks of the business model canvas on the diving centre. The information was collected from questionnaires and series of interviews with Blue Planet.

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Figure 24 Business model canvas analysis – scuba diving activity of Greek pilot (by Planet Blue)

Business Model Canvas - Tourism: scuba-diving

Key Partners

- Planet Blue ROV Services,
- -Diving Travel Agencies
- -Diving Clubs
- -Tech suppliers (including WINGS)
- Virtual Assistant
- IT remote support provider (scheduling system)

- MOTIVATIONS FOR PARTNERSHIPS:
- Optimization and lowering cost
- Reduction of risk and uncertainty,

Key Activities

- Training customers
- Training trainers and dive guides
- Management (managing boat trips)
- Rentals
- Marketing Diving - CRM
- Diving at interesting sites

Key Resources

- People
- Communication
- Sales data
- Customers' data
- Efficient procedures
- Automation systems
- Decision Support systems
- Website analytics
- Diving Industry Analytics
- Boat
- Divers (specialized)

Value Propositions

- Safety
- Confidence and trust
- Impeccable service
- Owner's experience
- Excellent equipment
- No risk taking
- Zero accidents record
- Optimum delivery of service
- All levels of diving (create value for all divers)
- Spectacular activity
- Online queries
- Excellent, personalized CRM
- Digital payment
- Low impact on environment
- Local experience

Customer Relationships

- Personalized relationships
- Quick response and prime attendance
- Social media interactions

Channels

- Website
- Social media
- Online videos
- Internet text search
- Diving clubs
- Diving travel agencies
- Potential to combine channels (e.g. website, advertising etc)

Customer Segments

- Niche market
- Segmented (income – age)
- Adventure seekers
- Sports oriented
- Tourists (domestic/international)

Cost Structure

- Taxes
- Rent
- Utilities
- Tech equipment acquisition
- Equipment maintenance
- Fuel
- Insurance
- Advertising
- Labor
- Communications
- Web hosting
- Boat, boat trips, and regulatory costs: licensing

Revenue Stream

- Diving training
- Diving excursions
- Rentals
- Sales

From the two business model canvases, we can identify benefits for both parties due to the existing similarities between the activities. These can be found

- **Shared customer segments**: Potential overlap in terms of **customer segment tourists** (domestic, international)
- **Joint value propositions**: Both companies aim to **offer customers a distinctly local experience**. There is also the Kastelorizo that sells its product in part as being environmentally low impact, which positively overlaps with the Blue Planet's value proposition for scuba divers.
- **Shared communication channels**: There is some potential overlap in the way the two companies reach customers, or complementarities, though more information is needed. The businesses could explore if they could collaborate on communicating with shared customers either to increase reach or decrease overall costs (e.g. combined cost of web or other advertising).
- Resources and activities:
  - The key multi-use resource is the aquaculture site, which is central to Kastelorizo's business and offers an interesting diving site for Blue Planet, which could **increase the value of scuba dives for tourists**.
  - **Cost savings** due to economies of scale and optimization (optimization of transportation and logistics through the joint use of transport vehicles): Both businesses need to use boats to transport customers (Blue Planet) or staff out to the aquaculture site. This offers a chance for collaboration to reduce costs (by sharing boats or boat trips).
  - Complementary needs also exist regarding **joint monitoring**: Kastelorizo needs to monitor and check the aquaculture site, which could be supported by Blue Planet on their visits (reducing Kastelorizo costs). The specialized dive skills of Blue Planet may also be useful for maintaining the infrastructure of the Kastelorizo fish farms, although the current agreement does not include Planet Blue offering any maintenance support to aquaculture, this could be included in the future. This increased knowledge regarding environmental impacts could be valuable to both businesses.
  - **Shared advertising, sales**: Both companies attract customers through advertising and communication. There is the possibility that they could share actions targeting the same consumers (e.g. domestic/international tourists).
  - Licensing: Kastelorizo has a ten-year exploitation license to carry out aquaculture at the multi-use site. If touristic activities are also allowed under the license, then this license also supports multi-use. There is also **potential for cost savings** (or cost increases) **related to regulatory costs**.
- Costs: Potential for costs savings, as identified above.
- Revenue: Planet Blue revenue would be boosted by offering new diving trips to the aquaculture site. It is unclear whether Kastelorizo will boost its revenue, though it could potentially develop packages with Blue Planet targeting tourists (e.g. combing diving and restaurant meals).

However, differences also arise:

- The multi-use project depends on the existence of an offshore aquaculture site, which can then support diving. As identified in the PESTELs, **legal and regulatory challenges** exist, especially on the side of the aquaculture business.
- Need to confirm that potential cost savings (e.g. fewer boats, fewer boat trips, coordinated advertising/sales) outweigh the management and organization costs.

6.3.3. SWOT analysis

The following matrix (Figure 25) presents the SWOT analysis of the Greek pilot. The SWOT assesses the strengths and weaknesses (i.e. what internal elements (e.g. the partners and the multi-use case will make it succeed or fail?)

and the opportunities and threats (i.e. what external elements could affect the related to the multi-use case). The exercise has been completed with the aid of the pilot partners.

Strengths

The main **strength** of the Greek pilot is the actual presence of two well-established profitable economic activities. Both companies are successful and provide attractive goods and services (aquaculture and tourism). Another strength is the setting, the location of both activities in appropriate for multiuse. In addition, both companies offer a local experience that is attractive to both tourists and domestic customers. Other strengths that can be found are related with the technical know-how and safety operations. The possibilities from multiuse for joint off-shore monitoring and shared internal systems is an added value plus both companies ran safe operations with zero incidents.

Weaknesses

There are several **weaknesses** such as a) an unclear legal setting (i.e.. unclear if aquaculture license will be affected by diving), b) both partners are affected by local and global economic situations (especially through domestic and international tourism), c) government delays in putting plans into place (e.g. diving parks); and, d) Public perception of aquaculture is quite poor.

Opportunities

The **opportunities** of the Greek pilot can be divided in legal, financial, and social. For the legal, there is potential for both companies to work together to access new sites. Thus, reducing the administrative burden in the future for applying for new licences. In terms of financial opportunities, there are many, such as: a) potential cost savings related to joint operations (e.g. boat trips, monitoring), b) potential to develop new activities and revenue streams (e.g. new diving activities, packages), c) potential of continued funding for multi-use (through research projects or from EU /local authorities e.g. EU European Maritime, Fisheries and Aquaculture Fund). Finally, and in terms of social opportunities, there is a clear potential to improve the social perception of aquaculture (with related benefits) also through educational trips and involvement of domestic tourists.

Threats

The **threats** facing the Greek pilot can be divided into legal and regulatory, environmental, and others. For the legal and regulatory threats, it is unclear how Greek Maritime Spatial Planning regulation will develop in the future, and how it will be implemented by local regulators (e.g. threat of future re-zoning of the site), which may affect the co-location of the activities in the future. In addition, the aquaculture license only runs for 10 years. This poses issues as to how its renewability may affect long term planning of the multiuse site. Regarding environmental conditions, climate change poses a serious threat. The unpredictability of extreme weather events or changes in average temperatures will undeniably affect business operations. Finally, there are other threats associated with the current pandemic, which has the potential for continued impact on both partners from associated mobility restrictions, affecting tourism for example. And because of its current impact, there is a threat for slow economic recovery, especially as economic conditions after the pandemic may turn into slow recovery of the tourism market.

