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DELIVERABLE 7.6

DEVELOPMENT AND IMPLEMENTATION OF A DECOMMISSIONING PROCEDURE

Work Package 7

Implementation of Multi-Use Concepts Within Pilots

31 December 2023

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Abstract	Deliverable 7.6 from the UNITED project describes decommissioning procedures for offshore aquaculture farms. The document advocates for nuanced approaches, considering partial decommissioning for restoration and biodiversity. The methodology analyses European policy challenges,

	emphasising the need for regulatory adaptation. Insights from specific pilots highlight diverse decommissioning approaches. In summary, this document provides concise insights into decommissioning procedures, challenges, and recommendations from multi-use offshore pilot projects, contributing valuable lessons for future sustainable ventures in dynamic marine environments.
Keywords	Decommissioning procedures, multi-use offshore platforms, European policy, pilot projects, aquaculture systems
Change Log	Resubmission 1 – change in cover page and introduction tables

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ACRONYMS

FuE	Forschungs- und Entwicklungszentrum Fachhochschule Kiel GmbH
JDN	Jan De Nul
MPA	Marine Protected Area
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

The purpose of Deliverable 7.6 is to delineate decommissioning procedures for offshore aquaculture farms, including an exploration of the ongoing discourse on the potential necessity for complete decommissioning and an assessment of current legislation. While European policy currently mandates complete removal of infrastructure, there's a growing recognition of the need for partial decommissioning, particularly when it proves valuable for restoration efforts or biodiversity conservation. The document underscores the potential repurposing of infrastructure and advocates for an open discussion on its utilization.

The document's methodology involves describing the current European policy on decommissioning, presenting decommissioning activities tailored to each pilot project, formulating recommendations based on hands-on experience, and suggesting ways to follow up on these recommendations. This process ultimately contributes to a roadmap for multi-use projects in WP9.

The discussion on current European policy within the context of multi-use offshore platforms focuses on challenges, such as the uncertain consequences at the end of operational life, especially for offshore wind farms (OWFs). Existing decommissioning regulations lack specificity on multi-use aspects, highlighting the need for adaptation and regulatory clarifications to address the complexities of multi-use platforms while preserving their benefits.

The German pilot, located 80km offshore west of the island Sylt in the North Sea within the safety zone of "FINO 3," a research platform, is dedicated to supporting wind farm research and presently focuses on offshore multi-use (MU) activities. Operated on the periphery of the safety zone of the DanTysk wind park, the pilot integrates an aquaculture system with algae and mussel units, complemented by a monitoring lander. The decommissioning process unfolded during the spring and summer of 2023, employing a systematic, stepwise approach to disassemble and recover the algae, mussel, and monitoring systems. Challenges emerged during the decommissioning of the monitoring system, leading to the formulation of specific protocols and the allocation of maritime resources. The algae components were meticulously transported to the port, and commercial divers played a crucial role in salvaging the monitoring lander, including the sea cable linking the monitoring system to the FINO3 Platform. Aiming to test a multi-use synergy effect offshore, technicians were mobilized to dismantle and prepare the data transmission equipment on the FINO3 Platform for air transport. Recommendations for enhancing future decommissioning processes include well-defined salvage and recovery procedures, involving specialized equipment and experienced divers. Coordination of transportation logistics is deemed vital, and the emphasis on accurate documentation throughout the decommissioning process serves as a valuable reference for continuous improvement. Implementation of these recommendations enables future multi-use projects to streamline their decommissioning processes, saving costs, minimizing unexpected challenges, enhancing safety, and optimizing data and equipment retrieval, ultimately contributing to more favourable outcomes and valuable insights.

The Dutch pilot, positioned at the North Sea Farmers Offshore Test Site, confronted the challenges of the rugged offshore conditions of the North Sea. This pilot project entailed the installation of two seaweed cultivation systems and an innovative floating solar pilot, marking the world's first offshore floating solar installation, alongside various measuring devices. Legal requirements in the Netherlands mandate full decommissioning of any activity within an offshore wind farm upon license expiration, aligning with the lifespans of seaweed farms, floating solar installations, and wind farms. The decommissioning of the seaweed installations, including moorings, was successfully accomplished, with mussel growth on the installation underscoring the importance of considering this factor in system design and maintenance. Notably, the decommissioning of the large data buoy presented operational and cost challenges, leading to the development of a smaller, more efficiently installed and decommissioned data buoy. This innovation substantially reduced costs and improved operational efficiency. The floating solar installation laid the groundwork for the North Sea 2 (NS2) project, expanding to a 1MW scale installation. The solar farm will undergo decommissioning at the conclusion of NS2 unless there is a subsequent project. The decommissioning procedure involves elements akin to the installation process, emphasizing equipment removal, planning, vessel selection, and execution. Recommendations for future multi-use projects within offshore wind farms include exploring synergies by combining decommissioning activities, examining opportunities for reusing elements, and considering retaining parts of the anchoring with artificial reef functions to preserve nature restoration activities beyond the lifespan of offshore wind farms and multi-use operations.

The Belgian pilot, positioned amidst the turbines of the Belwind wind farm, presented distinctive challenges due to its offshore location. This pilot delved into seaweed and flat oyster cultivation, as well as the potential restoration of flat oyster beds using windmill scour protection. Legal requirements in Belgium mandate full decommissioning when wind farm licenses expire, encompassing all activities within wind farms, prompting questions about the necessity of complete removal, particularly for projects beneficial to nature conservation. The decommissioning plan centres on the removal of aquaculture systems, including anchors. Concerns arise regarding the feasibility of removing screw anchors years after installation. The HORIZON EUROPE ULTFARMS follow-up project opted to retain parts of the UNITED infrastructure, including the oyster longline backbone and anchors, as well as the seaweed line screw anchors. The decommissioning procedure involves planning, vessel selection, and material retrieval, addressing challenges related to safety measures and the complex environment of the Belwind wind farm. Recommendations for future multi-use projects underscore the importance of aligning time horizons and activities, particularly in cases of nature restoration, and reassessing the conventional decommissioning approach. A holistic approach to wind turbine renewal is proposed to optimize ocean space usage and promote more efficient renewable energy development. Synchronizing life cycles and decommissioning operations across different activities is suggested to enhance efficiency and resource utilization, ultimately contributing to a forward-thinking framework for the future of multi-use projects and commercial enterprises in the evolving ocean environment.

The Danish pilot project introduces an innovative and sustainable approach to multi-use offshore endeavours, merging wind energy with tourism. In contrast to traditional decommissioning practices explored in other pilots, the Danish pilot focuses on repowering its existing wind turbines rather than opting for complete removal. This strategy aims to prolong the operational lifespan of the turbines, showcasing the efficiency of renewable energy structures. Visitors have the opportunity to explore the wind turbines and climb the monopiles, fostering awareness of renewable energy and community engagement. In summary, the Danish pilot exemplifies sustainability, longevity, and a unique integration of wind energy and tourism.

The Greek pilot project distinguishes itself as a unique approach in the realm of multi-use offshore endeavours. Instead of pursuing decommissioning, it concentrates on extending the license for aquaculture facilities. Legal requirements in Greece govern the decommissioning process, placing emphasis on environmentally friendly practices. Plans for decommissioning the UNITED pilot in Kastelorizo involve responsible and phased processes, to be executed upon the expiration or early termination of the aquaculture license. The technological equipment, encompassing cameras and sensors, will remain at the pilot site after the project concludes. The decommissioning procedure in Greece entails careful removal of aquatic animals, draining of water, dismantling structures, and land restoration. It underscores environmental protection, including the potential removal of sediment from the facility's bottom, under the supervision of a qualified engineer. Recommendations from the Greek pilot emphasize the importance of exploring synergies among different activities within multi-use projects, adopting eco-friendly practices, and prioritizing continuous monitoring and research to ensure sustainability throughout the project's lifecycle. These insights contribute to a more environmentally responsible and efficient approach within the dynamic marine environment.

