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DELIVERABLE 7.5

HARMONIZATION OF RESULTS AMONG PILOTS

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Author(s)	Nancy Nevejan, Zinzi Reimert, Dirk Vandercammen Eva Strothotte, Tim Staufenberger, Jessica Knoop, Alex Ziemba, Evaggelia Labrakopoulou, Hans Soerensen, Ivana Lukic, Sam Desmet, Annelies Declercq
Editor	Nancy Nevejan
Approved by	Ghada El Serafy
Abstract	Deliverable 7.5 summarizes what has been applied and achieved in the pilots in the pre-operational and operational phase. A total of 4 categories of characteristics are covered, relating to (1) infrastructure, (2) operation, (3) environmental impact, and (4) markets for goods and people. Based on the experiences of the pilots, common

	denominators were identified and reformulated into recommendations for future commercial multi-use operations
Keywords	Design concepts, recommendations for future multi-use development, synergies, operational challenges
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ACRONYMES

FuE	Forschungs und Entwicklungszentrum Fachhochschule Kiel GmbH
JDN	Jan De Nul
NSF	North Sea Farmers
OWF	Offshore Wind Farm
Park	Parkwind
ROV	Remotely Operated Vehicle
SPOK	SPOK consultants
UGent	Ghent University
UNITED	multi-Use platforms and co-locatioN pilots boostIng cost-effecTive, and Eco-friendly and sustainable proDuction in marine environments
Wings	Wings-ICT-Solutions
WP	Work package

EXECUTIVE SUMMARY

This Deliverable 7.5 reflects the internal project management structure of the UNITED project as described in the project proposal. Within WP 7, the primary objective of Task 7.3 "Post-operational phase", is to carry out a final analysis and overview on what elements will create economic and social synergy effects and to what extend benefits can be expected for each user when following the developed blueprint. Secondly, the decommissioning procedures will be specified. The purpose of this Deliverable 7.5 is to report the results of the subtask 7.3.1 which aims to harmonize the results among the pilots.

It summarizes what has been applied and achieved in the pilots in the pre-operational, operational and to a limited extend the post-operational phase. The later will be extensively described in D7.6. The activities that took place in the pilots were characterized into 4 categories, relating to (1) infrastructure, (2) operation, (3) environmental impact, and (4) markets for goods and people. This corresponds very well with the 5 pillars that run through the project, whereby legal aspects are touched upon in the category "operation".

While a full description of the pre-operational phase and operational phase of the different pilots can be found in D7.1 and D7.2 respectively, this exercise limits itself to the description of the major negative and positive experiences of the pilots while carrying out their activities. As such it reflects an internal evaluation of the demonstration platforms, whereby the aspects belonging to the 4 above mentioned categories are covered. However, Task 7.3.1 goes one step further and, based on the experiences of the pilots, common denominators were identified and reformulated into recommendations for future commercial multi-use operations.

The harmonization of the results will then feed into WP8 which will validate and assess the proposed solutions.

1. INTRODUCTION

1.1. AIM DELIVERABLE 7.5

The project document states that the results obtained during the pre-operational and operational phase should be harmonized among pilots. The subtask 7.3.1 will analyze :

- The environmental sustainability,
- The ecological footprint of the aquaculture products (with input from WP4).
- The economic- and societal sustainability, covering issues such as
  - job creation,
  - improved scheduling
  - health & safety measures (with input from WP3 and 5).

The primary aim is to synthetize all information that is necessary to conduct the validation and assessment (qualitatively and quantitatively) of the solutions in WP8. The harmonization of the results that will feed into WP8 are included in deliverable D7.5.

1.2. METHODOLOGY

To avoid repetition of content that is already gathered in the other deliverables, it was decided not to follow the classical United structure of the 5 pillars, but to take the activities of the pilots as the starting point.

Four categories of activities were identified : 1. Infrastructure, 2. Operation, 3. Environmental impact and 4. Market for goods and people. Each category covers different aspects, which can be common to the different pilots or pilot specific. An Excel sheet (Annex 1) was sent around to the pilots to gather in a nutshell a description of the current situation of the pilots, the major setbacks experienced by the pilots and the major advantages of the pilot's concept. The pilots had the freedom to add categories of activities which they considered important. It is useful to mention that the existing infrastructure of wind turbines was considered a given in this analysis since they were in place before the pilots started, but all other multi-use activities were evaluated. Finally, in a last column, some recommendations are formulated by the partners for future commercial enterprises or at least some points of attention that should be considered or changed when setting up a commercial multi-use unit.

Based on the information collected, this deliverable D7.5 wants to distil the best solutions for the many challenges multi-use activities at sea face, albeit of technical, legal, socio-economic or environmental nature. This includes the exploration and evaluation of the synergies between the different activities at one location. The results of this deliverable D7.5 will feed into WP8, where a validation and assessment of the solutions will be carried out.

The structure of the document is as follows : for each activity or aspect, first a summary is given of what is being done in the relevant pilots (not all activities take place in all pilots), as well as a description of the major set-backs experienced by the pilots. Secondly, overarching recommendations are formulated for future commercial exploitation of the considered activities, based on the specific experiences and results of the pilots.

2. PILOTS' INFRASTRUCTURE

2.1. Design aquaculture systems

The aquaculture longline systems tested in the Belgian, German and Dutch demonstration pilots of United were used to grow seaweed and bivalves. A full description of the systems can be found in D.7.1 (Review of pilot TRL, legal aspects, technical solutions and risks), D7.2 (Blueprint for the offshore site operation) and D7.4 (Joint production, monitoring, operation and maintenance protocol). They were designed based on previous experience of the partners and existing commercial systems used elsewhere in the world under less harsh environmental conditions and outside wind farms. In a next step, numerical analysis was carried out with the Moordyn-UGent software of UGent Maritime Technology Division and external engineering offices to calculate the forces that act upon the systems and to determine the necessary dimensions of the parts of the longline (backbone, anchor, …), and the necessary floating capacity. This process went through several iterations and innovative solutions, specific for the pilot's environment had to be found.

Different sorts of backbones were used by the three pilots and depended on the species grown : plain ropes were used for the seaweed. These backbones hung just below the surface since light is of major importance for seaweed to grow. For blue mussels (*Mytilus edulis*) and flat oysters (*Ostrea edulis*), plain ropes and PE-pipes flooded with seawater were used which hung at -7m to -9m below the surface. At these depths, the backbone is less exposed to wave actions and the animals are less shaken.

All pilots experienced problems with approaching and handling the backbones for sampling, cleaning, maintaining the culture systems or for harvesting. This is mainly due to the rough conditions of the North Sea, even nearshore. The semi-submerged systems were even more complicated to reach, since the lines needed to be lifted.

Different ways of anchoring were applied by the three pilots. Both screw anchors and drag embedded anchors were used (FlipperDelta anchors + concrete block). Screw anchors are routinely used for longlines in more sheltered areas : they are cheap and quick to install.

The aquaculture culture systems varied amongst the pilots and depended of course also on the species cultured. The seaweed was grown on 2-dimensional structures, namely nets. Different quality of nets were tested. They were kept straight by means of floaters on top and weights at the bottom (chain, sinkers, backbone, clump weights). Different techniques for seeding the nets were tested in a ring test between the 3 pilots. Trials with seeded ropes around the backbone didn't lead to good results.

Mussels were also grown on 2-dimensional nets in the German pilot while the flat oysters were cemented to ropes and sticks or kept in different kinds of baskets (cf D7.2)

Necessary floating capacity was determined through numerical analysis, carried out by UGent Maritime Technology Division and external engineering offices in all three pilots. A common concern was how to deal with the big difference in weight and hydrodynamic coefficient between the start of the culture and the moment of harvest. This led to uncertainty on how many buoys had to be installed at the moment of deployment of the longline and of what size. Different types of buoys were used, both in shape (pencil , round), volume (from 11L to 3000L) and filling (air or foam).

The aquaculture longline systems in all three pilots were weighed against internationally recognized safety standards, amongst which the Norwegian standards. Basically the systems were built to cope with the heaviest storm that occurs once in 50 years. All systems were foreseen to stay in place even when 1 anchor let loose. Specifically for the OWF, the longline was dimensioned and placed in such a way that the backbone would not touch the turbines, even if one end get loose.