Figure 25 SWOT analysis – Greek pilot

Strengths:	**Weaknesses:**
– Two well-established partners (profitable etc.) – Two successful, attractive services/goods – Location of multi-use appropriate for both activities – Local offering (attractive to tourists and domestic customers) – Technical know-how (e.g. offshore monitoring, internal systems) – Safe operations operating with zero accidents	– Unclear legal setting (i.e.. unclear if aquaculture license will be affected by diving) – Both partners are affected by local and global economic situations (especially through domestic and international tourism) – Government delays in putting plans into place (e.g. diving parks) – Public perception of aquaculture is quite poor
Opportunities:	**Threats:**
- Licensing, regulation – potential to work together to access new sites/reduce admin burden. - Potential cost savings related to operations (e.g. boat trips, monitoring) - Potential to develop new activities and revenue streams (e.g. new diving activities, packages) - Potential to improve the social perception of aquaculture (with related benefits) also through educational trips - Potential of continued funding for multi-use (through research projects or from EU /local authorities e.g. EU European Maritime, Fisheries and Aquaculture Fund)	- Aquaculture license only 10 years (renewability) - Unclear how Greek Maritime Spatial Planning regulation will develop, and how this will be implemented by local regulators (e.g. threat of future re-zoning of the site) - Coronavirus - continued potential impact on both partners (reduced tourism) - Climate change – extreme weather events, shifting average temperatures, weather, etc. - Slow economic recovery, especially slow recovery in expenditure on costly activities such as diving - Potential for accident or other events negatively affecting both partners

6.4. Financial analysis

In the financial analysis, we aim to answer the question what the financial impacts of multi-use are. For this, we need to identify a baseline case (or counterfactual) to compare the multi-use case. We believe that the most realistic baseline is a single use of the site by aquaculture. We use this baseline for the following reasons:

- A baseline of no use of the space is a possible relevant comparison in some contexts. However, in the Greek case, the multi-use pilot is being developed in a context where there already exists a use – the aquaculture site.
- Aquaculture could (and did) exist without multi-use (i.e. as an aquaculture farm); the reverse is not true as the site is only of interest to scuba diving due to the aquaculture site.
- The relative size and costs involved with the two activities: The costs and revenue involved with the aquaculture site greatly outweigh the costs and revenues of the scuba diving activity and the expected additional benefits of multi-use.

Having identified the baseline case, in the financial analysis we focus only on costs and revenues that differ between the baseline case (single use: aquaculture) and the multi-use case (i.e. aquaculture and scuba diving).

Table 11 identifies the cost and revenue categories that were identified as potentially being affected by the shift to multi-use for each business. As it shows, almost all direct cost and benefit differences between the baseline of single use: aquaculture and the multi-use case are faced by Planet Blue.

Table 11 Cost and revenue changes for Planet Blue and Kastelorizo due to multi-use

	Planet Blue	Both	Kastelorizo
Costs	Training dive guides	Advertising (including webpage hosting)	*All other impacts on Kastelorizo are indirect, rather than direct e.g. regulatory costs, licensing* *Potentially maintenance/ infrastructure cost savings due to regular monitoring*
Revenue	Revenue from scuba diving		*Indirect revenue impacts due to e.g. increased advertising increasing restaurant revenue*

Summary of finance implications: On Planet Blue side, there are no-cost savings. There are very minimal additional costs associated with establishing diving routes at the new site. In terms of revenue implications, it is challenging to conclude given the lack of evidence due to COVID's huge impact on tourism. However, Planet Blue had considerable additional interest and bookings at the start of the 2021 summer, indicating that the additional dive site would be expected to increase revenue. They estimate that the new site could increase revenue by 10-15%. Given normal (non-COVID) year revenue of approximately 110 000 €, this would be an increase in revenue by 11-16 500 € per year.

On the Kasterlorizo side, no significant direct impacts on costs or revenues were identified. Planet Blue did carry out some monitoring activity at the site, but this was unrelated to the touristic diving activity, so is not considered related to multi-use.

Considering the information presented in this section, it is difficult to evaluate the financial performance of the pilot to determine the feasibility of the pilot. Hence, at this stage, calculation of the financial metrics such as the ROI, the NPV, the debt-to-asset ratio, and the return on equity is very difficult and cannot be done. Further investigation on the different costs and revenues of each activity of the pilot is still needed. This will be done in a future deliverable (D3.3 UNITED).

6.5. Evaluation and Control

The main objective of the Greek pilot has been to evaluate the business case for multi-use case of scuba diving visits to an aquaculture site. Here, we identify some initial conclusions and key considerations for evaluating the business analysis.

- Financial data has been limited and needs to be extended and further analysed in follow-up studies.
- However, the available data has made it clear that the financial benefits of the multi-use case are, in aggregate, relatively small. While they represent a relatively large potential benefit for the scuba diving company (i.e. in terms of their revenue), they are a tiny proportion of the costs and revenues faced by the larger aquaculture partner. This suggests that non-financial benefits may play a significant role in motivating the multi-use case.
- These non-financial benefits include potential legal/regulatory benefits: as identified in the PESTEL and SWOT, the ongoing development of Greek maritime spatial planning policy poses a significant risk to each partner (and potential opportunity for multi-use). We have not evaluated this in this business analysis.
- The non-financial benefits also include societal benefits: the potential for the multi-use activity to improve the public perception of aquaculture was identified upfront by the aquaculture partner as a driver for their involvement; we have not investigated whether this has occurred in the business analysis, and this should be considered in a separate evaluation.

6.6. Conclusion

The business analysis of the Greek pilot has described the two partners' business models and evaluated their combined, multi-use business model. The external setting for the pilot poses some challenges and opportunities. Most pressing and uncertain is the regulatory/political situation related to maritime spatial planning and multi-use. The pilot is also exposed to the external economic setting COVID-19's negative impact on tourism.

Several synergies between the two businesses support multi-use. Most important is the aquaculture farm and location itself, which is attractive to both partners. Both partners share some similar customer segments (domestic and international tourists), offering potential advertising synergies. There is also potential for cost savings due to some overlaps in terms of costs (advertising and boats).

The financial benefits of the multi-use predominantly accrue to Planet Blue. They arise from revenue from scuba diving and some potential cost savings. The financial benefits for Kastelorizo are generally indirect. Overall, the financial benefit of multi-use compared to the baseline case of single use (aquaculture) is relatively small. Both partners can benefit from funding related to research projects.

The business analysis identifies that there are other motivations for multi-use for the partners, including social and legal/political. The aquaculture company sees potential for using diving to improve public perception of aquaculture. There is also a chance that multi-use may be useful for extending licenses to operate. These elements were not investigated in the business analysis.

In terms of general conclusions related to the business analysis, a key issue was setting a relevant counterfactual baseline to evaluate the impact of multi-use. Access to financial data was also a challenge.

7. CONCLUSIONS

The overall aim of this report is to identify and explore what are the potential synergies and/or conflicts, as well as economic risks, from multiuse combined activities and whether, these materialise in additional revenues and/or costs. Fundamentally, this report illustrates an application of the Business Analysis Framework developed under Deliverable 3.2 to five case studies – for each pilot of UNITED. Information was collected from various sources, including past deliverables and interviews with project partners directly involved in the pilots. The collected information consisted of up-to-date descriptions of a) pilots; b) the factors influencing their activities (internal and external); c) different targeted segments as well as value propositions, and d) a description of the financial performance of the pilots (when possible).

Key findings and issues encountered during the application of the framework were discussed in an online workshop with Task 1.3 partners. The main elements of the discussion served as input for the conclusions and are integrated into this section.

Different elements are discussed in this conclusion. First, the factors that led to **multi-use and combination of the activities**. These factors could be historical, legal/regulation reasons where the laws put in place by each Member State motivate the multi-use activity, and/or financial reasons where an activity benefits from the presence of another activity and thereafter reduce installation as well as operation and transport costs.

Second, the **targeted segment** for the pilots. It could be concluded from the case studies that even with the same combined activities, the pilots are targeting different markets. This difference is due to the difference in the distribution channels, and/or the commercial readiness for each pilot. Indeed, for a pilot that is already in a commercial phase, the distribution channel is much bigger and improved than a pilot that is still in a research phase.