1. INTRODUCTION

1.1. Aim of this report

During the planning of the project, decommissioning procedures for the five pilots were foreseen, which are detailed in this deliverable. However, during the final phase of the project, approximately six months before completion, a decision was made to extend or expand the pilots with additional goals. The results of this process are described in Chapter 3. For this purpose, we will assess the current legislation related to the decommissioning of offshore aquaculture farms. Presently, European policy dictates that everything should be removed by industry or investors once the facility's usage concludes. The legislation will be closely reviewed, and proposed adjustments to the rules will be recommended to support restoration efforts in the future.

Looking ahead, it is essential to consider the evolving landscape of offshore wind energy. With new technologies, larger turbines, and greater distances between them, the landscape is changing rapidly. Additionally, the European Commission's prioritization of food production at sea necessitates a review of decisions made in the past regarding the decommissioning of existing wind farms.

To this end, we should explore options for partial decommissioning of wind turbines. This is particularly relevant when restoration efforts are exceptionally valuable for re-introducing lost species or enhancing desired biodiversity, making it undesirable to lose these benefits when turbines and/or scour protection are removed.

It's advisable to keep the discussion open regarding the potential repurposing of some of these turbines as anchoring points once they cease functioning as energy producers. In Belgium, one consideration involves cutting the poles several meters above the sea surface, demonstrating a forward-thinking approach. This strategy aims to maximize the utility of existing infrastructure while aligning with evolving priorities and technologies. However, the ongoing debate on this matter is nuanced, with the scientific community strongly divided. Many argue that leaving man-made structures at sea disrupts the natural state of the marine ecosystem, a viewpoint that warrants careful consideration.

1.2. Methodology

The structure of the document is as follows. The current policy in Europe regarding decommissioning is first shortly described, followed by an overview of the decommissioning activities, planned and/or modified per pilot. Some recommendations are formulated per pilot, based on the hands-on experience. In a next chapter, all recommendations are pooled, and some suggestions are made to follow-up on them.

The results of this deliverable D7.6 will feed into WP9 (“Communication and Dissemination” work package), where a roadmap for multi-use will be presented.

2. CURRENT POLICY IN EUROPE

In the context of multi-use offshore platforms, a variety of activities, ranging from energy extraction to fishing and even tourism, coexist in a shared space. This intricate multi-use scenario calls for a tailored governance approach that takes into account the unique characteristics, infrastructure, and societal benefits associated with individual structures (as detailed in D3.2).

One of the key aspects addressed in D6.1 relates to the legal and insurance considerations, particularly concerning the uncertain consequences at the end of the operational life of one of the multi-use activities. Most offshore wind farms (OWF) are typically licensed for around 25 years, after which all infrastructure must be completely removed. However, when considering the success of aquaculture farms, it raises questions about what happens when OWFs are due for decommissioning.

This issue is further complicated by the lack of focus on multi-use aspects in existing decommissioning regulations. The requirements for decommissioning are often unclear, leading to complex removal procedures or the possibility of partial removal.

In light of these challenges, it is evident that the current policy in Europe regarding decommissioning must evolve to address the intricate nature of multi-use offshore platforms. Additional considerations, adaptations, and regulatory clarifications are required to ensure a smooth transition from active operations to decommissioning while preserving the benefits of multi-use platforms.

3. DECOMMISSIONING PLANS PER PILOT

3.1. German Pilot

The German pilot is situated 80 kilometres offshore in a highly exposed marine environment within the North Sea. The purpose of erecting the "FINO3" (Figure 1) research platform, standing at a height of 120 meters with a working platform positioned 22 meters above sea level, is to enable research endeavours aimed at facilitating the establishment of wind farms. A new focus of this platform is to serve as a testing option for MU activities. In close proximity to the DanTysk wind park, which harnesses the power of 80 wind turbines to generate 288 MW of electricity (source: www.dantysk.de), an aquaculture system has been established within the safety zone (radius 500 m) surrounding FINO 3. The aquaculture system consists of two parallel 40 m nets. One of these nets is dedicated to cultivating algae directly at the sea surface, allowing for maximal exposure to sunlight, thereby promoting optimal algae growth. The second net is designed for submersible mussel growth. To ensure the stability of the system, the nets for mussel growth are at a depth of 7 to 12 m, effectively removing the system from the wave zone. In between the two systems a “lander” with monitoring equipment was deployed.

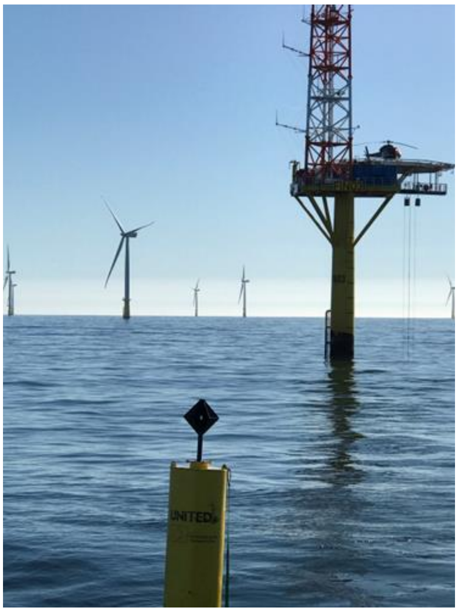

Figure 1: FINO3 Platform

3.1.1. Legal requirements in Germany

The system of the German pilot had to be approved by the Federal Maritime and Hydrographic Agency (BSH). Within the approval, various regulatory requirements are specified. Regarding decommissioning, it is stated that everything brought into the North Sea must be removed within 7 days after the conclusion of the approval period. This regulation is a standard requirement applicable to all equipment, anchors, and structures deployed in the oceans. Additionally, fundamental safety regulations are stipulated that must be followed to ensure secure operations during decommissioning, guarantee safety and facilitate ship traffic. It is imperative to adhere to and comply with the directives outlined in federal law throughout the decommissioning process.

3.1.2. Plans for decommissioning the German UNITED pilot (old, new) and concerns

The decommissioning process for the system, which consisted of algae, mussels, and monitoring units, was scheduled to take place during the spring and summer of 2023. Given the different components involved, a stepwise decommissioning approach was necessary. The initial phase involved decommissioning of the algae net in May 2023, followed by the removal of the monitoring unit, the connecting sea cable, the technical data transmission equipment on the FINO3 Platform, and finally the mussel unit in June 2023.

During the decommissioning phase, efforts were made to obtain final samples and retrieve data loggers from the mussel and algae system, as well as the monitoring lander. Unfortunately, the decommissioning of the monitoring system required a separate protocol.

3.1.3. Decommissioning procedure

To ensure a systematic and efficient decommissioning process, specific protocols were developed and implemented for dismantling and retrieving the algae, mussel, and monitoring systems (Figure 2). The decommissioning operation utilized maritime resources, skilled personnel, and specialized equipment tailored for the task.

To decommission the algae system, a dedicated boat was assigned to transport its various components back to the port. Great care was taken to handle and secure the components on board to prevent damage during transit.

The salvaging of the mussel and monitoring systems involved a more complex operation. It required the deployment of two boats and a team of three highly trained commercial divers. The divers conducted underwater searches for the monitoring lander, and upon locating it, they connected the boats' crane and winch system to the lander using a specifically adapted hoisting gear designed for this purpose. With precision and expertise, the lander was lifted from the water and brought on board the vessel.

After successfully retrieving the lander, the first boat followed the route of the sea cable closely. The sea cable, which linked the monitoring system and the FINO3 Platform, was reeled in and salvaged on deck.