RECOMMENDATIONS FOR THE DESIGN OF AQUACULTURE SYSTEMS

Submergible longlines are the way forward whereby the longline is less exposed to the wave actions, just like the semi-submerged longlines, but submergible longlines can be lifted towards the surface for maintenance purposes, or harvest and lowered to avoid the impact of storms. Submerged systems allow the culture of bivalves that can't fix themselves to substrate, such as oysters because they will be less shaken (still to be verified in the Belgian pilot) and it may lead to a lighter design since it is less impacted by the wave force. The regulation of buoyancy of the longline should be automatic and could include a mechanism that is triggered by weather alert. Automated regulation would also assist the farmer to cope with the changes in weight and drag coefficient of the backbone, due to growth of the aquaculture species and/or seasonal fouling. Modular buoys currently exist and may offer a temporary solution. Experiences with round and pencil-shaped buoys in the project were positive and therefore no clear preference can be given. Smaller buoys on the other hand are easier to handle than big ones and experience in Belgium teaches us that smaller buoys don't detach so easily from the backbone because the waves can roll over them.

Both the rope and PE-pipes filled with seawater work well in offshore conditions. However the design should be adapted to improve accessibility of the longlines. It should also be possible to leave the backbone at sea till the next seeding campaign.

The optimal anchoring system is very much sediment dependent. Screw anchors for offshore aquaculture proved to be possible, even in OWF. Drag anchors are considered less suitable for wind parks: it was difficult to immobilize them and there was a need for extra weight to hold it at place. Pile anchors are another possibility, although not tested in the pilots which should be installed through vibration in order to reduce the underwater sound It is also advised to use flexible mooring systems that are made out of rubber to dampen the rocking motion In light of the limited duration of the concessions and lifespan of the materials, it is mandatory to foresee complete de-commission of the entire aquaculture systems, including the anchors. Experience with screw anchors confirms this is possible.

The use of simulation software helps to predicts which zones in a OWF are most vulnerable when the aquaculture system fails. Taking this into account, reduces significantly the risks for the wind farm concession holder and may have a positive impact on the insurance fee. In addition the design can incorporate a "weak link" so in case there is failure due to for example a vessel crossing the installation, you know exactly where it will fail and you make sure that this failure doesn't result in loose parts or damage to the wind turbines.

The 2-dimensional nets are suitable for growing sugar kelp (*Saccharina latissima*) both nearshore and offshore, although they are expensive and good growth is only observed in the upper meter which makes nets of several meters in depth redundant, especially in the turbid North Sea. They also have some serious downsides in terms of practicality of seeding, installation and harvesting. On the other hand, nets do have an advantage regarding up-scaling and automatization of seeding and harvesting procedures. Commercial classical oyster baskets used for intertidal oyster culture, need to be protected by metal frames when deployed nearshore or offshore in the Belgian part of the North Sea, while rope culture of oysters, as practiced in sheltered bays, was working/not working

Solutions to remove the fouling from nets with blue mussels and baskets with oysters, are needed to support growth of the animals and reduce the drag and weight of the system. This is (almost) a pre-condition to turn offshore aquaculture of bivalves profitable. Self-tinning of mussels and stocking of oysters at the final densities is a good strategy to cope with the limited access to the offshore area due to the hostile wave climate and reduces at the same time the number of expensive boat trips.

Synergies between the different activities need to be actively created. As for now, synergies In the field have been restricted to the use of crew vessels for monitoring the condition of the longlines (position, presence of buoys, …). However, the multi-use approach is new for all actors : they are going through the learning process together while sharing their knowledge and experience with each other The common exploration of the multi-use concept leads to a better understanding of each other's concerns and priorities. This should lead to reduced development time for innovative solutions.

2.2. DESIGN RESTORATION SYSTEMS

Cross-pilot comparison is not possible since the Belgian pilot was the only pilot that included restoration activities. Tables were designed and contained scour protection material and sometimes UV-treated empty blue mussel shells as settlement material for the flat oyster larvae (*Ostrea edulis*). Some of the tables placed offshore were stocked with brood stock animals, while others were not and different positions around the turbines were also tested. All tables were placed on top of the scour. The installation was carried out with a MCA Cat. 1, but one table was misplaced and had to be recovered with a working class ROV and re-installed with a DP2 vessel.

The tables contained 6 gabions that can be sampled over time one by one. The sampling is done by highly experienced scientific divers on board of a research vessel.

RECOMMENDATIONS FOR TESTING NATURE INCLUSIVE SCOUR MATERIAL

A working class ROV was used for the recovery of one of the restoration tables. Although expensive, it is much safer than relying on divers for the recovery and the whole operation can be followed by the captain thanks to underwater cameras. The operations carried out by a working class ROV are also less weather dependent compared to when working with scientific divers. Fewer operators however offer this kind of service.

Using the scour material as settlement material explores the possibilities to use the existing scour protection as basis for reef builders, such as oysters, that need hard substrate. Placing the settlement materials at a height of at least 1 meter above the bottom reduces the risks of being buried under the sand. This is a condition to keep the bivalves alive. Tables proved to work well, although they are only suitable for research purposes.

3. PILOTS' OPERATIONS

3.1. VESSEL OPERATION

Installation of the aquaculture systems was done with working vessels such as multicats that fulfill all requirements to enter the OWF, have a low deck and are equipped with cranes. The required vessels were hired from the service provider that already has a service contract with the OWF and through market search for very specific operations.

Crew vessels or tug boats from the service providers, can be used for monitoring the aquaculture longlines or for aquaculture system handling (German pilot). However, they were not 100% suitable for the job. Shared use of boats is also happening in the Greek pilot, where touristic divers are brought to the aquaculture unit by the boats of the farm while the ROV equipment of the divers is used for monitoring the environment of the aquaculture cages. In the Danish pilot, the service boat of OWF was not available to transport tourists, and boats from external private operators had to hired. In the Dutch pilot vessels used for the installation and monitoring of the seaweed installation were the same ones used for the installation of the floating solar. Where possible, these operational activities have been combined.

RECOMMENDATIONS FOR VESSEL OPERATION

Installation of the aquaculture and alternative energy production systems is carried out by specialized vessels. If the service providers of the OWF have a large and diverse fleet, they are the preferred partner to work with. Their knowledge of the OWF and familiarity with the protocols and management, will support the administrative process to get clearance. However, equipment specifically needed for installation of screw anchors and longlines offshore, is rarely available and requires adaptations of the vessel.

Experience with installation of longlines is seemingly limited in Europe, especially when carried out inside OWF's. If offshore seaweed culture and bivalve culture is to take off in Europe, a new vessel, perhaps even modular, needs to be designed that fulfills all requirements, imposed by the location, the aquaculture systems used and windfarm operations. Innovative shipbuilding is necessary to extend the operational time window, to increase the maneuverability and stability of the vessel, to lower the fuel consumption and/or to use green energy. Vice versa, aquaculture systems should also adapt to the possibilities of the vessel. Examples where aquaculture systems and vessels are tuned to each other, exist. A good example is Smartfarm where mussel systems are easily installed and harvested with purpose-built boats. Recently, Smartfarm has developed a similar concept for offshore seaweed cultivation. It was tested in 2022 at the offshore test site of the Wier&Wind project, including mechanized harvesting.

3.2. MONITORING IN THE PILOTS

Monitoring of the crops, fouling and of the aquaculture systems themselves proved to be quite a challenge for all pilots. Use was made of satellite data (Copernicus) to get water quality related data, GPS to locate the position of the systems, loadcells to measure the forces that act upon the different parts of the longline, underwater cameras to observe the behavior of the fish and evaluate their welfare, a subsea-lander system with a series of probes to measure in situ the water parameters as well existing data buoys in the neighbourhood of the projects, C-PODs to evaluate the attraction of aquaculture systems to harbor porpoises, and ROV's to monitor the infrastructure. In addition, physical samples were taken of the water, the crops and fouling organisms for further analysis, sometimes by scientific divers.

Major obstacles were encountered by the partners. Some systems failed very shortly after deployment, others such as the cameras and water parameter sensors needed regular cleaning, while the latter also needed regular calibration.

For the Danish pilot that includes tourism as one of their activities, the visitors were asked to fill in a satisfactory form in order to collect some feedback.

RECOMMENDATIONS FOR MONITORING

It is advised to include monitoring as a standard operation. Remote solutions need to be developed in the future as it reduces shipping time and human intervention. Robotization and automatization are key factors that will make a big difference for offshore activities.

Cameras (under (if turbidity of the seawater allows) and above water) and GPS location are relatively easy and cheap to install and create the possibility to monitor clock-round. This gives a better control and hence reduces the risks and increases safety of the whole operation.

There is need to develop novel but cost effective monitoring equipment that can stand the harsh offshore conditions. Sophisticated systems such as the Lander, are risky to install in the rough environment of the North Sea. The use of cables, batteries and the network for sending the data real-time to shore, involves risk factors. When the system fails, it is very expensive and time consuming to retrieve, repair and re-install it. A proper insurance could alleviate this problem.