Additionally, the conclusion will focus on the **knowledge gaps**. Information to finalize the business analysis for each pilot is still missing. This is true for the financial analysis for each pilot. The acquisition of financial information from each pilot was challenging due to confidentiality issues. Thereafter, the conduct of financial analysis and feasibility study for each pilot was not possible due to the limited information.

Finally, some **key messages and recommendations** are also given in this conclusion.

7.1. Activity combination

The information revealed that most of the pilots with the same activity combinations have the same value proposition for their customers. Table 12 summarizes the combined activities per pilot. For example, for aquaculture activities, the pilot offers locally produced products, and the OWF offers sustainable green/blue energy.

The implementation of activity combinations is related to many factors:

- **Historical reasons**, where a historical event encouraged a combination of activities. This is the case for the Danish pilot. The cooperative responsible for the development of OWF was encouraged to add tourism activity after a visit tour for shareholders.
- **Legal reasons** where new regulations in some countries, notably in Belgium where the new Maritime Spatial Planning regulation imposes to add other activities such as aquaculture in the same marine space for the companies (already occupying marine space);
- **Spatial conflict for the distribution of sea space,** where the limited sea space in the Exclusive Economic Zone for each country motivated the decision-makers to adopt legislation encouraging and motivating multi-use activities.
- **Financial reasons** related to economies made from the multi-use activities. However, from the information presented in the case studies, not all multi-use are benefitting from this cost reduction. The activities already in place (pre-multi-use activities) do not observe any significant reduction in cost due to the combination of activities – the cost reduction is only seen for the added activities, at least in short term. The added activities are benefiting from the already existing infrastructure and/or transportation to offshore infrastructure to reduce cost. On the contrary, for the activities already in place, they are not seeing any significant cost reduction. Rather, for some of them (like the OWF), they are witnessing a slight increase in the costs in some cases, e.g. due to additional costs insurance costs needed.
- **Other economic reasons, such as to increase social acceptability** of certain activities. This is often the case with those activities engaging in multi-use with tourism. For example, in the Greek case study, the aquaculture company sees potential for using diving to improve public perception of aquaculture. In addition, there are **environmental and societal motivations** to engage in multi-use. For example, in the Dutch pilot, the installation of solar panels has the potential to reduce the intensity of waves through the wave dampening effect, which is potentially beneficial for the safety of seaweed cultivation on the plot).

Most of the pilots have similar costs and revenue structures. Costs and revenues of pilots depend largely on the activities combined, for example:

- For the **OWF**, all pilots reported that the major cost is related to the installation, operation, and maintenance of the OWF; the revenue stream is related to selling electricity (note: subsidies for renewable energy production exist for some pilots – depending on the countries in which they are operating).
- For the **aquaculture** activities, the costs are related to the installation, maintenance, and monitoring of aquaculture lines. The revenues are generated by selling products and by-products for different markets (e.g. final consumers, restaurants, pharmaceutical companies, etc.).

Overall and for the identification of the most relevant synergies and conflicts of multi-use in the pilots and strategies to deal with them, the analysis has shown that multi-use projects can benefit from synergies between the different opportunities. These can result in cost savings, for example from sharing transportation, monitoring, and maintenance work, land-based and offshore facilities, staff and training, or insurance premiums. Based on the available data it was not possible to definitively assess the scale of the financial benefits of multi-use. Realising these benefits requires trust and cooperation between different blue economy sectors, which still need to be strengthened in most pilots.

However, the analysis showed that in some cases the financial benefits of multi-use are not evenly shared between the partners. In the Greek and German case, for example, financial benefits will likely not be significant for the already existing activity (i.e. the aquaculture farm in Greece, or the OWF in Germany), but only for the activity that is enabled by multi-use (i.e. the scuba diving tours in Greece, or the offshore aquaculture in Germany).

This highlights the importance of motivating factors beyond financial benefit for realising multi-use projects, such as environmental or social benefits. The Danish, Greek, and German pilots recorded that potentially increased social acceptance is a motivating factor for multi-use. In addition, regulatory benefits could incentivize multi-use, such as easier access to permits or subsidies. Now, only Belgium has a political requirement for multi-use among all cases considered.

In general, political, and legal insecurities with regards to multi-use are a challenge for the scaling up of projects and result in economic risks. Economic risk also stems from the implementation of complex technical projects in harsh offshore environments with little pre-existing experience, especially in the German, Dutch, and Belgian cases.

7.2. Targeted segments

A wide variety of products and services are provided by the pilots due to the combination of different activities. Two market segments can be identified (see Table 12)

- **Macro-segments** target a high number of consumers without any geographic, economic, or demographic preferences. The products and services are targeting most of the population. This is the case for nearly all pilots.
- **Niche segments** could be defined as specific products for a specific group of consumers. This could be the case with luxury products or products used in specific industries (e.g. pharmaceutical companies).

Table 12 Targeted segments per pilot

	Activities				*Value Proposition*	*Targeted segment*
Pilot	Aquaculture	OWF	Tourism	Floating Solar		
DK		x	x		Educational tours on offshore wind/renewable energy; Raising awareness, better acceptance of future OWF projects.	**Macro-segment** (e.g. all customers willing to learn and buy renewable energy).
NL	x	x		x	Production of sustainable raw materials from the North Sea; Production of clean green/blue renewable energy.	**Macro segments** to **niche segments** depend on the demand and the need of consumers (e.g. pharmaceutical industry, biofuels, final consumer).
BE	x	x			Locally produced oysters and seaweed; Production of clean green/blue renewable energy.	Aquaculture: **Niche segment** (luxury product and pharmaceutical industry); Oysters: **Macro segment** (e.g.) restaurants and other consumers OWF: off-takers
DE	X	x			Offering locally produced mussels and seaweed; Production of clean green/blue renewable energy.	Mussels: Currently the German pilot is targeting a **niche market** (e.g. local consumers, gastronomy) due to its small size, but scaling up could lead to targeting the macro-segment
GR	X		x		Sustainable local seafood; Offering local safe recreational activities (e.g. scuba diving).	Tourism: **macro-segment** Scuba-diving: **niche market**

Fish: **niche** and **macro segments** (e.g. local market restaurants and international markets).

From the case studies it is interesting to note that differences exist in the targeted markets, even between the pilots with the same combined activities:

- The Belgian and the German pilots both combine OWF with aquaculture activities. The Belgian pilot targets a very large majority of consumers and industries (e.g. final consumers, restaurants, pharmaceutical companies, etc.). In contrast, the targeted market is focused on a local market near the pilot for the German pilot. The differences in the targeted markets may be related to different factors, be it to the distribution of products and services, and/or the consumers' preferences for aquaculture products.
- The Danish and the Greek pilots where differences exist within the same sector (tourism). In fact, for the Danish pilot that is offering a variety of educational tours that might interest a large majority of the population and the tourists, the Greek pilot is offering more recreational activities (e.g. scuba diving) that might interest only a niche/micro-segment of consumers.

7.3. Knowledge gaps

The work carried out in this task was based on several sources of information. However, information is still missing notably concerning the financial data. Financial information for the pilots is not readily available and, in most cases, confidential. The missing information did not allow the conduct of financial analysis to study the feasibility of each pilot. The information presented in the financial analysis sections presents first evidence on what could be the costs/revenues for pilots and what could be the benefits of multi-use activities. Further investigation on financial data is still needed.