Simultaneously, the second boat focused exclusively on retrieving the mussel system. The team on this vessel carefully disassembled and recovered the mussel unit.

Once all the components, including the algae system, monitoring lander, sea cable, and mussel unit, were successfully salvaged, they were transported ashore to Cuxhaven.

Apart from the equipment situated at sea, focus was directed towards the apparatus positioned on the FINO3 Platform. Offshore technicians assumed the responsibility for dismantling the data transmission equipment. These units were disassembled and readied for air transport, ultimately being transferred ashore via helicopter.

The decommissioning plans had to be adjusted and adapted throughout the process, but ultimately, all equipment was decommissioned in a safe and secure manner.

Figure 2: Decommissioning from left to right: algae system, lander and far right detail of the lander.

3.1.4. Recommendations for future multi-use projects/commercial enterprises

Throughout the decommissioning phase, a methodical and strategic approach was utilized to guarantee the secure removal of diverse components while salvaging as much as possible. Despite encountering unforeseen challenges such as broken parts and damaged sensors during the operational phase, ongoing efforts are in progress to retrieve valuable data, which will be integrated into upcoming deliverables.

To enhance future decommissioning processes, we propose the development of well-defined salvage and recovery procedures. The utilization of specialized equipment such as cranes and winch systems, along with the involvement of experienced divers, should be considered to facilitate efficient retrieval. The establishment of clear protocols for locating and recovering components will effectively mitigate the risk of damage or loss. Additionally, meticulous planning and coordination of transportation logistics are crucial. Depending on the project and equipment involved, appropriate modes of transportation, such as specialized boats or helicopters, should be arranged to ensure the secure and efficient transfer of components from offshore sites to onshore locations.

The maintenance of accurate documentation throughout the decommissioning process is of utmost importance. This encompasses recording procedures, encountered challenges, salvage operations, and efforts made for data retrieval. Such documentation will serve as valuable references for future projects, enabling continuous improvement in decommissioning processes.

By implementing these recommendations, future multi-use projects and commercial enterprises can optimize their decommissioning processes, minimizing the occurrence of unexpected challenges while maximizing the retrieval of valuable data and equipment.

The following recommendations are expected to be of great value for future offshore projects:

1) One recommendation is to aim for decommissioning procedures without the need for divers. Diving operations are extremely costly and always an additional risk. This needs to be considered from the beginning of the design process.

2) Another recommendation is to strive for lighter and more compact equipment. Throughout all phases of the pilot—transport, pre-assembly, installation, maintenance, and deinstallation—significant challenges, risks, and costs were revealed due to the use of heavy and bulky materials. Vessel availability for working with such structures' dimensions is limited, especially during the few suitable weather windows in far offshore rough conditions. These insights will be integrated into the planning phases of upcoming offshore projects. Embracing lighter materials would reduce requirements, allowing for the use of smaller vessels, expanding the number of operational weather windows offshore. This, in turn, creates more opportunities to share vessels with other offshore users (e.g., CTVs) and promotes safer operations.

From 2001 to 2023, the region experienced only 41 days with a maximum wave height of 1m. If operations were feasible with a wave height of up to 1m, an additional 52 days would become available. Further, considering the possibility of operating until a maximum wave height of 1.9m, an extra 48 days would be accessible. This could potentially result in a doubling or tripling of suitable weather windows.

3) An additional suggestion is to thoughtfully assess the consequences of a complete decommissioning. A profound monitoring should accompany the situation before, during and after the offshore activity. Offshore structures can serve the ecosystem by providing lost habitats for a specific area. These accidentally or willingly achieved habitat restoration would be destroyed by complete decommissioning.

This will contribute to more favourable outcomes and ensure the acquisition of valuable insights.

3.2. Dutch Pilot

Seaweed installation is decommissioned, solar panels stay under new project NS2

The Dutch pilot was installed at the North Sea Farmers Offshore Test Site, 12km of the coast of The Hague and therefore subject to the rough offshore conditions of the North Sea. At this location, two seaweed cultivation systems were installed by UNITED partner “The Seaweed Company” together with North Sea Farmers for two growing seasons. Next, a floating solar pilot (the first offshore floating solar installation in the world) was installed by UNITED partner “Oceans of Energy”. Additionally, a few measuring devices have been installed. Both as part of the pilots (for example force measurement on the system) as well as with a big and a small data buoy by “North Sea Farmers”. A full description of the systems can be found in D7.1 (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).

3.2.1. Legal requirements in the Netherlands

In the Netherlands, the decommissioning of an offshore wind farm is mandatory upon the expiration of licenses. This requirement extends to all activities within the wind farms, including aquaculture, solar energy production, or restoration. Consequently, the lifespan of a seaweed farm or floating solar installation is intricately linked to the wind farm's lifespan. Specifically, at the Dutch pilot location, the North Sea Farmers Offshore Test Site, the permit mandates the complete decommissioning of all activities by the permit's expiration.

3.2.2. Plans for decommissioning the Dutch UNITED pilot (old, new) and concerns

The decommissioning of the two seaweed installations, along with the mooring of the Dutch pilot, has been accomplished successfully, as illustrated in Figure 3. Notably, the photo reveals substantial mussel growth on the installation. It is crucial to consider this growth in the system's design, ensuring that the floating devices can accommodate the additional weight. For a sustainable long-term farm or installation, regular cleaning of the floating devices is recommended as part of routine maintenance.

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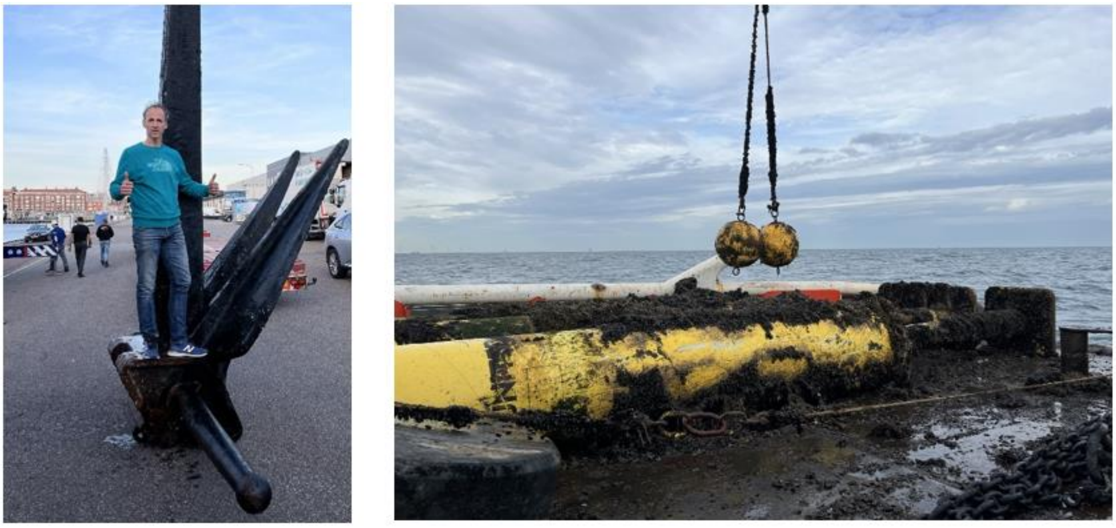

Figure 3: Impression decommissioning seaweed installations Dutch pilot

The big data buoy has been taken out of the water / decommissioned twice. In between, maintenance took place for the second operational period. For this big data buoy, a vessel with a high crane capacity of 10 t was needed. Both maintenance and decommissioning of this buoy turned out to be challenging operations, because of the high cost and of the difficulty in finding an available vessel to operate when needed. Hence, a novel approach was embraced: crafting a compact data buoy suitable for installation and decommissioning using a small vessel and crane. Operating with a smaller buoy offers increased ease, as there is a greater availability of smaller vessels capable of handling installation, maintenance, and decommissioning tasks. This also presents the opportunity to synchronize these operations with other activities. Furthermore, the associated costs for the installation and de-commissioning would be only 10% of those linked with the operation of the larger buoy. Figure 4 illustrates the contrast in vessels between the small and large buoys.