The use of remote sensing data allows to have long-time series of data (periods of 10 years are easily covered) which are needed to build predictive models on growth and habitat suitability. Therefore it is advised to have a platform where the publicly environmental data are stored and made accessible to everybody who wants to work in the area but also where data collections from different projects and research institutes are (conditionally) accessible. HiSeas is an example of such commercial platform.

3.3. HEALTH & SAFETY IN THE PILOTS

Safety first is the motto in all pilots. Strict regulations needed to be followed and were non-negotiable. As a basis, people on board must have followed a sea-survival training, first aid training and need to be medically approved. Protective clothing is also mandatory. For the tourists that visit the wind turbines in the Danish pilot, different rules applied.

RECOMMENDATIONS FOR HEALTH & SAFETY

Although the currently organized trainings are highly appreciated and considered necessary to prevent accidents and for people to become aware about the risks and potential dangers of offshore activities, more advanced trainings could be more oriented towards multi-use. Currently the training focusses on either offshore wind or fisheries. In function of future developments, a modular approach could also be beneficial whereby people are allowed to follow only these modules that are applicable for their job in a multi-use setting.

3.4. TRANSPORT & HANDLING BIOLOGICAL MATERIAL

The seed, necessary to start up the culture of oysters and seaweed, originated mainly from hatcheries. Precautions were taken to use/import certified specific disease-free (*Bonamia* and *Marteilia*) oyster seed and in the case of seaweed, that they belonged to the same genetic population.

In the Belgian Pilot, very poor yields of sugar kelp were observed with nets that were seeded with the direct seeding method, where small sporophytes were mixed with a seaweed glue and applied to the nets just prior installation in comparison to nets that were seeded with gametophytes and experienced a nursery period. Yields could be improved by altering the seeding methodology of the direct seeding to a two-step direct seeding, applying the seaweed juveniles first and covering them with a layer of glue. However, yields were still not as high as when seeded with gametophytes and kept in a nursery for 4-6 weeks.

From the results in the different pilots, it is still a question/discussion whether nets really facilitate higher yields and economic benefit as they are expensive and good growth is only observed in the upper meter - at least in the North Sea with high water turbidity.

Mechanized harvesting of seaweed on land and in the harbor has been tested in the Dutch pilot, while the harvest in the other pilots was done manually.

RECOMMENDATIONS ON TRANSPORT AND HANDLING BIOLOGICAL MATERIALS

It’s a challenge to match the seeding of the seaweed nets with a proper weather window for installation of the seeded nets at sea. This is the same for small oyster spat or brood stock that are imported and need to be brought to the offshore longlines as quickly as possible upon arrival. In order to have more flexibility, it is therefore recommended to have access to a **facility on land** that can provide clean temperature-regulated seawater, holding (and/or settlement) tanks and aeration. The same facility can be expanded to receive and/or process the harvested products. Fish auctions could be a good choice.

Mechanical seeding and harvesting of seaweed is the way forward for faster preparation of the nets and better yields. It is recommended to rely on the expertise that already exists in this field in the rest of the world and adapt the systems for the local use. A new project ZeewierSEEDER will try to optimize the direct seeding on nets (including tests with a machine) the coming two years.

Harvesting under water with robots, without the need to lift the net out of the water, is an unexplored field that deserves more attention. Examples of mussel thinning under water exist in the sheltered waters of The Netherlands and could be a source of inspiration

3.5. SYNERGIES

The different pilots looked actively at possibilities to merge installation, maintenance and monitoring activities between the different uses of the same space. Different activities were combined in the pilots such as sampling of oysters with harvesting of seaweed, or feeding the fish with transporting recreational divers, or maintenance flights for OWF with transport of goods for the mussel farm. These cost-saving operation however, involved a lot more planning and were difficult to match because each activity took some time while time is the limiting factor for any operation offshore. The most suitable slack tide period is limited to 1,5-2 hours.

Inspection and monitoring activities proved to be the best examples where synergies were possible, as well as the shared training and information sessions. Another important field of synergy identified is the sharing of data related to the location (hydrodynamic conditions, weather forecast, …), operation (vessel information, monitoring preparation, best practices) and equipment (anchors, monitoring equipment, …).

RECOMMENDATIONS RELATED TO OBSERVED SYNERGIES

The different actors should **co-design the location**, so that the physical preparation of the location (e.g. UXO survey) covers the complete grid of interest. Data of the location are collected, communicated and stored in a shared platform. Monitoring equipment can be designed together and data shared. Shipping routes are determined together and vessel operations coordinated. A communication channel is set-up with all regional stakeholders

3.6. DECOMMISSIONING

At the moment of writing this D7.5, the projects in Belgium and Germany are still awaiting decommissioning. The solar panels in the Dutch pilot will be part of a new project and therefore are not decommissioned either. The seaweed installation and the mooring of the seaweed longlines (similar to the solar panels) in the Dutch pilot are decommissioned successfully. One of the biggest concerns is whether the screw anchors (Belgian pilot) can be removed several years after installation. In commercial aquaculture farms elsewhere in the world, the anchors are cut 2 m below surface. However, experienced service providers are confident that screw anchors can be removed.

The OWF in Belgium, Germany and the Netherlands need to be fully decommissioned when the licenses expire. This is also true for any other activity taking place in the wind parks, be it aquaculture, solar energy production or restoration. This has major implications since in this scenario, the lifespan of an aquaculture farm is determined by the duration of the concession of the windfarm.

Restoration activities at sea have by definition a long-term horizon while a wind farm concession typically last minimum 20 years. It is obvious that in some cases, this mismatch may lead to conflicting situations and hamper the multi-use of ocean space.

RECOMMENDATIONS FOR DECOMMISSIONING

In view of future developments where wind energy at sea will expand drastically its capacity and new technologies imply bigger sized turbines which will be installed at greater distance from each other, and considering the fact that food production at sea has become a priority for the European commission, it is recommended to review the decisions that were made in the past concerning the decommissioning of the current wind farms.

Possibilities should be explored to partially decommission wind turbines, if the restoration efforts to re-introduce lost species or to increase desired biodiversity are too valuable to be lost when the turbines and/or the scour protection are removed.

It is recommended to keep the discussion open for the aquaculture or other activities to use some of the turbines as anchoring point when they stopped functioning as energy producers. A scenario whereby the poles are cut at several meters above the sea surface is a possibility that is currently considered in Belgium.

4. ENVIRONMENTAL IMPACT

4.1. LAW & REGULATION

Impact assessments of the offshore activities are obligatory in all European countries. The impact of OWF on the marine environment has been continuously monitored in Belgium and the Netherlands for the last decades. The same will be true for any additional commercial activity that takes place in a wind farm. In some cases, legislation determines which species can be grown in OWP (only extractive aquaculture in Belgium) or imposes a positive effect on the biodiversity (The Netherlands). Biosecurity measures are in place and often regulated by different governmental agencies. This may lead to conflicting points of view. In general, it is a long process to obtain all necessary licenses, even for a research project (Germany).

RECOMMENDATIONS ENVIRONMENTAL IMPACT – LAW & REGULATION

It is recommended to harmonize the regulation on multi-use at European level by promoting communication and exchange of data between the licensing authorities. At national level, a one stop-shop is recommendable and could shorten the procedures.

A commercial enterprise will depend on seed production of selected seaweed species and bivalves in case it is not possible to collect it from the wild (as with blue mussels). Production of seed in a hatchery or import of seed from neighbouring countries is then necessary. Guidelines on exchange of seed and brood stock animals are necessary to ensure maintenance of genetic diversity and protection of local populations. The risk of accidental introduction of hitchhiking organisms cannot be underestimated.

Monitoring of large scale projects is needed, as they can be used to validate the current models. In addition key performance indicators (KPIs) can be set to make sure the activities will be carried out in a nature inclusive way.

4.2. DATA COLLECTION AND REPORTING

As mentioned in 3.2, the environmental impact of the different activities on the marine environment was monitored by taking samples of the fouling organisms, installing cameras, C-PODs and water quality sensors.

RECOMMENDATIONS ENVIRONMENTAL IMPACT – DATA COLLECTION AND REPORTING

It is mandatory to follow-up the positive and negative impacts of additional structures (OWF, aquaculture) on the ecosystem. Invasive exotic species may take advantage of the presence of these new hard substrates.
Another source of data, could be a hotline, set-up for aquaculturists to report unknown organisms, mortality events etc. and vice versa for researchers that can reach out to the marine people to look out for specific organisms or events.