Furthermore, several issues were encountered during the application of the Business Analysis Framework related to:

- **Collection of information and data availability**: The needed information was not always present and needed to be collected from different sources and by interviewing different experts and partners working with the pilots.
- **Testing of products:** For some pilots, the products and services are still in the testing phase and not present in the market. This makes the identification of targeted markets and the costs and revenues of the activity difficult.
- **Non-commercial stage of some pilots:** Not all pilots are commercially operating multi-use businesses yet. Some of the pilots are still in the research phase such as the German pilot that is implementing a demonstration offshore wind and aquaculture multi-use project, which is not set up to be profitable yet, and Belgium and Dutch pilots. Moreover, not all external and internal factors that would influence a commercial multi-use project are relevant to the German pilot. To present, only two pilots are in the commercial phase: the Danish and the Greek pilots. The activities are based on tourism to existing OWF or to already installed aquaculture farms.
- The same **Business Analysis Framework** for all pilots (with different activities) makes it challenging to acquire the needed information.
- **Confidentiality of information**, notably information for the financial analysis. Financial information for most of the pilots is confidential and cannot be communicated publicly.
- **Representation of sectors:** Not all relevant sectors are represented in the pilots, e.g. the German pilot does not have a partner from the offshore wind industry. This made access to relevant information more difficult.

7.4. Recommendations and key messages for future work

Different key messages come out of this report

- **Financial benefits** are not always the only factor motivating businesses to engage in multi-use activities. This is especially relevant because the financial benefits of multi-use are often more significant for one partner than the other. If the multi-use consists of one already existing and one added activity, the financial benefits are often larger for the latter. The benefits are often larger for one activity than the other. This is true for the added activity and not for the activity that is already in place. In the absence of a strong financial motivation for multi-use, other factors such as societal benefits, Corporate Social Responsibility, and/or environmental benefits are important to motivate companies to engage in multi-use
- **Political incentives or requirements** (e.g. subsidies, easier access to permits, requirements for multi-use, etc.) are important to encourage companies to engage in multi-use activities, especially when the financial benefits from multi-use are less significant
- Multi-use projects often depend on **existing investment** decisions and/or **existing infrastructure** (e.g. existing OWF or aquaculture infrastructures). In these cases, the baseline for the evaluation of multi-use is not an absence of activity but rather the existing use of marine space.
- Looking at conservation goals and rewilding, to **achieve a set number of activities**, the only way a full additional activity can exist within reduced space is by interlacing and combining activities – desired economic activity within confined space (compliance with policy and limits).
- **Multi-use depends on an effective, trusting relationship between partners from different industries**, especially in the early testing/piloting stages.

7.5. Next Steps and Limitations

This report has explored the business case for ocean multiuse through the application of a business framework analysis in the UNITED pilots. This work is linked with **Task 1.3 Optimise business cases and requirements definition** and **Task 3.3. Application of assessment framework within pilots**. This work will feed into the following deliverables of the project: **D3.3: Assessment of the added value of MUCLs within pilots** and **D3.4: The Business Case for Multi-Use Platforms: Costs, Benefits, and Lessons from Practice**.

In this respect, the different tests conducted illustrate many arguments for the financial viability of multi-use. However, it has been difficult to evaluate the financial performance of the pilots to determine their business feasibility. Hence, at this stage, calculation of the financial metrics such as the Return on Investment (ROI), the Net Present Value (NPV), the debt-to-asset ratio, and the return on equity is very difficult and cannot be done accurately because of lack of information. Further investigation on the financial performance of each activity once multiuse is fully operational and matured would still be needed to run these financial tests.

This report nevertheless has also identified that there are other types of benefits and costs, beyond those of a market nature, that are important for some sectors to engage in multiuse activities with other sectors. This can take the form of environmental or social benefits. These will be explored in a future deliverable (Deliverable 3.3 of the UNITED project), which will aim to explore the societal added value of multiuse.

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9. ANNEX I – SEMI STRUCTURED QUESTIONNAIRE

9.1. Section 1: Pilot overview

1) What is the pilot's objective?

___

___

2) What is the pilot's mission and vision?

___

___

3) What are the pilot's goals to be achieved?

___

___

4) Who are the pilot's owners/partners?

Company/institution	Role in the pilot	Main interest to join in the pilot	Contact person

5) What are the services provided by the pilot's owners? Can you give a description of the: provided technologies and TRL levels?

___

___

6) What are the combined activities and why the pilot chose to combine these activities? What are the compatibility of activities and expected synergies?

___

___

Compatibility of activities	Expected synergies

7) What is the current TRL of the MUCL and what TRL is expected to reach at the end of the pilot?

___

___

8) What is the strategic roadmap that the pilot will undertake to reach the targeted TRL level?

___

___

9) What are the technological and business requirements to reach TRL target?

___

___

9.2. Section 2: Identifying risks and barriers

1) PESTEL analysis

a) What political factors are happening that could influence (favorable/unfavorable) the pilot? What governmental policies and actions are likely to affect the pilot? What changes are likely in governmental policies are likely to affect the pilot?

___

___

b) What economic factors are happening that could influence (favorable/unfavorable) the pilot? Are there any economic trends or indicators that are favorable/unfavorable towards the pilot? Are there any economic/financial changes, in the future, that could affect the pilot?

___

___

c) What social factors are happening that could influence (favorable/unfavorable) the pilot? What key influences are affecting people's attitudes and behavior in ways that might affect the pilot? Are there trends discernible in particular groups that have implication on the pilot? What social changes in the future could have impact on the pilot?

___

___

d) What technological factors are happening that could influence (favorable/unfavorable) the pilot? What emerging technologies might have impact on the pilot? Will any changing technologies have an impact on political or economic events with implication for the pilot?

___

___

e) What environmental factors are happening that could influence (favorable/unfavorable) the pilot? What are the effects of the pilot on the environment?

___

___

f) What legal factors are happening that could influence (favorable/unfavorable) the pilot? What regulations/laws, in the future, could have an influence on the pilot? What regulations are limiting the development of the pilot?

____

____

2) Business Model Canvas

a) What is the customer segment (e.g. single market or multi-sided market)? Is the pilot targeting the macro segment (e.g. overall customers) or micro segments (e.g. individual customers)? What job/services is the pilot providing for the customers? What needs are the pilot fulfilling?

____

____

b) Which of the problems/needs identified in the customer segments are the pilot fulfilling? What is unique about the pilot value propositions and why does the customers prefer them to their current alternatives? What things do the pilot do that actually cause a customer to pick the pilot products over a competitor or alternative?

____

____

c) What are the channels to reach customer? How does the pilot deliver goods and services? What is the best way to reach customers and deliver goods and services provided by the pilot?

____

____

d) How does the customer interact with the pilot throughout the sales process? Do they have dedicated personal contact? What is the relationship between the pilot and customers?

____

____

e) What are the strategic assets that the pilot need to deliver value? What are the key resources of the pilot to compete?

____

____

f) What are the key activities that the pilot must complete to deliver the value proposition to the customers? What are the key services?

____

____

g) Who are the key partners which the pilot relying on to carry out the key activities and deliver value to customers? Who are the key suppliers?

____

____

h) What is the cost structure of running the pilot to achieve its goals? What are the major cost drivers? How are they linked to revenue? What are the fixed costs and the variable costs?

____

____

i) How does the pilot earn revenue from the value propositions? What are the revenue streams of the pilot? Which one has the largest proportion?

____
____

3) SWOT analysis

a) What are the strengths that give the pilot an advantage over others? What is the unique selling point of the pilot? What is the pilot competitive edge? What does the pilot do better than other organizations/companies with similar activities?

____
____

b) What do other companies with similar activities do better than the pilot? What element of the pilot adds little or no value? What are potential improvements?

____
____

c) What political, economic, social, technological environment or legal changes are happening that could be favorable to the pilot? What trends could the pilot take advantage of? What new innovations could be brought to the market?

____
____

d) What political, economic, social, technological environment or legal changes are happening that could be unfavorable to the pilot? What is the pilot competitor doing that could negatively influence the pilot?