Figure 4: (Left) vessel for installation & decommissioning of big data buoy; (right) vessel that will be used for the small data buoy

Therefore, a new approach was adopted: designing a small data buoy that can be installed and decommissioned with a small vessel and a small crane. Operation with a smaller buoy would be easier, as there would be more, smaller, vessels able to conduct installation, maintenance and decommissioning, opening even the opportunity to couple these operations with other activities. In addition, costs for installation and decommissioning would be only 10% of the costs associated with operation of the big buoy. Figure 4 shows the difference in vessels between the small and big buoys. Multiple small vessels could do the installation / decommissioning (or even combine it with other activities) and the costs are 10 % of the installation / decommissioning of the big data buoy.

The floating solar installation serves as the foundation for a new venture: North Sea 2 (NS2), expanding to a 1 MW scale installation, as depicted in the impression in Figure 5. Consequently, the solar farm will not undergo decommissioning within the UNITED project but is expected to be decommissioned at the conclusion of NS2, unless a subsequent project is initiated in NS2.

Figure 5: Floating solar installation by Oceans of Energy as part of follow-up NS2 project

3.2.3. Decommissioning procedure

The steps before decommissioning are similar to the installation procedure, with the addition that it is important to verify that all the equipment is removed.

- Agree of the reuse or disposal of all the elements of the installation.
- Make a decommissioning plan of approach including the planning, vessel, handling approach, etc. Check whether decommissioning activities can be combined with other offshore (decommissioning or other) actions.
- Find the right corresponding vessel for the job and agree on the plan of approach with the operator/crew/captain.
- Plan and execute all the activities (decommissioning and reuse or disposal) and verify if all the equipment offshore is removed.
- Evaluation and reporting.

3.2.4. Recommendations for future multi-use projects / commercial enterprises

The following recommendations for (commercial) multi-use within an offshore wind farm are provided:

- Exploring synergies: combination of decommissioning activities for different multi-use activities and/or combination with the decommissioning of the offshore wind farm itself, as the timeline / lifespan will be similar.
- Exploring the reuse of the different elements, for example floating devices.
- Exploring the possibilities of keeping (parts of) the anchoring with artificial reef function in place, to ensure that the nature restoration activities are not disturbed and can continue after the lifespan of the OWF and multi-use activities.

3.3. Belgian Pilot

Extension of the activities under ULTFARMS

The Belgian pilot zone is situated between the turbines of the windfarm Belwind, which makes it unique and particularly challenging to operate. The aquaculture longline systems tested in the Belgian pilot were used to grow sugar weed and European flat oysters. Possibilities to restore flat oysters' bed, using the scour protection of the windmills as a starting point were also investigated. A total of four tables filled with rocks, were installed on top of the scour protection of two windmills. Two of these were also stocked with mature adult broodstock, in order to evaluate the usefulness of pre-stocking the tables with broodstock animals to attract and produce oyster spat. 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).

3.3.1. Legal requirements in Belgium

The offshore wind farm (OWF) in Belgium is obligated to undergo full decommissioning upon the expiration of licenses. This requirement extends to all activities within the wind farm, encompassing aquaculture and restoration efforts. The significant implication of this mandate is that the lifespan of an aquaculture farm is intricately tied to the concession duration of the wind farm. Moreover, any ongoing restoration initiatives would be affected when wind turbines undergo decommissioning.

This concern is not applicable to the current location of the Belgian pilot, as the area is not a natural habitat for European flat oysters. Effective restoration should focus solely on reinstating species and habitats in locations where they would naturally flourish if threats were eliminated. The Belgian pilot successfully tested a method for oyster reef restoration, yielding promising results. This approach may be replicated in more suitable areas, such as the Belgian Vlaamse Banken Marine Protected Area (MPA) and the newly designated offshore wind farm area, the Princess Elizabeth Zone.

In the context of active restoration facilitated by a multi-use environment, such as a wind farm combined with low-trophic aquaculture, careful consideration should be given to the decommissioning of these wind farms. It is essential to avoid compromising the achieved habitat restoration. This consideration should be integrated into the design and installation of both existing and future wind turbines, anticipating a decommissioning process with minimal impact on the marine environment. Potential approaches include partial decommissioning or the retention of basic structures for reuse in subsequent wind farms during decommissioning and re-installation, leaving the turbine bases and scour protection intact. Currently, there is no legislation permitting partial removal, and the conditions for such removal are not yet defined (D6.1).

3.3.2. Plans for decommissioning the Belgian UNITED pilot (old, new) and concerns

Considering the restricted duration of concessions and the finite lifespan of materials, it is imperative to anticipate the comprehensive decommissioning of the entire aquaculture systems, anchors included. However, a significant apprehension arises regarding the feasibility of removing screw anchors several years post-installation. In aquaculture farms elsewhere globally, the common practice is to cut anchors 2 meters below the surface. Notwithstanding, seasoned service providers express confidence in the removal of screw anchors (D7.5). With the approval of the follow-up project ULTFARMS, the decision has been made to retain certain components of the UNITED Belgian pilot infrastructure, specifically the oyster longline backbone and the screw anchors of the seaweed line.

3.3.3. Decommission work performed summer of 2023

Planning and preparations

In adherence to the safety measures implemented in the Belwind wind farm and the demanding environment, a multicat with dynamic positioning (DP) or 4-point mooring was preferably employed. However, chartering such a vessel for a specific task during the peak season proved to be exceptionally challenging. In lieu of this, a multicat without dynamic positioning could be deemed acceptable, provided that the contractor substantiates, through a comprehensive method statement, their capability to execute the work safely.

Once the vessel was chosen, the wind farm operator subjected it to a vetting process, and a method statement was formulated outlining the procedures for the safe execution of all work.

Decommissioning

To recover all materials from the longlines, the multicat approached the longline until its crane could lower a hook to pick it up. The crane then brought part of the longline on deck, where deckhands removed all structures attached to the longline. Subsequently, the longline was lowered into the water again, and the process was repeated further down the line. This sequence was reiterated until all attached structures had been successfully retrieved.

Harvesting of seaweed nets

The seaweed nets have been removed one by one from the backbone and all Velcro connectors could be cut. Furthermore, the five 120 L yellow buoys were to be removed from the backbone. The following steps were included:

1. The seaweed backbone (Figure 6) had to be lifted until the nets were visible. This action was contingent on current and weather conditions, a decision made on the day upon reaching the location and as recommended by the captain of the vessel. The net system, situated between the two corner buoys, required the retrieval of the backbone either at the commencement of the first or last net.