As mentioned earlier, sharing data sources and linking them together through a common data platform is highly recommended. Publication of the findings in the grey literature would contribute to a better understanding by the general public of the oceans and the changes that occur due to human activity.

5. MARKET FOR GOODS & PEOPLE

5.1. LAW & REGULATION

There are no specific regulations for food that has been produced in a multi-use context. They will follow the existing national and European food safety rules and other food related regulations.

RECOMMENDATIONS FOR OFFSHORE FOOD PRODUCTION REGULATION

Governmental support will be necessary for the emerging aquaculture sector in Europe and more specifically the offshore aquaculture, just like for the agriculture sector or fisheries sector. There are good examples in neighbouring countries, such as France and Ireland where the bivalve sector is supported by national research institutes.

5.2. COMMERCIALISATION

Harvest

Eating habits are changing in the Western world. There is a general trend for the youth especially to eat much less meat and to follow a vegan or vegetarian diet. From that perspective, seaweed has an interesting potential as human food in Europe. As “blue food” production, such as seaweed and bivalves, has a much lower carbon food print than terrestrial life-stock and crops, it is important to promote it.

The key exploitable results of the **Dutch pilot and the Belgian pilot** project include a seaweed cultivation system including seeding and harvesting machines, small data buoys and telemetry for multi-use (seaweed cultivation or other), and the seaweed itself. The projects are focused on developing economically viable and technically feasible seaweed cultivation in offshore environments, such as the challenging conditions of the North Sea. The successful testing of automated seaweed harvesting machines in the Dutch pilot is a significant step toward achieving this goal. Industrial production of high-quality seaweed could be a lucrative business, and combining it with wind farming could lower costs and increase overall efficiency. The commercial potential of seaweed is vast, including use in cosmetics, food, feed, bio-stimulants, fuel, and building materials.

The commercial potential of the **German pilot and the Belgian pilot** lies in the development of aquaculture in wind farms, which can provide a sustainable source of food and energy while enhancing safety and efficiency in offshore operations. The team at FINO 3 (Germany) has been focused on testing and proving the feasibility of blue mussel and seaweed cultivation in combination with wind energy production, while the Belgian pilot focused on the feasibility of flat oyster and seaweed cultivation in an OWF. As a result of the UNITED work, the pilots can now offer advice on optimized vessel layout, longline design, mooring technology, and offshore aquaculture permitting to ensure the success of future investments in seaweed and mussels cultivation offshore.

RECOMMENDATIONS COMMERCIALIZATION MARINE PRODUCTS

As further development and promotion of seaweed-based food products is recommended, more attention should be paid to setting up the necessary logistics to harvest, process and transport the products. The same is true for oysters and mussels, when produced locally for the first time.

Based on the findings of the Dutch, German and Belgian pilots of UNITED, the following recommendations can be made for promoting the commercialization potential of seaweed and shellfish in Europe:

- Encourage the adoption of seaweed as a food source: As Western consumers increasingly embrace vegan and vegetarian diets, the low carbon footprint of seaweed production makes it an attractive food source. Seaweed has significant commercial potential as an ingredient in plant-based food products such as meat substitutes, snacks, and condiments. Education campaigns can be used to raise awareness of seaweed as a nutritious and sustainable food source.
- Promote the use of seaweed in building materials: Seaweed has the potential to be used as a sustainable building material due to its fire-resistant properties, thermal insulation, and potential for carbon sequestration. The development of new seaweed-based building materials could open up new commercial opportunities and reduce the environmental impact of the construction industry.
- Support the development of seaweed-based bio-stimulants: Seaweed contains growth hormones and micronutrients that can be used as bio-stimulants for crop production. As the demand for organic and sustainable agriculture increases, there is a significant commercial potential for seaweed-based bio-stimulants. Some seaweed compounds are also known to stimulate the immune system in invertebrates through production of radicals.
- Encourage collaboration and knowledge-sharing: The UNITED project has brought together research partners from Belgium, Germany, and the Netherlands to share knowledge and expertise in the field of seaweed cultivation. Encouraging collaboration and knowledge-sharing between industry stakeholders can help to promote the commercialisation potential of seaweed and accelerate the development of new products and technologies.
- Advocate for policy changes to support seaweed cultivation: In order to fully realise the commercial potential of seaweed, there may be a need for policy changes to support the development of the industry.

This could include the creation of regulatory frameworks for offshore seaweed cultivation and the provision of financial incentives for seaweed farmers and investors.

Tourism

In the **Danish pilot** the Middelgrunden Wind Farm, located off the coast of Copenhagen, is not only a vital source of renewable energy for the city, but also an extraordinary educational and tourist destination. Visitors can join guided tours, climb one of the turbines during open house days or organised group tours, and experience the beauty and power of offshore wind up close and personal. This gives an excellent opportunity for offshore experts, investors, wind developers, universities and students, and the locals to learn about the importance of renewables and their sustainable integration into the local socio-economic context. The touristic boat tours to the wind farms have significant commercial potential, as they provide a unique and valuable educational experience for visitors, while also promoting renewable energy and sustainability. On the other hand, in the **Greek pilot** the, the scuba diving tours organized by Planet Blue offer a unique natural beauty experience for divers, with the abundance of marine life next to the aquaculture farm. This creates an opportunity for the local community to benefit from increased tourism, with the potential for additional revenue streams from services such as accommodation, restaurants, and transportation. The success of the pilot has the potential to be replicated in other suitable areas in Greece and beyond, demonstrating the positive impact that multi-use can have on local communities. As a result, investors and stakeholders interested in sustainable tourism and aquaculture could benefit from exploring the commercialisation potential of this pilot and the potential for scaling the concept to other locations.

RECOMMENDATIONS TOURISM

Based on the experience in the Danish and Greek pilots the following recommendations for the rollout of tourism in the multi-use context can be considered:

- Explore the potential for commercialising touristic boat tours to wind farms, as they can provide a unique and valuable educational experience for visitors, while also promoting renewable energy and sustainability.
- Consider the potential for replicating successful pilot projects, such as the Greek scuba diving tours organised by Planet Blue, in other suitable areas to demonstrate the positive impact that multi-use can have on local communities.
- Encourage investors and stakeholders interested in sustainable tourism and aquaculture to explore the commercialisation potential of these pilot projects and the potential for scaling the concept to other locations.

Energy technologies

The Dutch project's floating solar energy pilot has also shown promising results. The business case for offshore floating solar is being built, and potential partners and investors are being identified. If successful, floating solar technologies could play a significant role in meeting the growing demand for renewable energy sources. The offshore test site at the Dutch pilot project has the potential to incubate the offshore technologies of tomorrow. The project could serve as a model for future developments in seaweed cultivation and floating solar energy production in offshore environments, with the potential for roll-out to other suitable areas in the North Sea and beyond. In conclusion, the Dutch pilot project for seaweed cultivation and floating solar energy production has demonstrated significant potential for commercialization, particularly in the fields of seaweed cultivation and floating solar energy production. The project's key exploitable results and successful testing of new technologies could pave the way for the commercialization of seaweed and floating solar technologies in offshore environments.

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RECOMMENDATIONS ENERGY

Based on the experience in the Dutch pilot the following recommendations for the rollout of alternative energy technologies in the multi-use context can be considered:

- Explore the potential for alternative energy technologies in windfarms, and the potential to use the same grid to bring energy on land. Interesting synergies could exist and lower the overall costs of exploitation.
- Consider the potential for replicating successful pilot projects, such as the Dutch pilot in other suitable areas to demonstrate the potential of combining food production with energy production. The wave attenuating effect of seaweed, when deployed at a large scale, may be beneficial for the floating solar panels.
- Encourage investors and stakeholders interested in sustainable energy production and aquaculture to explore the commercialization potential of this pilot project and the potential for scaling the concept to other locations.

5.3. ACCESS TO OFFSHORE INDUSTRY

Offshore wind energy is a mature sector now that will expand fast in the coming years, because of climate change and the energy crisis. EU wants to become more self-reliant for energy but also for fisheries products through the promotion of aquaculture production and supporting offshore development. This is an important incentive for EU nations to support multi-use activities at sea. New jobs are being created. However, because of the high costs (installation methodology – distance – risk – weather conditions – technical requirements – permit & legal conditions – insurance), offshore activities including aquaculture tend to be exclusive for big companies or consortia. Small SME don't have the carrying capacity. In addition, the offshore aquaculture is still experimental and risky.