____
____

9.3. Section 3: Other information

1) Is there any other information need to be added? If yes, please specify:

____
____

10. ANNEX II – FINANCIAL TEMPLATE

	Pre Multi-use		Post Multi-use	
	Cost in €/year	**Comments**	**Cost in €/year**	**Comments**
Costs categories				
Operation & maintenance cost of OWF				
Installation of OWF				
Trasnport cost (fuel, boat rental, etc.)				
Personnel cost				
Installation of Oyster Spat				
Starting material for seaweed				
Insurance cost				
Monitoring cost				
Operation & maintenance cost for aquaculture activities				
Operation & maintenance cost for seaweed farm				
Concession cost				
Processing and packaging cost				
Cost on onshore building				
Decomissioning cost				
Other Costs (please specify in the comment column)				
Other Costs (please specify in the comment column)				
Other Costs (please specify in the comment column)				

Revenues categories	**Revenue in €/year**	**Comments**	**Revenue in €/year**	**Comments**
Revenues from selling Electricity				

Government subsidies for OWF				
Revenues from selling seaweed products				
Revenues from selling food products				
Revenues from selling by-products				
Revenues from selling oysters				
Revenues from tourism activities				
Other Revenues (please specify in the comment column)				
Other Revenues (please specify in the comment column)				
Other Revenues (please specify in the comment column)				

Assets

Short-Term Assets

Cash	
Treasury bills	
Marketable securities	
Short-term investments	
Inventories	
Accounts receivable	
Pre-paid expenses	
Other	
Total Short-Term Assets	0,00 €

Long-Term Assets

Property and equipment	
Leasehold improvements	
Equity and other investments	
Less accumulated depreciation	
Long-term investments	
Intangibel assets	
Total fixed assets	
Total Long-Term Assets	0,00 €

Liabilities and Shareholders' Equity

Short-Term Liabilities

Accounts payable	
Accrued wages	
Accrued compensation	
Income taxes payable	
Unearned revenue	
Other	
Total Short-term Liabilities	0,00 €

Long-Term liabilities

Mortgage payable	
Total Long-Term Liabilities	0,00 €

Stakeholders' Equity

Investment capital	
Accumulated retained earnings	
Total Shareholders' Equity	0,00 €

Other Assets

Goodwill	
Total Other Assets	0,00 €

11. ANNEX III – T1.3 ONLINE MEETING/WORKSHOP AGENDA

European Union funded project as part of the Horizon 2020 BG Initiative: Grant Agreement 862915
T1.3 meeting
2nd of December
Online meeting via Zoom

UNITED T1.3 coordination meeting

Thursday 2nd of December 2021

Online Meeting

AGENDA

Day	Time	Item
Thursday 2nd of December	10h00	Opening the meeting & welcoming participants (ACTeon)
	10h10	Recalling the objectives of Task 1.3 and the Business Analysis Framework (ACTeon)
	10h20	Presentation and discussion of key findings per pilot: • BE pilot (ACTeon) • DK pilot (ACTeon) • DE pilot (Ecologic) • GR pilot (Ecologic) • NL pilot (WUR)
	12h00	Lunch break
	14h00	Discussion on the main findings (ACTeon)
	16h00	Structure of the final deliverable and deadline (ACTeon)
	16h15	Next steps
	16h30	End of the meeting

12. ANNEX IV – QUESTIONNAIRE – COVID-19 IMPACT ON BLUE ECONOMY

1.) In which sectors of Blue Economy would you see your UNITED pilot activities:

- *floating solar*
- *diving tourism*
- *mussel aquaculture*
- *fish aquaculture*
- *flat oyster aquaculture*
- *seaweed cultivation*
- *offshore wind energy*
- *tourism*
- *marine/maritime research*
- *Other (please specify):*

2.) What is your company's role in UNITED? Who are you working with in the pilot?

3.) Tell us about your company…

a) Is your company an SME? Y/N

b) About its size:

  a. Turnover per year in Euro/year

  b. Total number of employees (full time equivalents)

  c. What is the gender balance (female/male workers ratio)

  d. What is the ratio between technical/specialized workers versus administrative workers.

c) What goods and services does your company provide?

d) Who are your costumers or who do you sell these goods and services to?

4.) Has your company been negatively impacted by COVID-19? How?

a) Have you encountered less demand for your products/services? have you seen a decrease in quantity of sales?

b) Have you seen operation costs rise?

c) Have you encountered supply chain disruptions? or delay in operations?

d) Have you seen a decrease in prices for your products/services?

e) *Because of COVID related restrictions, have you experienced shortages of qualified personnel for important tasks?*

f) *Other: please include any other negative impacts*

5.) Have you experienced any positive impacts due to COVID-19?

a) *Have you experienced higher demand for your products/services? have you seen an increase in quantity of sales?*

b) *Have you seen operation costs drop (e.g. maintenance, other)?*

c) *Have you seen an increase in prices for your products/services?*

d) *Other: please include any other positive impacts*

6.) How has your company coped with these impacts since the beginning of the pandemic?

a) *Has it developed a strategy for this?*

b) *How successful has your company been in dealing with negative impacts/ taking advantage of positive impacts? Please name examples of coping activities*

c) *Have you received state aid/ sectoral funding? (Could you elaborate on the different national support actions?)*

d) *Were employees sent into short time work*[63] *or were even dismissed?*

e) *Did you cancel any planned investment in your company's infrastructure and/or production due to the COVID-19 outbreak?*

7.) What further impact do you expect beyond 2021/2022?

a) *For instance in terms of employment, investments, revenues…*

b) *Are you prepared to deal with it? How?*

c) *When do you think, your company's operations will return to 2019 levels?*

[63] Short-time working or short time (in German: Kurzarbeit, In Belgium: tijdelijke werkloosheid) is a governmental unemployment insurance system in which private sector employees agree to or are forced to accept a reduction in working time and pay, with the state making up for all or part of the lost wages.

8.) With your experience in MULTI-USE[64], does it help to adapt to the situation?

a) *What are your thoughts about how multi-use may help to increase financial resilience in the face of a crisis situation?*

b) *Are your activities more resilient as you may target multiple markets as part of the combined activities? Or are you more exposed because more complexity is added than targeting single markets?*

c) *Could negative impacts been softened/increased by Multi-Use? (If yes, can you explain, why?)*

d) *Could positive impacts been softened/increased by Multi-Use? (If yes, can you explain, why?)*

e) *Does multi-use increase or decrease the potential for government support?*

9.) Have there been any national support measures for your activity or sector?

a) *For example if the government wants to ensure that your company survives until post pandemic, then what would be most useful?*

b) *For example if the government wants to ensure that your company continues to employ workers, what would be most useful?*

c) *Or, for example if the government wants to ensure support investment, what would be most useful?*

d) *Specific choices, (please allow respondents to cover as many as they think necessary)*

- *Deferral of taxes, duties and other expenses*
- *Exception of taxes, duties and other expense-related obligations*
- *Enlargement of your credits by your bank or financial institute*
- *Direct state aid*
- *Change of labour laws (support for part-time workers)*
- *No support measures are necessary at the present moment*
- *Other (please specify)*

10.) For your activity or sector, which support measures at national level do you think are most necessary in the current situation?

a) *For example if the government wants to ensure that your company survives until post pandemic, then what would be most useful?*

[64] Definition of Multi-Use in UNITED: The term ocean multi-use will be used to refer generally to multi-use, including but not limited to co-location in maritime platforms.

b) For example if the government wants to ensure that your company continues to employ workers, what would be most useful?

c) Or, for example if the government wants to ensure support investment, what would be most useful?

d) Specific choices, (please allow respondents to cover as many as they think necessary)

- *Deferral of taxes, duties and other expenses*
- *Exception of taxes, duties and other expense-related obligations*
- *Enlargement of your credits by your bank or financial institute*
- *Direct state aid*
- *Change of labour laws (support for part-time workers)*
- *No support measures are necessary at the present moment*
- *Other (please specify)*

11.) What do you think about the role the European Parliament/Commission is playing in answer to the crisis generated because of the pandemic?

a) *Do you welcome green growth recovery plans?*

b) *Any specific advise/recommendations?*

12.) Anything else you would like to add or suggest?