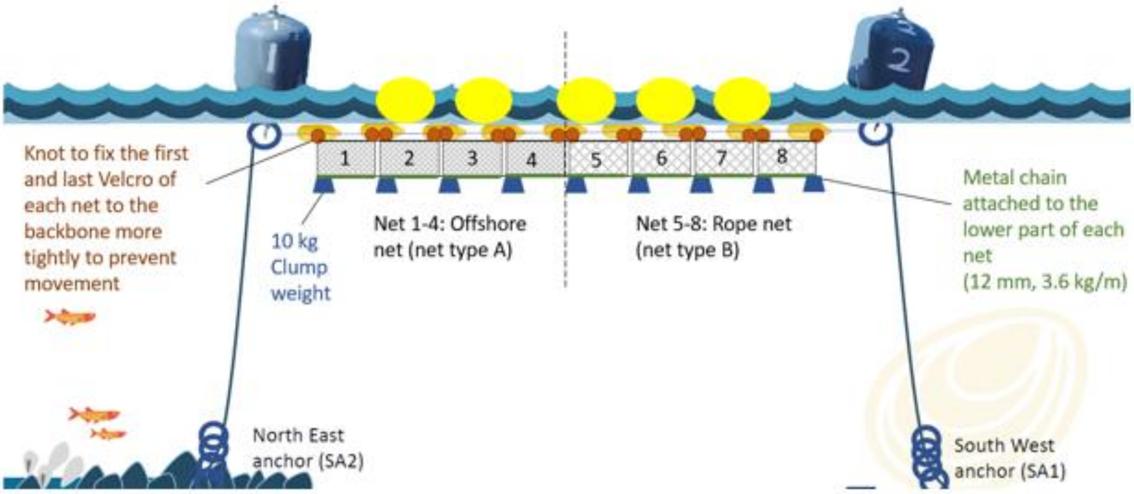

Figure 6: Illustration of seaweed longline

2. Once the backbone was connected, the backbone was lifted out of the water until the first seaweed net was in reachable position and secured.
3. The winch was connected to the net to allow pulling of the net on board.
4. The Velcro connectors (the attachment of the net to the backbone, Figure 7 below) were cut and the lose net could be hauled on deck by the winch.

Figure 7: Velcro connection of nets to the backbone and the next following net

5. This procedure needed to be performed for all eight nets.

6. In a later stage, the backbone will be replaced by an alternative backbone system during the HIRIZON EUROPE ULTFARMS project.
7. The screw anchors stay in place to be used for the alternative backbone systems.

Overall, the activity was estimated to take 2-3 hours, but two separate sea missions were needed. Back in the harbour, the seaweed nets were lifted to the pier using the crane of the vessel. Remaining seaweed samples, buoys and materials were removed from the boat to the pier.

Removing structures from the oyster longline

- The backbone (Figure 8) was to be lifted until the structures became visible.

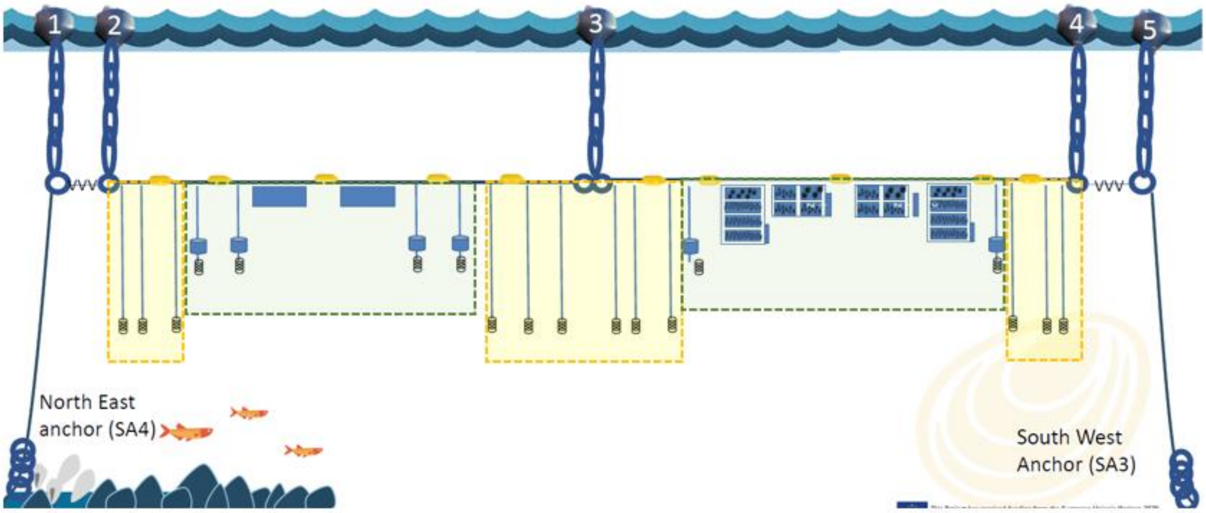

Figure 8: Illustration of oyster structures to be removed from the backbones. Yellow background: ropes seeded with oysters, blue background: metal structures.

- Removal of the blue baskets and ropes: to do so, it is suggested for the blue baskets – attached to the backbone via a rope – and ropes with cemented oysters to first drag on board the weight at the lower part of the blue basket and, when secured on the vessel, cut the rope at the top end from the backbone.
- Removal of the heavy metal frames from the backbone: suggestion is to attach first one handle of the cage to the winch. When secured, the one side of the cage can be cut from the backbone. The same can be repeated for the other handle.
- Removal of the other four metal structures: the cages can be cut from the backbone. To do so, it would be suggested to first attach one side to the winch, then cut the cage from the backbone on that side and repeat for the other side by attaching the other side to the second winch and cutting subsequently that side from the longline. Then, the cage can be winched in.
- Some buoys would be removed as well to keep the backbone straight. The backbone and screw anchors remain to be used for ULTFARMS.
- The evaluation of the lines extending from the screw anchor to the sea surface will primarily involve a theoretical assessment. Should this evaluation indicate a potential risk of the lines snapping during the retrieval of the screw anchors, then alternative measures may be considered. It's worth noting that the use of divers for this purpose would be an absolute last resort, mainly due to existing safety restrictions. In the unlikely event that diver deployment becomes an option, a comprehensive method statement must be provided well in advance, much like the preparations for vessel operations. This method statement would undergo a rigorous review and approval process by HSSE (Health Safety Security & Environment) to ensure safety compliance.

Planned decommissioning of the screw anchors at the end of ULTFARMS in 2026

Initially, all the structures attached to the longlines will be carefully retrieved, as previously detailed. Once these structures have been successfully retrieved, the vessel will reposition itself directly above the screw anchor by following the anchor rope that connects to the seabed. Subsequently, the anchor rope will be secured to the primary winch onboard the vessel. The winch will then initiate the process of lifting and pulling the screw anchor from its position within the seafloor.

Throughout this operation, stringent safety measures will be diligently adhered to by all crew members and passengers onboard the vessel to ensure a secure and risk-free procedure. Once the screw anchor is disengaged from the seafloor, it can be hoisted onto the vessel's deck. Simultaneously, the longline connected to the screw anchor can be gradually reeled in, while the vessel navigates towards the opposite end of the longline where the second screw anchor is situated.

Upon reaching the location of the second screw anchor, the outer end of the longline is intentionally severed to prevent any interference with the removal of the second screw anchor. The same method and process described above are then meticulously repeated to extract the second screw anchor from the seafloor.

3.3.4. Recommendations for future multi-use projects / commercial enterprises

In the realm of multi-use projects, particularly in the context of restoration efforts within wind farms, a set of significant recommendations emerge to address the intricate interplay and long-term sustainability of ocean space utilization.

First and foremost, there is a need to align the time horizons of activities in this domain. Restoration efforts at sea inherently come with a long-term perspective, while the typical lifespan of a wind farm concession spans 20 to 25 years. This temporal misalignment can potentially lead to conflicts and impede the sustainable development of multi-use ocean space. In Belgium, a forward-looking vision for wind farm decommissioning has been developed and presented to the Minister of the North Sea (Van Maele et al., 2023). A central aspect of this vision involves recognizing that when nature restoration efforts aim to reintroduce key species to their original spatial habitat, where wind turbines have been installed, the conventional notion of decommissioning everything should be reevaluated. Specifically, the positive impact of hard substrates introduced by the scour protection of wind turbines on biodiversity is considered insufficient justification to remove the rocks or lower parts of the poles.