RECOMMENDATIONS TO IMPROVE ACCES TO OFFSHORE INDUSTRY

Skilled sea-workers are needed for the emerging sector. Their training should cover a wide range of skills in the light of multi-use exploitation of the sea. A separate curriculum can be thought off, to be incorporated in existing naval or fisheries schools. Better communication and more efforts to reach out to (retired) fishermen for them to get involved in the offshore aquaculture sector, is necessary (transition of knowledge). Some of their skills are highly wanted. Until now, there is little understanding between the fisheries and the aquaculture sector, as aquaculture is competing for marine space. Therefore, the multi-use approach may convince fishermen that coexistence is possible.

Lessons should be learned from the Danish pilot where 50% of the OWF is owned by a cooperative. This creates the opportunity for everybody to be involved in offshore wind energy. This example could be expanded to other activities at sea as well, such as aquaculture since it will enhance greatly the support base. In the Netherlands, it was decided that every new OWF will include multi-use, which opens the doors for other entrepreneurs to develop their activities offshore.

6. ANNEX 1

D7.5_Information_Sheet_130223.xlsx - See Tables Below if link no longer works or is inoperable

Infrastructure	current situation	major set-back	major advantage	Future best solution
design aquaculture system-backbones and anchoring				**design aquaculture system-backbones and anchoring**
Belgian pilot	**Seaweed** : Backbone directly below surface (1m below) of 42m length, provided with 8 nets which are connected with velcro strips. The 4 offshore nets have a 4m chain of 12 mm at the bottom as well as 2 clump weights of 10kg at each corner. Anchoring : screw anchors are used of 6 meter at each end ; mooring line of 51m between anchor and backbone **Flat oyster** : submerged backbone at -9m of 119m long with 5 surface buoys of 850L. Anchoring : screw anchors are used of 6 meter at each end ; mooring line of 44m between anchor and backbone	Special operator is necessary to drill screw anchors : expertise is not easily found in Europe and vessels also need to full the requirements of the OWF Positioning of the vessel is required (DP or mooring weights). Decommisioning of screw anchors is possible but still needs to be proven.	If weather conditions are good, 4 screw anchors per day can be installed offshore (only with DP2 vessel). In case of mooring weights it takes more time. Anchors are not expensive and don't move Backbone system allows automatization of harvest in the future 2-dimensional seaweed nets result in higher production per meter	**Seaweed and Mussels:** adapt design to allow for handling at rougher conditions, Make backbones bettter reachable for sampling, maintenance and harvesting; Leave backbone in place after harvest for the next growing season **Submerged systems** are better for oysters and other bivalves that can't attach themselves. In addition, the systems will be less impacted by the waves and can be designed lighter. This means that we should be able to regulate the depth of the longline systems automatically to allow sampling and cleaning operations or to avoid heavy storms. **Optimisation of anchoring.** Looking into novel or other applicable anchoring solutions for the respective area: pile or screw anchors can be used for offshore wind farms
German pilot	**Seaweed:** Backbone directly below water surface Backbone: net with upper- and lower- backbone including floats and sinkers Anchoring: each end with 2,5t FlipperDelta anchor and 6t concrete block both systems are using standard marine anchor chains Rough assumptions, refined in several iteration steps and subsequently verified by an external engineering office and UGent. **Mussel:** semi submerged - backbone at 7m depth Backbone: PE-Pipe flooded with seawater - spar buoys attached to pipe Anchoring: each end with 2,5t FlipperDelta anchor and 6t concrete block	**Seaweed:** usage of netstrucuter caused additional licemsing steps -> prolonged licensing procedure leading to leading to a one year delay **Mussel:** usage of netstrucuter caused additional licemsing steps ->prolonged licensing procedure leading to one year delay **General:** offshore material leading to higher purchasing prices necessary heavy offshore material results in higher risks for staff during installation -> requires good weather for handling (only few days per month) saftety margine for offshore use had to be higher than expected and were not foreseeable, as there were no comparable pilots in the region or on the scale. FFor the scale of the pilot the interest of suppliers is relatifly low and results in high prices for small amount of equipment.	**Seaweed:** same system as in NL-Pilot - comparison of side specific differents. **Mussel:** System very sturdy withstand heavy weather system Rental of chains is much more efficient instead of purchase for short term period pilot	
Dutch pilot	**Seaweed:** pilot finished, so system offshore; two years of cultivation with two systems (one parallel and one perpendicular to the current) <u>Anchors</u>: drag embedment <u>Backbone</u>: each system has a backbone of ~175m with two nets of 50m and two sparbuoys **Solar:** use of drag embedment anchors, same as seaweed pilot	Soil conditions: challenge to get the drag embedment anchors in place, though it finally worked This type of anchoring cannot be used in an offshore wind farm	Easy to decommission and no large vessels needed for installation / decommissioning, low costs Backbbone can stay in place when the net are harvested and brought to shore for the nextt season	
design aquaculture system - aquaculture holding structures				**design aquaculture system - aquaculture holding structures**
Belgian pilot	**Flat oyster systems :** classical oyster baskets need to supported by metal frames in order not to break or get lost. Ropes with cemented oysters gave mixed results nearshore and are being tested offshore. Less fouling problems are expected with this technique **Seaweed systems** : 2-dimensional nets are working but proper weaving techniques and twine need to be used (which one ?)	Cleaning of ropes is impossible. Metal frames around the baskets makes the structure heavier. Oyster baskets clog easily due to fouling with reduced growth of oysters as a consequence	Fouling on oyster ropes may enhance the fixation of the oysters to the ropes Fouling on oyster baskets is seasonal	Offshore oyster culture systems are stocked with the final densities, so dedoubling is not necessary
German pilot				
Dutch pilot	Cultivation net with floaters and sinkers to keep it vertically, installed between the spar buoys and connected to the back-bone	Floaters & sinkers take up space for storage between harvest & seeding	Floaters & sinkers can be used for guidance of the net in the seeding / harvesting machine (like a double chain)	
Greek pilot				
design aquaculture system-buoys				**design aquaculture system-buoys**
Belgian pilot	Calculation of number of buoys and their volume was based on numerical analysis by the Moordyn-UGent software of UGent Maritime Technology Division and Gael Force. All buoys are foam-filled and knotted to the backbone. The corner buoys were foreseen of light signal (AIS system) **Seaweed system** Nine intermediate foam-filled buoys keeps the backbone system floating (11L offshore), together with 1 large buoy (1350L) at each end. **Oyster system** 5 surface buoys of 850L keep the backbone at its place together with 4 submerged 11L buoys to keep the backbone on the same level	big difference in weight and hydrodynamic coefficient between start culture and moment of harvest leading to uncertainty how many buoys have to be deployed at the start of the culture and what size Large distance from shore makes it difficult to add or remove buoys in function of growht or fouling	Round buoys were used so waves can go over them easily Foam filling avoids implosion of the buoys when going under water	automatic adjustment of volume of buoys in function of crop growth numerous small buoys work better than few big ones shape buoys (spheric versus pencil) is important/not important ? algae net: big side buoys are very big and bulky to handle : smaller buoys or bigger ship? Instead of heavy steel buoys, use lighter, easier to handel plastic buoys Use "flexible mooring system" made out of rubber to dampen the rocking motion Make harvest possible offshore without the need to take the net out Smart connections / shackles that don't break