13. ANNEX V – UNITED COVID-19 NOTE

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THE IMPACT OF COVID-19 ON UNITED BLUE ECOMONY BUSINESSES

Work Package 3
Economics of Multi-Use Platforms

Date: 26.08.2021

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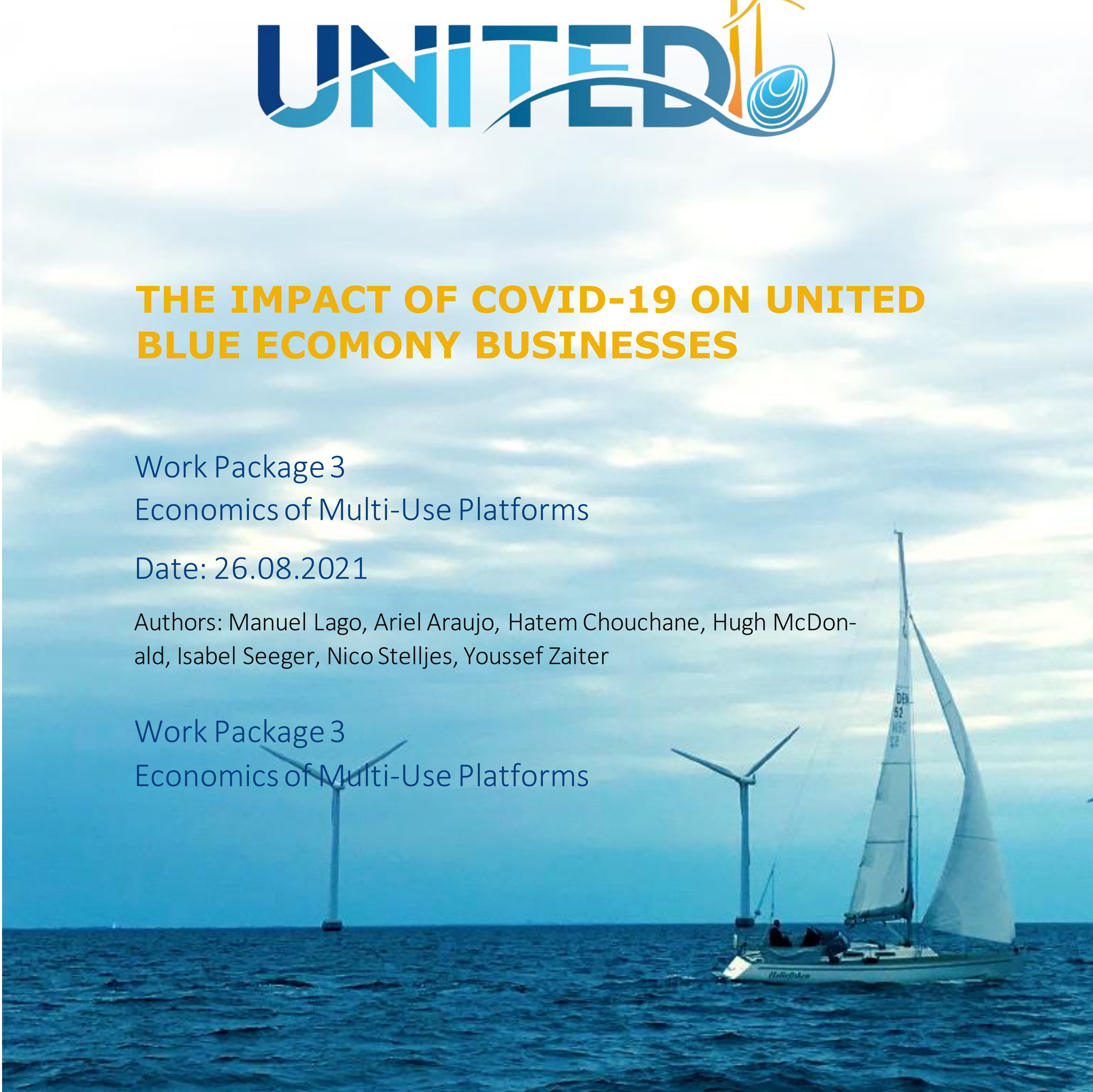
Work Package 3
Economics of Multi-Use Platforms



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Introduction

The Covid-19 pandemic and its associated restrictions is having huge impacts on all economic sectors worldwide, the blue economy included. While the Covid-19 crisis continues to evolve, the first evidence of its impacts is becoming clear. In this brief, we draw on interviews with 10 offshore businesses - covering tourism, aquaculture, marine technology and seafood - to investigate how Covid-19 and the government responses have been felt by EU blue economy businesses.

The blue economy has been seriously affected by Covid-19. Just examining one sector, a recent European Maritime Safety Agency (2021) report found that in 2020 marine traffic in the EU fell by 10.2% compared to the previous year, with shipborne EU trade falling by more than 9% over the same period. This exceeds the estimate global impact of a 4.2% decrease in global trade in 2020 (UNCTAD, 2020). The decrease in marine traffic occurred was felt more strongly by some types of ships. March et al. (2021) found that passenger ships were dramatically affected, with the density of passenger ships on global waters declining by an average of approximately 20% across April-June 2020. Over that same short period, globally, there appeared to be little negative impact on fishing vessels and smaller negative impacts on cargo and tanker ships (March et al. 2021).

Covid-19 and its associated restrictions, along with the indirect impacts of the economic downturn, affected all blue economy sectors. However, some were affected more strongly than others. The European Commission's 2021 Sustainable Blue Economy report found that the marine technology and offshore energy sectors appear to have fared the best, with medium to small impacts and swift recoveries (European Commission, 2021). The situation looks very different for the coastal tourism industry (and associated hospitality and accommodation sectors), which was strongly impacted and is still yet to recover. The shipbuilding and repair industry has also been hit hard. The impact within Europe has been particularly high, due to the importance of cruise ship construction, with orders for cruise ships dropping by 34% in 2020 (EMSA, 2021). All other sectors were strongly affected, though most were expected to see relatively prompt returns to previous levels of activity. However, as identified by van Tatenhove (2021), these recoveries will depend on EU policy responses over the medium-term. With a longer-term vision and the right actions, the recovery can even contribute towards building a sustainable ocean economy (Northrop et al, 2020).

The H2020 project UNITED has partners across the blue economy. In this note, we draw on their experiences to translate these headline Covid-19 affects into impacts on real businesses. In addition to assessing how the different companies fared over the last year, we also asked them to evaluate government responses and identify opportunities for a stronger recovery. Given the project's focus on multi-use of marine space, we also assessed whether multi-use increases businesses' resilience in situations of crisis. This brief summarises key messages and recommendations on Covid-19's impact on the blue economy – and how to recover.

MethodologY

A questionnaire was developed (see Annex I) and shared with all companies included as partners in the UNITED project. The questionnaire was developed by members of the UNITED-Team from a Business and Economic perspective (nested in Tasks 1.3. and 3.3.). The written questionnaires were followed up by semi-structured interview, if clarification or further information was needed. Then a synthesis of the results for each company was prepared (see Annex II).

The questionnaire includes a total of twelve leading questions with sub-questions. Of special interest for UNITED is question eight regarding whether and how multi-use impacts businesses' resilience in the face of crisis situations. The economic sectors addressed with the questionnaire follow from the different pilots and their maritime activities within UNITED (see Figure 1). Our results cover the eight specific sectors of UNITED: floating solar, diving tourism, mussel aquaculture, fish aquaculture, flat oyster aquaculture and restoration, seaweed cultivation, offshore wind energy, and tourism. In total, eleven companies responded to the questionnaire.