Furthermore, a holistic approach is advocated to enhance wind turbine renewal. Complete decommissioning of wind turbines can facilitate the installation of newer, more efficient wind turbines. This approach optimizes the use of ocean space, allowing for the development of more effective renewable energy sources (Van Maele et al., 2023).

Moreover, there is a strong case for synchronizing the life cycles of different activities, such as aquaculture and wind energy, to enable the renewal of infrastructure and promote long-term co-existence. This synchronization also extends to decommissioning operations, where different activities could potentially make use of the same vessels and expertise, improving efficiency and resource utilization.

In conclusion, these recommendations offer a comprehensive and forward-thinking framework for the future of multi-use projects and commercial enterprises in the dynamic and evolving ocean environment.

3.4. Danish Pilot

No decommissioning but repowering

3.4.1. Legal requirements in Denmark

The Danish pilot did not install any additional large-scale infrastructure at their pilot site. Thus, there was no requirement to decommission anything at the end of the UNITED project.

The only infrastructure present at the Danish pilot site is the Middelgrunden Wind Farm itself, which was already constructed in the year 2000 and is operated independently of the Danish pilot. The operating license of the wind farm has not yet expired.

In Denmark there is no law that includes specific requirements regarding the decommissioning of offshore wind farms (Bech-Bruun, 2017). The decommissioning liabilities are regulated in the construction license off the wind farm, the electricity production authorisation that is issued by the Danish Energy Agency, and the concession agreement, documents that usually describe the obligations of the wind farm owner regarding restoring the area to its former conditions (Bech-Bruun, 2017). An example of one of the demands in the permission for establishing an offshore wind farm is to re-establish the seabed, i.e., moving the gravity foundation from the seabed. There is some uncertainty regarding the requirements for sea cables, as it is up to negation whether a buried sea cable can stay on the seabed or not. The discussion in that negotiation will be about how much pollution from sediment you create by removing the sea cable contra the "pollution" of keeping it on the seabed.

3.4.2. Plans for decommissioning the Danish UNITED pilot (old, new) and concerns

In the dynamic landscape of multi-use offshore projects, the Danish pilot stands out with its innovative and sustainable approach. Combining wind energy and tourism, the project offers a fresh perspective on the potential of offshore structures. Unlike some of the other pilots, where decommissioning procedures were explored, the Danish pilot is taking a different path.

In a noteworthy departure from traditional decommissioning practices, the Danish pilot does not foresee the need for complete removal or dismantling of its existing wind turbines. Instead, the focus here is on repowering, a strategy aimed at extending the lifetime of these turbines. This forward-thinking approach aligns with the growing recognition of the longevity and efficiency of renewable energy structures.

The repowering process involves refurbishing and upgrading the existing wind turbines, ensuring they continue to harness wind energy efficiently. This not only contributes to the sustainability of renewable energy sources but also showcases the potential for long-term coexistence of multi-use projects. By optimizing the performance of the turbines, the Danish pilot underscores the viability of combining wind energy and tourism as a harmonious and enduring solution.

Tourism plays a vital role in this unique Danish pilot, where visitors have the opportunity to explore the wind turbines, even climbing the monopiles for a panoramic view of the sea. This interactive and educational experience not only promotes renewable energy awareness but also fosters a deeper connection between the public and sustainable energy initiatives.

In essence, the Danish pilot exemplifies a multi-use project that seeks to repower and revitalize its wind turbines, ensuring their continued contribution to the energy grid while concurrently offering an engaging and informative experience for tourists. This innovative approach redefines the possibilities of multi-use offshore projects, emphasizing sustainability, longevity, and a strong connection with the community.

3.5. Greek Pilot

No decommissioning but extension of license

3.5.1. Legal requirements in Greece

The rules of aquaculture decommissioning in Greece are governed by the Greek Aquaculture Law 4076/2012. The law states that all aquaculture facilities must be decommissioned in a timely and environmentally friendly manner. The specific requirements for decommissioning vary depending on the type of aquaculture facility, but the general principles are the same.

The decommissioning process must begin as soon as the aquaculture facility is no longer in use. The first step is to remove all the fish and other aquatic animals from the facility.

3.5.2. Plans for decommissioning the Greek UNITED pilot (old, new) and concerns

Decommissioning plans for the UNITED pilot in Kastelorizo involve carefully managed and phased processes to ensure that the closure of the site is conducted responsibly and in compliance with regulations. As Kastelorizo holds an exploitation license to carry out aquaculture at the multi-use site until 2030, decommissioning will occur after the expiration of the license in case of no renewal of license or if there is a need for early termination due to specific circumstances.

Concerning the technological equipment (cameras and sensors) in Kastelorizo, it is planned that they will remain at the pilot site following the conclusion of the project. Additionally, cameras for data validation have been installed at other sites and are intended to remain in place beyond the project's completion.

3.5.3. Decommissioning procedure

The decommissioning procedure for marine aquaculture facilities in Greece follows a series of specific steps to ensure a responsible and environmentally friendly process.

Removal of Floating Installations and Operating Equipment:

- Towing of floating installations (cages, nets) towards the shore.
- Materials that are reusable will be repurposed as spare parts, while the rest will be removed to certified disposal sites.
- Use of vessels: Floating vessels will be utilized for the removal of floating installations and operating equipment.

Removal of Anchors:

Anchors, including materials such as blocks, ropes, anchors, chains, etc., will be lifted from the seabed. Functional items will be reused as spare parts or reinforcements, and the possibility of utilizing them in an-other area of interest will be explored.

- For lifting the anchors, a suitable vessel with a crane will be employed.
- Specialized diving teams will be required for the cutting and lifting of the anchors.

The procedures adhere to environmental regulations and guidelines to ensure responsible and eco-friendly decommissioning. The process involves the careful removal of materials, prioritizing reusability, and environmentally sound disposal practices.

3.5.4. Recommendations for future multi-use projects / commercial enterprises

The decommissioning procedure of the Greek pilot serves as a source of valuable recommendations for guiding future multi-use projects and commercial enterprises towards enhanced sustainability and efficiency.

An overarching recommendation emerges from the Greek pilot experience, emphasizing the importance of exploring synergies among different activities within multi-use projects. The collaborative approach seeks to identify opportunities where diverse activities can work together, sharing resources and efforts, ultimately streamlining operations, reducing costs, and mitigating environmental impacts. This approach fosters a harmonious coexistence of activities within the multi-use framework. In addition to synergy exploration, promoting eco-friendly practices and environmental stewardship lies at the core of future multi-use projects. This includes the adoption of sustainable aquaculture methods, reducing ecological footprints, and minimizing disturbances to marine ecosystems. Furthermore, future multi-use projects must prioritize continuous monitoring and research throughout their lifecycle. This commitment should extend beyond the operational phase, encompassing the decommissioning process. Regular assessments of environmental conditions, marine life, and the long-term impact of the project are essential for making informed decisions and ensuring the sustainability of multi-use endeavours.

By adhering to these recommendations, future multi-use projects and commercial enterprises can strive for an environmentally responsible and efficient approach while maximizing the benefits derived from synergies among various activities. These insights contribute to a more sustainable and harmonious coexistence within the dynamic marine environment.

4. RECOMMENDATIONS FOR DECOMMISSIONING MULTI-USE ZONES

4.1. Innovation needed (for complete removal)

Multi-use zones have brought about new challenges in the decommissioning process, and traditional methods may not be sufficient for the complete removal of structures. Our experiences from various European pilot projects have highlighted the crucial need for innovation in decommissioning multi-use zones. To meet this challenge effectively, we propose the following recommendations:

- Rethinking wind turbine decommissioning: In the modern age of wind energy, conventional decommissioning practices may no longer be suitable, especially when it comes to taking apart advanced wind turbines. We must explore innovative approaches that not only ensure the safe removal of these structures but also improve the efficiency of the process. By reassessing the methods for decommissioning wind turbines, we can keep up with technological advancements and develop strategies that cater to the specific needs of these advanced energy solutions.