German pilot	**Seaweed:** two main spar-buoys (~3000L) , spreaders and floats on the backbone of the net. **Mussel:** several spar-buoys (~250L) attached to the backbone **both systems** refined in iteration steps and subsequently verified by an external engineering office and UGent.	big difference in weight and hydrodynamic coefficient between start culture and moment of harvest attachment-eye of buoys at mussel-system turned out to bea a weak link (material-defect and/or manufacturing failure) and had to be replaced	mussel system: shape of buoys worked very well during operational phase - always upright and little movement even during extreme storms. algae system: side buoys very stable	
Dutch pilot	Cultivation net with floaters and sinkers to keep it vertically, installed between the spar buoys and connected to the back-bone	Floaters & sinkers take up space for storage between harvest & seeding	Floaters & sinkers can be used for guidance of the net in the seeding / harvesting machine (like a double chain)	
Greek pilot				
design aquaculture system - safety and health				**design aquaculture system - safety and health**
Belgian pilot	Longline setups through numercial analysis of the longline characteristics and weighing against internationally recognised safety standards: - norwegian standard NS9415 - DNVGL OS-301 - DNVGL OS-C101 - DNV RP-C205 - Norsok standard N-003	Practical examples are very few, so the design of the longlines is based mainly on nearshore/non-exposed experience in other countries and modelling. Oversizing the systems leads to extra costs and heavier systems that are more difficult to handle	Several safety factors were incorporated in the technical design in order to minimize risk of breaking the backbone structure. Experience from previous projects (Edulis) is very valuable. Distance from the turbines and length of backbone is chosen in such a way that it doesn't hit the turbine when 1 anchor lets loose. Systems are located close the 500m safety zone of the windparcs and where least traffic of crew vessels is expected.	see above, lower weights result in higher handling safety Predictive modelling assist in identifying the zones with least risks, especially when the aquaculture system is failing.
German pilot	systems veriefied for a 50 year storm event according to different offshore codes (DNVGL, ABS and ISO) systems are designed to stay in place even if one end of mooring/chain etc. fails	no existing standard/code/guideline to design offshore aquaculture systems in general design of the system for a 50 year event even though it has only been in operation for 1-2 years (the statistical 50 year event has occurred 4 times in the last 10 years)	Systems are designed to stay in place even if one end of mooring/chain etc. fails Systems survived maximum wave heigth of 10m during operational phase	
Dutch pilot	Calculations + years of experience used to make the right design; Both the seaweed & the solar installations survived a once in 50 year storm (2022)	First year set-back due to innovation in rope for the cultivation net that turned out to not be an improvement; Failure of shackles, probably due to failure of the welds	In case of single failure in the system, it is possible to repair it again (systems are designed to stay in place even if one end of mooring/chain etc. fails)	
Greek pilot				
design aquaculture system - synergies				**design aquaculture system - synergies**
Belgian pilot	ringtest for seaweed between Germany, the Netherlands and Belgium (Jessica ?) installation of the anchors of the two longlines for oyster and seaweed at the same time crew vessels monitor the position of the longlines	OWF has no aquaculture experience nor interest, so also their crew can't take up aquaculture activities (no training) Crew vessels are not adaptable for carrying out aquaculture activities	comparison between the different pilots **cost reduction** : - when anchors for different crops are installed together - crew vessels do part of the monitoring while being present in the OWF for other jobs	no obvious synergy in terms of crew nor vessels co-location is possible but perhaps the safety zone around OWF is more suitable for commercial exploitation. Corridors need to be foreseen synergy between aquaculture and restoration of flat oyster is demonstrated in the sense that adult oysters have most probably provided spat on scour material (results genetic analysis available ?) Great distance from shore and limited window of operational time remains a very important bottleneck for any aquaculture business to become economically viable, as well as the availability of the correct vessels.
German pilot	**Seaweed** same systems as the one in the Dutch pilot **Mussel** adapted system of a former pilot of the Dutch partners		reduced development time comparability between pilots possibility to share equipment (seeding/harvesting machine) use of tug boats, no necessaty to use specialized ships.	
Dutch pilot	See above, and synergy between seaweed & solar for anchoring and O&M + training activities	Challenge for the future of multi-use: no specific trainings, vessels, etc. yet.	Share knowledge, experience, O&M, vessels, procurement, etc.	
Greek pilot				
Danish pilot				
design flat oyster restoration systems				**design flat oyster restoration systems**
Belgian pilot	Tables of 1m50 height in galvanized steel, forseen with cages or with 1 cage divided into compartments proved to work well to test scour material as settlement substrate	not representative for scour protection around the turbine (too small) Only scientific divers on board of research vessels are allowed to take samples.	Tables on top of the scour protection are high enough to allow flat oysters to survive, and most probably to reproduce and settle. Synergy with aquaculture is possible (needs still verification) Tables are stable	Tables on top of the scour protection can work to test flat oyster settlement and fouling development
decommissioning				**decommisioning**
Belgian pilot	everything that is placed in OWF needs to be decommissioned by law	restoration initiatives have a maximum life span of 20 years	installation of new infrastructure is not hampered by remains of old ones	Suggestion : attempt to adapte the rules of decomissiong set forth by legislation. to reduce impact , only partial decomissionig (leaf underwater structures in for future restoration purposes)
German pilot	everything needs to be decommissioned by the end of the licensing time (May 2023)	short permisssion time during project, 15-25 years in commersial project		
Dutch pilot	Seaweed pilot is decommissioned already, Solar energy is part of a new project and is expanding		Follow-up with seaweed farm in Dutch offfshore wind park (North Sea Farm #1 2023/2024) + follow-up solar energy pilot in new project towards 1MW system and possibly connection with electriciity cable to shore	
Greek pilot				

Operation	current situation	major set-back	major advantage	Future best solution
vessel operation				**vessel operation**
Belgian pilot	Crew vessels are only used for monitoring the position of the longlines. Installation happens with hired specialized vessels that have to go through a ship vetting while sampling is organized together with research vessels that have a license to enter the OWF for monitoring purposes.	very difficult to find a proper vessel suitable vessels are extremely expensive weather forecast is poor, which makes it very difficult to plan activities, hire boats etc.	Vessel problem was a concern to which all partners tried to find a solution. Partners were very flexible and changed their agenda in function of the weather and planned activities.	adjust ship size? Go with bigger ships to allow for work at higher waves! design a modular ship that can serve multiple purposes, both for the OWF and aquaculture enterprise
German pilot	close cooperation and communication with tug-boat company current vessels not 100% ideal for offshore aquaculture supplies	alternatives are very limited interest of big players is relativly low due to the pilot scale we have to make the best of what is available	close cooperation and communication allready in discussions for future ideas -> adaptation of the systems to the available ships -> ideas for vessels adaptions	
Dutch pilot	Seaweed farm not operational anymore, solar energy is. Work permit system for Offshore Test Site in place. Solar energy has it's own inspection vessel,		Automatic work permit system, own inspection vessel	
Greek pilot	Crew vessels used from the aquaculture farm are transferring the aquaculture farm members once per day for feeding. 2-3 times per week are used by the farm's diver to for monitoring. ROVs are being used by the diving company for monitoring purposes around the aquaculture farm and the vessels to transfer the divers during the touristic periods.	high cost of fuels	good way of reaching the cages of the farm and combining the monitoring of the two activities	
Danish pilot	We are using boats from two different operators in the Copenhagen region. The operator used by the service providers for the wind turbine is not available as they have to be ready with very short notice and they cannot find benefit in getting involved in the tourism as that will frame them.	If we had access also to the service boat operator it would give us more flexibility. But rules about passenger traffic are different from traffic with service people.	The two involved boat operators are very dedicated to fulfilling our demands.	
monitoring				**monitoring**
Belgian pilot	**at sea** limited to sampling 4-5/year nearshore and 2-3/year for offshore ; and end-result at harvest sampling of aquaculture species (oyster, seaweed) and fouling organisms inventarisation of the systems and reporting lost goods water parameters collected from existing measuring buoys and satelite images **on land** hachery phase for seaweed testing different seeding techniques ; disease control on oysters after staying in the Belgian part of the North Sea	there was no budget for in situ measuring water parameters, so it will be a challenge to link the biological performance to the environmental data. When culture systems are lost because of storms f.eg, very little data are left because of low sampling frequency (risky)	A lot of data are available and for modelling practicses, long term data collections are much more interesting. Retrieved biological data can be used to validate the different models that were developed to predict growth of oysters, seaweed and habitat suitability.	more remote solution, easy of use with minimal ship time, sensor retreival system to grant access for repairs At least use GPS, load cells & camera's; additionally need for better data buoys / remote monitoring equipment
German pilot	subsea-lander and mussel-system monitoring system surveillance of aquaculture site from FINO3. C-POD survailance by hydrophones of harbor purpoises	failure of lander shortly after deployment (most of the data will be missing) failure of musssel-system monitoring after two months of operation. C-pod retrieval very hard due to anchoring system	Covering a part of the missing data with data recorded by the BSH at FINO3 surveilleance worked non-stop during operational phase of aquaculture site	
Dutch pilot	Both seaweed & solar: load cells, GPS & cameras; additionally use of data buoys and sampling	Sensors on data buoys need to be calibrated regularly to make sure the datasets are reliable	Load cells give (after retrieving the information) good insight in the forces on the structure; Combination of GPS & camera's gives security if the systems are in place (for example affter a storm)	
Greek pilot	use of sensors inside the cages of the aquaculture farm for water quality monitoring, use of camera in the cage of the aquaculture farm for fish behavior and welfare, ROVs for infrastructure monitoring	cleaning of sensors and camera from fouling especially during the summer period	real time data of fish performance, added value fish health and emvironmental footprint, surveillance with less human movements	
Danish pilot	Monitoring is about how many people and turnover, so it is just standard PC activity			
health & safety				**health & safety**
Belgian pilot	Seasurvival training for everybody joining the vessel on-line test Parwind (for accessing the OWF) medical approval protective clothing	Seasurvival training is organized only a few times per year and is costly.	creation of awareness about the risks involved with work at open sea mental preparation for actions when things go wrong better understanding of the strict conditions for a trip to take place	modular approach for offshore multi use health and safety training, book and do only what you need to have in your future job