This exercise is of explorative nature with mainly open-ended questions. It is not intended to give a definite picture of the impacts of the Covid-19 pandemic on the Blue Economy as a whole or any of its sectors. Instead, this note serves as a snapshot of the situation of single businesses that are part of the UNITED project.

Figure 1: location and sector of the five UNITED pilots[65]

Overview of the UNITED companies

Kastelorizo Aquaculture (Greece) is a Greek SME which is producing and selling fish and shellfish in Greece and abroad. They are operating two aquaculture farms, as well as seven restaurants. The company has about 98 full-time employees (30% female, 70% male) and an annual turnover of €5.4 million (2020).

Planet Blue (Greece) is a diving center based 60km south of Athens, offering diving tours for groups and individuals and Remote Operating Vehicles (ROVs) services for mapping, inspection and repair of aquacultures. Planet Blue has two full time employees (50% female, 50% male) and an annual gross turnover of €110K Euro.

The **Kieler Meeresfarm (Germany, short: KMF)** operates a near-shore mussel in the Baltic Sea. They serve both the gastronomy sector as well private clients. The business has three self-employed founders who work full time (33,3% female, 66,6% male) and an annual turnover of €30K-€50K Euro.

4HJena Engineering (Germany) provides marine technology for offshore measurements and monitoring. They have about 40 employees (40% female, 60% male).

SPOK (Denmark) is a consulting company active for the offshore renewable energy sector. The CEO of SPOK is shareholder and Board Member of the cooperative which owns ten turbines of the Middelgrunden wind farm and is also responsible for the program organizing touristic excursions to the windfarm. SPOK has two full-time employees (50% female, 50% male) and a yearly turnover of €43K.

The Seaweed Company (Netherlands) was founded in 2018 and specializes in developing high-value products for humans, animals, soils, and plants and cultivating traceable seaweed species commercially. The Seaweed Company has its seaweed production locations in Ireland, Morocco, India and The Netherlands and has developed products that contribute to sustainable agriculture. The Seaweed Company is actively involved

[65] Source: https://www.h2020united.eu/pilots

with innovative research around applications in the medical field (Alzheimer and diabetes), functional food (alternative proteins), sustainable materials (natural composites) and sustainable seaweed cultivation methodologies. It is currently developing projects in the Dutch part of the North Sea".

North Sea Farmers (Netherlands) is a non-profit organization that aims to create a network between seaweed engineers, entrepreneurs, policymakers, pioneers, fishers and researchers within the seaweed sector of the Netherlands. They support both small and big initiatives that collaboratively work toward building a 400 km2 seaweed farm in the North Sea. The company have seven full-time employees (70% female, 30% male) and a turnover of €1 million".

ParkWind (Belgium) finances, develops and operates offshore wind farms. They are currently operating four wind farms in the Belgian North Sea. The company has the full time equivalent of 118.20 PTE employees (38% female, 62% male) and an annual turnover of €30.40 million (2020).

The JanDeNul Group (Belgium) provides engineering services for the construction and maintenance of maritime infrastructure, such as artificial oyster reefs and offshore longlines for aquaculture. The company has more than 6000 employees.

The Colruyt Group (Belgium) is a large retail company offering various goods and services including food products such as fresh fish, mussels and oysters. They also own several non-food shops gas stations, an energy company and a catering company, among others. They have more than 3600 employees and a yearly turnover of €9.6 billion.

Brevisco (Belgium) engages in mussel aquaculture, flat oyster aquaculture, and seaweed cultivation. They offer support to other aquaculture businesses and participate in innovation projects, but also have their own production. The business has eight employees (25% female, 75% male) and an annual turnover of €301.972,71.

Synthesis of results

Negative impacts of the Covid-19 pandemic

Unsurprisingly, all surveyed blue economy companies reported some negative impacts due to the pandemic. In this section, we summarise key takeaways from the interviews:

Tourism-exposed industries hit particularly hard: Restrictions on tourist travel and activities, such as entry bans or limited number of people allowed on boats, directly affected two of the surveyed respondents: SPOK, which hosts visitors to its wind farm, had to stop all of its touristic activities. The diving company Planet Blue in Greece could only open for four months between the start of 2020 and June 2021. As a result, staff members went into part time.

Food industries bear the flow-on effects of pandemic-related restaurant and tourism restrictions: All four food-related companies surveyed had seen significant decreases in demand for their products. KMF saw a 70% decrease in customer demand for their mussels, due to lockdown coinciding with harvest season. Kastelerizo, Brevisco, The Seaweed Company and Colruyt also saw lower demand for their maritime food products, as restaurants and catering companies were either closed or faced limitations on the number of people allowed per table.

Increases in costs affected all blue economy businesses: Covid-19 and the accompanying regulatory restrictions created new costs for many businesses, such as testing and costs associated with working from home. Some businesses reported that regulations in response to Covid-19 also generated costs by reducing the efficiency of work, for example, regulations limiting the number of employees on a ship meant that some routine work practices took longer or repeated trips had to be made.

Supply chain costs and delays affected the bottom line across the sector: Increases in costs in other sectors also flowed down the supply chain. For example, two respondents pointed to the increase in container ship transport costs as a significantly increasing their own costs. Brevisco, Planet Blue, 4HJena and Colruyt all reported significant supply chain disruptions, with consequent delays in their own work. Reasons for disruptions were for example due to closing of borders, quarantines and hamstering in the food shops.

Finding qualified staff was a challenge across the sector: Colruyt, Brevisco and Parkwind reported that travel restrictions meant there was a shortage of qualified personnel for important tasks, delaying work plans.

Lockdowns got in the way of work: Lockdown restrictions blocked some companies from carrying out essential activities, for example, The Seaweed Company reported that two harvests were missed during the pandemic as they were not allowed to travel. Brevisco and Colruyt faced similar issues.

Positive impacts of the Covid-19 pandemic

Of the surveyed respondents, five had nothing positive to say about the pandemic's effect on their business. However, a few companies were able to identify positives aspects, which included:

Covid-19 increased flexibility and made time for secondary priorities: Three of the companies identified that home-office and online meetings increased employee flexibility and the level of trust between employers and employees. One respondent, the KMF, also identified that the lockdown created more time to focus on research projects, which otherwise they find it difficult to prioritise.

Two companies reported stronger-than-normal business: 4HJena saw increased prices and sales for its technology and software products. Colruyt reported that an increase in sales for its food products was noticeable. Reasons for the increase was hamster shopping in the food shops and customers seemed to prefer local food products instead of the non-local alternative. A third company, the Kieler Meeresfarm, which saw lower prices and demand during the pandemic, remained nevertheless hopeful that there would be a positive bounce back, with increased demand following lockdown due to customers being happy that the business was open again.

Coping mechanisms: what worked and what did not work, as well as plans for the future

None of the UNITED companies questioned went out of business during the Covid-19 pandemic. Besides national government support, which will be discussed in the next section, they deployed several coping mechanisms to stay afloat:

Developing novel approaches to business helped soften negative impacts: The pandemic forced companies to develop novel approaches to business in order to stay afloat during the crisis. The KMF introduced collective orders for their mussels allowing them to reduce expensive food testing costs and SPOK developed virtual visits to their offshore wind farm while touristic operations were shut down. Planet Blue implemented a strong advertising campaign, hoping that demand for their scuba diving services will increase once the tourism restrictions are over. Some companies are also expecting to permanently shift their business strategies in response to the pandemic: the KMF to wants to increase the share of end consumers from 30% to 50% to be less reliant on gastronomy.

Some businesses were able to shift revenue or delay investments: While this is not possible for all businesses, some were able to shift revenue to the future. The KMF will be able to sell the mussels that could not be harvested due to the pandemic in the next year, even asking a higher price for these premium mussels. The risk associated with letting the mussels grow longer is that they might leave the farm during a very warm summer, in case of which the revenue would be lost. The KMF was also able to partially postpone planned investments for increasing the mussel farm size. This allowed them to reduce limit costs while their income is compromised by the pandemic, but will also negatively increase future revenue. Other businesses, such as Brevisco, did not need to cancel any planned investment or production due to the Covid-19.