- Designing with end-of-life in mind: Innovation in decommissioning extends beyond the process itself. It requires a proactive approach to design and construction, with considerations for end-of-life integrated from the very beginning. Exploring alternative design strategies that simplify decommissioning should be a top priority. This includes designing structures with a focus on their eventual removal, making disassembly and retrieval more efficient and cost-effective. By considering alternative designs, we can create structures that simplify decommissioning, minimize their impact on the marine environment, and optimize resource use.

Embracing innovation in the decommissioning of multi-use zones allows us to navigate the changing landscape of offshore structures and address the specific challenges posed by modern wind turbines and other advanced systems. These recommendations open the door to new possibilities, providing a pathway to more sustainable, efficient, and environmentally responsible decommissioning practices.

4.2. Safety and Health

The decommissioning of multi-use offshore structures demands unwavering commitment to ensuring the safety and well-being of both human operators and the marine environment. The lessons drawn from our pilot projects have underscored a set of recommendations that are central to this paramount concern:

Safety for human workers: Decommissioning activities should place paramount importance on the safety of the personnel involved in the process. This entails the provision of comprehensive safety training, the deployment of appropriate safety equipment, and strict adherence to established safety protocols. By prioritizing the well-being of the workforce, decommissioning can proceed with minimized risks and enhanced safety.

Environmental safety: Minimizing disturbances to marine life and the broader environment during decommissioning is a critical imperative. This encompasses addressing factors such as noise pollution, turbidity, and other potential environmental impacts that may arise during the process. Robust impact assessments should be conducted as a prerequisite before the commencement of decommissioning activities. By doing so, we can better anticipate and mitigate potential ecological consequences, ensuring that decommissioning aligns with environmental protection principles.

4.3. Vessel Operation

Efficient vessel operations are a critical component of decommissioning in multi-use zones. These operations not only affect the cost and duration of the decommissioning process but also play a significant role in minimizing environmental impacts. Here, we expand on the importance of vessel operations in decommissioning and offer additional recommendations:

1. Resource optimization: Efficient vessel operations are characterized by the judicious use of resources. To maximize efficiency, it's imperative to assess the specific needs of decommissioning activities within the multi-use zone. This assessment can help determine the appropriate type and size of vessels required, as well as the equipment and personnel necessary for a smooth decommissioning process.
2. Synergy and shared resources: Collaboration and synergy between different activities within the multi-use zone are key to optimizing vessel operations. By coordinating the use of vessels for various tasks, such as removing offshore structures, transporting materials, and conducting environmental monitoring, significant cost savings can be achieved. Shared resources not only reduce expenses but also minimize the environmental footprint of decommissioning.
3. Environmental impact mitigation: Vessel operations during decommissioning have the potential to impact the marine environment. Noise pollution, water turbidity, and disruption of marine ecosystems are potential concerns. To minimize these impacts, vessel operations should adhere to strict guidelines and codes of practice. This includes conducting environmental impact assessments before decommissioning, employing noise-reducing technologies, and implementing best practices to prevent spills and other forms of pollution.
4. Safety and training: Vessel operations in the often-challenging offshore environment demand skilled and well-trained personnel. Safety should be a paramount concern. Proper training programs and certifications for vessel operators and crew should be mandated. Safety protocols, such as emergency response procedures, must be in place to protect both human workers and the marine environment.
5. Technology and equipment: The deployment of modern and specialized vessel equipment can significantly enhance decommissioning operations. This includes cranes, winches, and other specialized tools designed for safely lifting and transporting heavy structures. Investment in state-of-the-art vessel technology can improve efficiency, reduce risks, and minimize the duration of decommissioning activities.
6. Waste management: Proper waste management during decommissioning is essential. Vessel operations should include the transportation of decommissioned materials to designated facilities for recycling, disposal, or repurposing. Efficient waste management not only reduces the environmental impact but also supports a circular economy by recovering and reusing materials when feasible.
7. Monitoring and reporting: Vessel operations should be closely monitored, and comprehensive reporting should be maintained throughout the decommissioning process. This documentation is essential for transparency, accountability, and ensuring compliance with environmental regulations and safety standards.
8. Adaptability to local conditions: Each multi-use zone has its unique environmental and operational characteristics. Vessel operations should be adaptable to these local conditions, considering factors like water depth, weather patterns, and marine life. Customizing vessel operations to the specifics of the location is crucial for successful decommissioning.

4.4. Flexibility/Adaptation to local circumstances

Decommissioning multi-use offshore structures is a complex process that demands meticulous planning, adaptability, and responsible decision-making. Our experiences from pilot projects across Europe have yielded valuable insights and recommendations for optimizing decommissioning procedures. These lessons highlight the importance of flexibility in accommodating local circumstances, particularly when deciding between nature restoration and habitat creation.

In the multi-use offshore landscape, each location possesses its own unique ecological conditions, marine life, and environmental requirements. Consequently, decommissioning strategies should not follow a one-size-fits-all approach. Instead, they must be tailored to the specific circumstances of each site.

One of the primary considerations in decommissioning is the choice between nature restoration and habitat creation. In some instances, the structures set to be decommissioned have evolved into vital habitats for marine life during their operational lifespan. These structures provide shelter, breeding grounds, and ecological niches for various species. In such cases, it is crucial that decommissioning strategies are flexible enough to adapt to these local ecological conditions.

Our pilot projects have shown that decisions regarding nature restoration versus creation should be made based on a deep understanding of the specific circumstances. In certain locations, retaining portions of the decommissioned structures may be more environmentally responsible and ecologically beneficial than complete removal.

To ensure successful and environmentally responsible decommissioning, the following recommendations are proposed:

1. Comprehensive site assessment: Before decommissioning, conduct extensive site assessments to gain a thorough understanding of the existing ecological conditions, including the species present, their habitats, and the role of the structures in supporting local biodiversity.
2. Science-based decision-making: Base decommissioning strategies on scientific studies and ecological impact assessments. Involve experts and biologists to provide insights into the ecological dynamics of the site.
3. Consultation and collaboration: Engage with local communities, environmental organizations, governments and stakeholders to gather their input and perspectives on decommissioning. Collaboration ensures a more comprehensive approach that considers the interests and concerns of all parties.
4. Adaptive management: Implement adaptive management strategies, allowing for real-time adjustments during the decommissioning process based on observed ecological responses.
5. Flexible regulations: Advocate for regulatory frameworks that allow for flexibility in decommissioning strategies, especially when structures have evolved into ecologically significant habitats. Regulations should support responsible decision-making based on local conditions. Hence, for our pilots, each site in that way will have the need for different decommissioning strategies.
6. Monitoring and reporting: Establish post-decommissioning monitoring programs to track the ecological impact and recovery of the site. Regular reporting and transparency are crucial for accountability.

In conclusion, decommissioning multi-use offshore structures is a nuanced challenge that necessitates a tailored and adaptive approach, particularly when considering the balance between nature restoration and habitat creation. These recommendations underscore the significance of thorough site assessment, science-based decision-making, collaboration, adaptive management, flexible regulations, and ongoing monitoring. By adhering to these principles, we can ensure that decommissioning strategies align with the unique circumstances of each location, resulting in more ecologically responsible and sustainable outcomes that benefit both marine life and the broader community.

4.5. Circular Economy

In the context of retiring or dismantling multi-use offshore structures, embracing the principles of a circular economy proves to be a win-win approach. Not only does this approach contribute to environmental responsibility, but it also offers significant economic advantages. Our experiences from diverse pilot projects have illuminated the importance of promoting a circular economy in this critical phase.