German pilot	Seasurvival and enhanced first aid training for everybody joining the vessel Medical approval Personal first aid backpack to be independent from the ship		awareness and respect for risks during operations -> leads to planning to avoid risks from beginning no injuries or accidants with personelle damage, safety procedures wher so good, that trainings never had to be in real live	
Dutch pilot	GWO Sea Survival & First Aid; Work Permit System; Protective clothing	There is no specific training for multi-use (it's either offshore wind or fishery)	Everyone has the same training, standard, understanding Awareness of the risks of offshore work Good preparation	
Greek pilot	restricted guidelines with ISO for personal protective equipment in the aquaculture farm (e.g helmet, gloves), ISO 9001:2015 Management System (Scuba training, recreational diving, scuba gear rental, filling of tanks), ISO 14001:2015 Environmental Management and ISO 45001:2018 Occupational Health and Safety Management for the diving part.	No specific training for multi use.	Awareness of the risks during the operation and the diving activities. Avoidance of injuries since safety procedures are obligatory and personnel well trained	
Danish pilot	Health and safety have been developed especially for the tourism activities climbing a wind turbine.	It has been difficult for professional service people with other H&S rules to understand our special demands	Before the UNITED project little focus have been on this. It is a big step forward to have it analyzed and revised.	
transport seed and harvest				**transport seed and harvest**
Belgian pilot	**Oyster**spat was important from hatcheries that could certifiy that the spat was free from the protozoa *Bonamia* . Spat was imported from UK and France. Adults were also *Bonamia* -free certified and came from Norway. Transport was cooled. Harvested oysters were kept at the MSO facility of Vliz **Seaweed** spores of sugar kelp were both collected in France, derived from specimens that belong the same population and purchased from NV Hortimare. Harvest was brought to harbour by vessel.	The need for *Bonamia* -free certification limits the available sources for oyster spat or broodstock animals. The protocol to import live animals is an administrative burden (certification *Bonamia*- free, certificate of origin, FAVV trace for transport live animals) No commercial stockroom/shed with cooling and seawater tanks is available for the project		usage of seeding machines for better yield and faster preparation of net Facilties on land to recieve the harvested products, oyster and seaweed, should be availble, including cooling and seawater water tanks. Fish auction sites for examples can serve the purpose Improvement of automatic seeding & harvesting
German pilot	**Mussel** System is still in the water and has not been harvested yet no seeding -> natural settlement of the mussel larvae to the system **Seaweed** System is currently nearshore at the operational harbour (Cuxhaven) Cultivation of the seedlings in the hatchery and subsequent pre-seeding onshore manually by hand	**Seaweed** aligning scheduling of algae (cultivation) and weather for installation. prolonged licensing forced storage of seeded net in turrbid nearshore port waters. incident during installation led to loss of second seedlings (destroyed net and seedlings -> wrapped around propeller)	**Seaweed** close communication, collaboration aswell as fast and flexible response of algea hatchery	
Dutch pilot	Seaweed (not applicable for solar): Two cultivation seasons, both with saccharina latissima (seeds from Hortimare) Seeding & harvest with machine: first time used on land, second time harvest on a vessel in the harbour	Timing of biological process of the seaweed seeds and the weather forcast to be able to immediately install the seeded nets offshore is a challenge	Seeding & harvest with a machine (instead of by hand)	
Greek pilot				
Danish pilot				
synergies scheduling operations				**synergies scheduling operations**
Belgian pilot	Sampling of oysters is combined with harvest of seaweed or with sampling of restoration tables	synergy operations of OWF and aquaculture limited to monitoring of the position of longlines by crew vessels	sometimes the MOB costs could be avoided because the vessel was already reserved for OWF activities.	identifiy site specific synergies, open up good communication channels with regional stakeholders. If OWF are being installed, sonar and uxo operations have to be carried out, which can also benefit other activities such as aquaculture and restoration activities by including their specific locations When combining activities, design the projects upfront in such a way that makes synergies easier to adapt
German pilot	combined maintenance trips of aquaculutre site and FINO3 refueling combined maintenance flights to FINO3 and material transport for monitoring system of aquaculture site	rising energy costs failed installations (due to incident and weather at location after arrival)	close communication, collaboration aswell as fast and flexible response of FINO team	
Dutch pilot	Where possible O&M or inspection trips of solar & seaweed were combined, monitoring data is shared and preparations (like training, vessel information, etc.) is shared as well	Combining trips makes planning more of a challenge	Reduced costs of O&M and inspection Best practices of vessels, monitoring equipment, anchors, etc. shared	
Greek pilot	When possible during the summer period one vessel from one company can be used for combining activities (feeding, diving). ROVs when scheduled do the infrastructure monitoring instead of the personnel	Combining trips is difficult because of the different time needed for each activity	reduced costs of transportation	
Danish pilot	If we can involve the boats used for the wind turbine service teams, synergy can be obtained.	Service operation is difficult to foresee and has all the time priority. As tourist groups cannot accept large delays it is almost impossible to combine the two activities.	Reduced costs of transport	

Environmental impact	**current situation**	**major set-back**	**major advantage**	**Future best solution**
law and regulation				**law and regulation**

Belgian pilot	import of flat oyster seed from France, UK and Norway for research purpose wild collection of seaweed spores in France (jessica?) for research purpose only extractive aquaculture allowed in OWF	Not certain that the Belgian part of the North Sea is Bonamia-free, so perhaps there is no need to take all these precautionary measures Exotic fauna and flora that live on or in the oysters can be imported unintentionally	Precautionary principle is followed for the Bonamia-issue, as also recommended by NORA. Since there are no native flat oyster banks anymore in the Belgian part of the North Sea, restoration will depend on import. The different flat oyster populations are known, and oysters from France and UK belong to the same population (cluster Ireland/France/UK) while the Norwegian population probably belongs to the Dutch/Denmark cluster. Since the North sea is rather undeep (20-30m), there is little scope for fish production in cages anyway. Since spores of the same seaweed population were used, there is no genetic pollution.	european exchange between licensing authorities, shortened procedures, implementation of multi use prerequisite for all offshore in european waters. More clarity is necessary about the presence/absence of Bonamia and Marteilli in the Belgian part of the North Sea A commerical enterprise will depend on seedproduction of selected seaweed species and bivalves. If not possible to collect from the wild (as with blue mussels), a hatchery production becomes necessary or import from neighbouring countries. Guidelines on exchange of seed and broodstock animals are necessary to ensure maintenance of genetic diversity and local populations. Monitoring on large scale projects needed, they can be used to validate the current models. In addition KPIs can be set to make sure the activities will be carried out in a nature inclusive way
German pilot	first offshore multi-use pilot leads to increased authority attention	very prolonged licensing procedure (8 months instead of 8-12 weeks) additional unplanned costly requirements (CPODs, Pinger, third party reporting etc.)		
Dutch pilot	Scale too small to be able to measure the impact, large scale projects needed. A lot of research is performed in making models that predict the impact, validation needs to take place with the (large scale) projects	For future projects: not defined yet what the restrictions or KPIs are that need to be met	First insights in the important KPIs, possibilities for measurement and development of prediction models.	
Greek pilot	small scale pilot in order to get concrete conclusions. What we know till now, is that through aquaculture more marine species are being attracted which leads to a rich fauna for divers and raising awareness for marine biology. Constantly monitoring through sensors, leads to avoidance of unhealthy conditions.	small scale pilot	attractance of other fish species, more ecological niches	
Danish pilot	Each kind of activity has its own rules.	Non	Better economy and less pollution	
monitoring				**monitoring**
Belgian pilot	sampling of aquaculture species (oyster, seaweed) and infrastructure on the presence of fouling organisms water parameters collected from existing measuring buoys and satelite images	there was no budget for in situ measuring water parameters nor hydrodynamic parameters	Presence of non-indigenous species is monitored as well as the introduction of new non-indigenous species due to import of animals from abroad	adaptation of cost effective solutions to be adjusted to higer wave hights and harsh weather conditions Follow-up of fouling organism is necessary to evaluate the (positive and negative) impact of additional structures (OWF, aquaculture) on the ecosystem
German pilot	subsea-lander and mussel-system monitoring system surveillance of aquaculture site from FINO3	failure of lander shortly after deployment (possible risk of loosing data) failure of musssel-system monitoring after major storm event (loss of solar panel)	Covering a part of the missing data with data recorded by other paublic projects FINO3 surveilleance worked non-stop during operational phase of aquaculture site	
Dutch pilot	Monitoring with data buoys, inspections and by sampling	Scale of the pilot small, no sensor equipment available for all data	More insight in monitoring methodologies	
Greek pilot	use of sensors inside the cages of the aquaculture farm for water quality monitoring, use of camera in the cage of the aquaculture farm for fish behavior and welfare, data are being used for fish performance indicators	cleaning of sensors and camera is needed because of the fouling	constantly monitoring thanks to real time data	
Danish pilot	Monitoring is about how many people and turnover, so it is just standard PC activity.			
evaluation				**evaluation**
Belgian pilot	final evalutation will be done towards end 2023	Preliminary results indicate the presence of non-indigenous species on the introduced oysters. Large-scale production of bivalves will contribute to the enrichment of the bottom with organic material (carbon). This will influence bottomlife and may lead to shifts in populations.	Since the North Sea is considered eutrophic, the culture of bivalves on a large scale will contribute to the removal of nutrients when harvested and accelerate the nutriënt cyclus by filtering the microalgae. Seaweed is also extracting inorganic nutriënts from the environment.	linkage of data sources early in the project The production of extractive aquaculture, such as bivalves and seaweed, is a good choice in eutrophic environments such as the North Sea and also complies with the regulations set in the MSP.
German pilot	final evaluation is still to be carried out after decommisioning	missing data (Lander not functioning)	data will also be used from divers open source data platforms for location of FINO3	
Dutch pilot	Seaweed pilot is finished, solar still running	Scale of the pilot small for measuring significant impact	Combination with models Deltares	
Greek pilot	tourists become a bit more familiar with the idea of aquaculture from what they have expressed as opinion. Data coming from the monitoring system are being checked.	locals still need time to accept the idea of aquaculture farm in the area.	Data have shown that when the farm is being monitored with sensors and camera lower FCR is being recorded resulting to less feed needed and higher SGR coming from optimal feeding and environmental conditions.	
Danish pilot	People are very positive to the synergy.	Most wind turbine owners today don't see the benefit	Could increase the acceptance of offshore wind	
reporting				**reporting**
Belgian pilot	Reporting lost goods is mandatory	Only specialist can do the identification of fouling organisms	Data on fouling organisms will be published and can serve as input for the Environmental Impact Assessment.	need for more grey literature on benefits of multi-use activities on the environment setting-up a hotline for aquaculturist to report unknown organisms, mortality events, ... and vice versa where researchers can ask people to look out for specific organisms (fouling, birds, mammals, etc;)
German pilot	final reporting is still to be carried out after decommisioning	additional reporting to authorities including evaluation of CPOD data by third party company		
Dutch pilot	Reporting will be done via the deliverables			
Greek pilot	reporting via the deliverables			
Danish pilot	Reporting via the deliverables			