Staff management during the pandemic differed strongly between businesses: Some companies such as SPOK, Park-Wind and Brevisco did not send any employees into short time work. Others, such as the JanDeNul Group, Kastelorizo and Planet Blue, did. These employees received state aids for short time work. The JanDeNul Group, a large company, set up a dedicated Covid-19 department where employees could ask questions. Colruyt only send very little employees into part time work, but shifted staff between the different sections of the company. In a very different case, the three KMF staff, which are all self-employed, had to take on temporary jobs outside the blue economy to secure an income.

Some companies will bounce back to pre-pandemic levels sooner than others: One company (4HJena) has already returned to 2019 levels, whereas some others are hoping to do so in the near future. Brevisco is expecting to return to normal levels of operation by 2022 and also Planet Blue is hoping to resume pre-Covid-19 activity levels as soon as restrictions on the tourism sector are lifted. The Seaweed Company thinks that they will encounter a significant financial risk and short-term cash challenges in case the situation of the pandemic will continue beyond 2021/2022.The KMF will only return to pre-pandemic levels in 2023, because they had to partially delay increasing the size of their farm and will thus only be able to obtain a larger harvest at a later point. The recovery of most of the companies heavily depends on the further development of the pandemic.

Smaller business had more flexibility in adjusting to the pandemic: While being a larger business offered some advantages during the pandemic, two small business (KMF and North Sea Farmers) have nonetheless indicated that being small has the advantage of being highly flexible, therefore adjusting more easily to the Covid-19 crisis.

Role of multiuse to increase resilience?

Regarding whether and how multi-use can increase resilience in crisis situations, the answers from the companies strongly varied. While some held that multi-use can increase resilience, others found that it actually renders a business more vulnerable. Some companies saw no relation between multi-use and resilience to crises, like The Seaweed Company or North Sea Farmers.

Multi-use offers opportunities for diversification, which increases resilience: Multi-use can be advantage when faced with a crisis situation, because if offers the opportunity for diversification and thus helps to prevent a 100% loss, as KMF stated. Also, Planet Blue benefitted from diversification during the pandemic. While their scuba diving activities were shut down, they continued their ROV (Remote Operated Vehicle) business for emergency or critical projects, thereby even increasing the size of their target market and consequently potential revenues.

Multi-use can help navigate operational challenges: Multi-use also facilitated the combination of activities in order to counter operational delays caused by the pandemic. For example, the JanDeNul group reported wind farm maintenance and seaweed harvesting trips were combined, thereby softening negative impacts of the pandemic on the seaweed harvest.

Multi-use might increase access to government support: However, Kastelorizo sees their involvement in multiuse activities as an opportunity to for increased access to government support, as the combination of aquaculture and tourism might be of greater interest to the government than aquaculture alone.

Realising the benefits of multi-use is not always feasible in practice: Others agree that generally multi-use can increase the resilience of a company, but note that this is not always feasible in practice. Kastelorizo pointed out that the multi-use of aquaculture and touristic expeditions ceased during the pandemic, due to the government restrictions placed on scuba diving.

Multi-use adds complexity, which may leave companies more vulnerable: Companies with a rather sceptical view mentioned, that multi-use likely leaves companies more exposed in situations of crisis, because it renders their activities more complex, like SPOK or 4HJena reported.

Multi-use not always softens the negative impacts of a crisis situation: While some companies indicated that multi-use helped them overcome the challenges due to the pandemic, others such as Brevisco or 4HJena felt that negative impacts were not softened by multi-use.

Recommendations for support measures from their perspective at MS level and EU level

Most of the UNITED business received some kind of support during the pandemic and hope for further support in the future, from both national governments and the EU:

All countries had some support measures for the blue economy in place: The national support measures offered to the blue economy sector includes deferral or exception of taxes, duties and other expenses, direct state aid, enlargement of credit, as well as support for short-time or suspended workers. However, the availability of specific measures varied by country.

Some companies received no government support, although for varying reasons: While national support measures of some form were available in all countries, not all companies received them. The reasons for this are varied: The KMF was not eligible due to a recent company restructuring and SPOK did not receive support due to the income from the UNITED projects and 4HJena and North Sea Famers did not require national support for their companies.

National government support is not the sole option: The KMF indicated that good personal relations helped it immensely in dealing with the pandemic. These have enabled it to enlarge their farm besides their difficult financial situation: With the help of contacts in the area they were able to buy used anchor stones and rent a crane that was already in the area, thus saving costs.

Companies believe that a range of support measures are necessary in the current situation: Those companies, which require national support, largely believe that further exception or deferral of taxes, duties and other expenses, as well as direct state aid measures are most necessary in the current situation. For other companies, such as the KMF or Kastelorizo, the enlargement of credit is a priority, as they currently have difficulties obtaining loans.

There is a wish for increased government support for the sustainable blue economy: Many of the companies interviewed expressed their wish for more government investment into the sustainable blue economy. Specifically, SPOK spoke about releasing funding for specific studies related to offshore renewable energy and Brevisco mentioned increased support for innovation projects. There is also a wish for their governments to advertise their national blue economy both locally and internationally and provide incentives and stable legal and taxation rules, which will attract foreign investment, as expressed by Planet Blue.

The EU green growth recovery plans are widely welcomed, though there is hope for further support of innovation: The companies held largely positive opinions about the green growth recovery plans by the European Union and especially hope that there will be significant investment into innovation and research for the blue economy. SPOK specifically expressed that they hope for funding for offshore demonstrations of multi-use renewable energy projects. 4HJena and ParkWind welcomed the plans, though they stated that more could have been done prior to the Covid-19 crisis to support the blue economy.

Conclusions

As stated in the introduction, the blue economy has been severely impacted by the Covid-19 pandemic. This corresponds with the findings of our interviews with selected UNITED businesses. The tourism and aquaculture sector were hit especially hard by restrictions as a response to the pandemic, but also businesses in the other sectors suffered from increased operational costs, supply chain disruptions and difficulties in finding qualified staff. The positive effects of the pandemic reported in the interviews are very limited.

Although Covid-19 challenged the UNITED businesses, none of them had to file for insolvency. In order to stay afloat in the past one-and-a-half years, the companies employed different coping mechanisms, such as developing novel approaches to business, exploring diversification opportunities or delaying investments. Other relied primarily on national government support such as direct state aid or sending employees into short-term work. Companies' expectations of national support are mainly directed at monetary aspects. These can include, for example, simplifications in the procurement of external capital, tax reductions or direct state financial support. With regards to the EU, businesses widely welcome the EU green growth recovery plans, but are hoping for further investment into the blue economy as a whole and innovation specifically.

Most companies expect to get back on 'normal' levels of business in a time span of one or two years, whereas others have already reached pre-pandemic levels again. Their recovery if of course conditional upon the absence of renewed pandemic-related restrictions. It remains to be seen whether the pandemic permanently shift the manner in which companies do business, for example, whether the practice of remote work continues or whether products and services developed specifically during the pandemic remain on offer. When asked about the influence of multi-use on their ability to cope with crisis, companied gave varying responses: Whereas some stated that multi-use can increase resilience, others stated that on the contrary, multi-use could lead to more complexity and is counter-productive to building businesses resilience.

It also became apparent, that different sectors in the Blue Economy are affected differently and that even within a single sector impact can differ. For example, KMF reported from an almost completely decrease in their sales of shellfish, Colruyt reported an increase in their aquaculture sales. In order to understand how the Covid-19 pandemic impacted - and continues to impact - blue economy businesses, further research is necessary. This note made a first step by detailing the impacts on eleven UNITED blue economy businesses and exploring how they coped with the challenges.

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