The key recommendation in this area is to focus on the recovery and reuse of materials from decommissioned structures. This process involves investigating opportunities to salvage and repurpose materials, especially metals and various components. By adopting this strategy, we can achieve two essential goals: a reduction in waste generation and significant cost savings.

Recommendations for promoting a circular economy in decommissioning:

1. Materials recovery assessment: Prior to decommissioning, conduct a comprehensive assessment to identify materials that can be salvaged and reused. This assessment should encompass metals, structural components, and other valuable resources.
2. Technical feasibility studies: Explore the technical feasibility of reusing materials in other projects, industries, or applications. This may involve refurbishing components, repurposing metals, or considering alternative applications for salvaged materials.
3. Economic viability evaluation: Assess the economic viability of materials recovery and reuse. Calculate the potential cost savings associated with salvaging materials compared to procuring new resources.
4. Sustainable practices: Implement environmentally responsible practices for materials recovery, such as minimizing waste generation and reducing the environmental impact of decommissioning operations.

5. Regulatory support: Advocate for regulatory frameworks that encourage and facilitate materials recovery and reuse. Clear guidelines and incentives can promote a circular economy approach in decommissioning.
6. Collaboration and knowledge sharing: Foster collaboration and knowledge sharing among stakeholders, including project operators, environmental organizations, and recycling industries. Sharing best practices and experiences can accelerate the adoption of circular economy principles.

By prioritizing the recovery and reuse of materials during decommissioning, multi-use offshore projects can significantly reduce waste production, minimize disposal costs, and contribute to a more sustainable and eco-friendly approach. This not only benefits the environment by reducing the strain on natural resources but also enhances the economic feasibility of decommissioning operations.

4.6. Monitoring Post-Decommissioning

Effective monitoring post-decommissioning is essential to ensure the long-term impact of the removal process. Our recommendations encompass:

- Material left behind: Detailed documentation of any materials left behind should be maintained. This ensures a clear understanding of the environment post-decommissioning.
- Pollutants and leaching: Periodic monitoring should be conducted to assess any potential leaching of chemicals or pollutants from decommissioned structures, especially when considering structures with long lifespans.
- Recovery area: If the decommissioned area is expected to recover naturally, monitoring should track the restoration progress.
- Safety: Monitoring should ensure the area remains safe for all activities and marine life.
- Legal responsibility: Clear legal responsibility should be defined, including the duration of monitoring obligations after decommissioning.
- Monitoring authority: Establish a designated authority responsible for ongoing monitoring activities, ensuring the integrity and safety of the decommissioned area.

These recommendations have emerged from our experiences in European pilot projects, offering valuable insights into optimizing decommissioning practices in the dynamic landscape of multi-use offshore projects. By implementing these suggestions, we aim to contribute to the sustainable development of multi-use ocean spaces while promoting environmental stewardship and long-term economic viability.

5. SUMMARY

In the decommissioning procedures for offshore multi-use projects across different European pilots, valuable recommendations have emerged to enhance future practices and ensure more favourable outcomes.

Germany: The decommissioning process of the German pilot involved the removal of the mussel, algae, monitoring system, and data transmission equipment from the FINO3 platform. It occurred in stages, with the algae net, monitoring unit, sea cable, and mussel unit being successfully removed. Specialized protocols and equipment, including dedicated boats, divers, and specialized gear, were employed for the decommissioning. Recommendations for future projects from this experience include the development of clear salvage and recovery procedures, the utilization of specialized equipment and experienced divers, meticulous planning and coordination of transportation logistics, and the maintenance of accurate documentation throughout the process for continuous improvement.
These insights and recommendations have been gathered from experiences in Germany and are part of a broader effort to optimize decommissioning practices in the evolving landscape of multi-use offshore projects in Europe.

The Netherlands: In the Netherlands, recommendations for multi-use within an offshore wind farm encompass exploring synergies, such as combining decommissioning activities for various multi-use operations and the wind farm itself, as their timelines and lifespans align. Additionally, examining the reuse of different elements, like floating devices, and considering the retention of (parts of) anchoring with artificial reef functions can ensure uninterrupted nature restoration activities.

Belgium: In the realm of multi-use projects in Belgium, with a focus on restoration efforts within wind farms, a significant set of recommendations has emerged to address the intricate interplay and long-term sustainability of ocean space utilization. These recommendations include aligning the time horizons of activities, enhancing wind turbine renewal, and synchronizing the life cycles of different activities. By implementing these recommendations, the aim is to optimize decommissioning processes, minimize unexpected challenges, and maximize the retrieval of valuable data and equipment, contributing to more favourable outcomes and the acquisition of valuable insights.

Denmark: The Danish pilot, focusing on the combination of tourism with wind energy, foresees no decommissioning within the project's timeframe. Instead, the existing wind turbines are being refurbished to extend their lifetime, highlighting the importance of ongoing maintenance and upgrading.

Greece: In Greece, the emphasis is on exploring synergies, indicating the significance of identifying areas where different activities within multi-use projects can collaborate and mutually benefit from shared efforts and resources.
By implementing these recommendations, future multi-use projects and commercial enterprises can optimize their decommissioning processes. This not only minimizes the occurrence of unexpected challenges but also maximizes the retrieval of valuable data and equipment. These insights contribute to more favourable outcomes, ensure the acquisition of valuable insights, and promote the sustainable development of multi-use ocean space.

6. CONCLUSIONS

In the journey of decommissioning offshore multi-use structures across diverse European pilot sites, a wealth of insights and recommendations have surfaced, providing a valuable roadmap for the future. Each pilot site, from Germany to the Netherlands, Belgium, Denmark, and Greece, has contributed its unique perspective on multi-use offshore projects, shedding light on the complex interplay of activities within the evolving ocean environment.

Germany demonstrated a systematic and strategic approach to decommissioning, emphasizing the importance of safe component removal and data salvage. Their recommendations encompass the development of clear salvage and recovery procedures, the utilization of specialized equipment and experienced divers, meticulous transportation logistics, and the maintenance of comprehensive documentation. These insights from Germany pave the way for enhanced decommissioning practices.

The Netherlands offered recommendations that emphasize the power of synergy, urging the combination of decommissioning activities for various multi-use operations and coordination with offshore wind farm decommissioning. The focus on exploring the reuse of elements and retaining anchoring with artificial reef functions highlights the need to ensure the uninterrupted continuation of nature restoration activities.

Belgium, driven by the goal of restoring ocean spaces within wind farms, proposed a set of significant recommendations. These recommendations include aligning the time horizons of activities, enhancing wind turbine renewal, and synchronizing the life cycles of different activities. By implementing these recommendations, Belgium seeks to optimize decommissioning processes, minimize unexpected challenges, and maximize the retrieval of valuable data and equipment.

Denmark provided a unique perspective by highlighting the importance of ongoing maintenance and refurbishing, rather than decommissioning, within the context of tourism and wind energy. This approach underscores the value of sustaining and upgrading existing infrastructure to extend its useful life.

In Greece, the focus was on exploring synergies among different activities within multi-use projects. This emphasis on collaboration and mutual benefit among activities underscores the importance of shared efforts and resources.

These recommendations, born from diverse experiences, offer a comprehensive and forward-thinking framework for the future of multi-use projects and commercial enterprises in the ever-evolving ocean environment. By embracing these insights and implementing them in practice, future projects can optimize their decommissioning processes, minimize unexpected challenges, and maximize the retrieval of valuable data and equipment. This collaborative effort paves the way for more favourable outcomes and ensures the acquisition of valuable insights, furthering the sustainable development of multi-use ocean spaces.

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