Market goods and people	current situation	major set-back	major advantage	Future best solution
law and regulation				**law and regulation**
Belgian pilot	harvest project can not be commercialized nor tasted	offshore is not recognized as shellfish water, which will have a major impact on the commercialization of the bivalves produced offshore. Costs for analyzes (faecal coliforms, harmfull algae and their toxines, heavy metals and organic contaminants) will be for the aquaculture farmer and not for the government.		governmental support for the emerging auqaculture sector will be necessary, just like in the agriculture sector or fisheries sector. There are good examples in neighbouring countries, such as France and Ireland where the bivalve sector is supported by national research institutes.
German pilot	as the operators of the German pilot do not have a food licence, the products to be harvested cannot be processed further afterwards.		Market is allready established in Germany and regualtions are know n and can be dealt with	
Dutch pilot	Depending on the application, different laws/regulations will be in place (food, feed, biostimulants, building material, etc. for seaweed; or energy for solar)			
Greek pilot	there is no specific regulation for multiuse.			
Danish pilot	No special rules for MUP	Without demand for MUP it will not take place very often	Multi use will results in many small advantages.	
seaweed				**seaweed**
Belgian pilot	an emerging market for seaweed products in combination with the small volume of the harvest (pilot scale) makes it difficult to find interested companies to go commercially.	future as healthy food maybe, not yet well introduced in the Belgian kitchen or feeding habits possible health issue with arsenicum (?) production of alginate is not competitive with large scale production elsewhere (Asia, Norway, ...) production of seaweed for biofuel is doubtful (cf story with microalgae) large surface needed for 1 ton dry weight of seaweed : limited space available in the Belgian part of the North Sea	considered healthy food with lots of minerals youth and upcoming vegetarian/vegan lifestyle will contribute to the demand for seaweed possible resource for biorefinery	- further development and promotion of seaweed-based food products such as hamburgers, ... - explore possibilities with biorefinery industry - Steps in logistical process getting seaweed from offshore location in good condition/quality to the consumer/processer/client
German pilot	as the operators of the German pilot do not have a food licence, the products to be harvested cannot be processed further afterwards.		Market is allready established in Germany and regualtions are known and can be dealt with	
Dutch pilot	The current focus for the use of offshore seaweed is on: food, feed, biostimulants and biomaterials. The harvest from the pilots is used for research purpose only, follow-up project in wind farm will produce seaweed for the market.	Quality of the seaweed was not good as the net with seawweed stayed in the warm water of the harbour for a couple of days before harvest (due to logistic issues with weather & vessels)	There are many opportunities to use seaweed, therefore there is a great potential	
oysters & mussels				**oysters & mussels**
Belgian pilot	oysters are very well known by customers, although cupped oysters much more than flat oysters	flat oyster more expensive than cupped oyster fresh market only sales are concentrated around Christmas period sanitairy measures are very important	existing market for oysters, also flat oyster flat oysters are part of our cultural heritage, so the restoration of flat oyster beds is applauded good logistical network in Belgium	Combination of wind energy, oyster culture and oyster restoration is a very nice story that sells well to the benefit of all actors. downstream facilities are missing (dewatering facility in the harbour)
German pilot	as the operators of the german pilot do not have a food licence, the products to be harvested cannot be processed further afterwards.		N	
fish				**fish**
Greek pilot	fish are being sold and used in the restaurants		fish from the aquaculture farm is cheaper than the wild	
tourisme				**tourisme**
Greek pilot	tourists dive around the aquaculture farm	the cost of diving with the use of a vessel has been higher because of increased fuel costs	tourists like the idea of diving in such a diverse area with rich fauna	
Danish pilot	Is ongoing.	No solution still found for visits by few people not in a “large” group fit to the boats.	Tourism activities is growing.	
job creation				**job creation**
Belgian pilot		inflow of new people need to be trained, both for OWF & aquaculture Fishermen are often suggested to work at aquaculture facilities at sea, but till now there is very little interest	need for skilled seaworkers	future jobs are divers and cover many facets of marine , offshore multi use work. There is need for a training school that covers a wide range of skills in the light of multi-use exploitation of the sea Better communication and more efforts to reach out to the fishermen
German pilot				
Dutch pilot	Currently both seaweed & floating solar are in the innovation phase: this generates jobs for researchers, innovators, etc. but also for subcontractors like captains (vessels), manufacturers, etc.	No constant demand yet	Collaboration with local community (for example use of vessels, steel manufacturer, fabrication of nets, floaters, etc.)	
Greek pilot		not any demand yet		
Danish pilot	going up		Positive for guides and boat owners	
access to offshore industry				**access to offshore industry**

Belgian pilot	offshore industry belongs to multi-nationals and big consortia	Because of the high costs, offshore aquaculture tends to be exclusive for big companies or consortia. Small SME don't have the carrying capacity	new jobs are being created which may attract youth Offshore wind energy is a mature sector now that will expand fast in the coming years, because of climate change and the energy crisis. eu wants to become more self-relient for aquaculture products and support offshore development. This is an important incentive for EU nations to support multi-use activities at sea.	Better communication and more efforts to reach out to the fishermen to get involved. Some of their skills are highly wanted. Danish example where 50% of the OWF is owned by a cooperative created opportunities for everybody to be involved in offshore wind energy. This example could be expanded to other activities at sea as well, such as aquaculture. It will enhance greatly the support base. In the Netherlands every new OWF will include multi-use.
German pilot			Presentation of ideas to German Offshore wind association.	
Dutch pilot	Dutch wind farms owners are part of the North Sea Farmers network. Collaboration with wind farm owners on multi-use in wind farms.	Offshore wind industry is more mature, not possible for multi-users to meet those standards yet.	Multi-use is the future in the Netherlands, first steps in collaboration with OWF are made	
Greek pilot				
Danish pilot	The wind turbine owners don't see any synergy.	The owners are only seeing problems. Farms far away from the ports is very often not relevant.	Multiuse must be attractive in more ways: demand, incentives …	