



Nordic BioBuz

From biodiversity-enhancing ecological engineering to a stronger business case for offshore wind

Project partners:



Funded by:



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Executive Summary

The Nordic BioBuz project, a collaboration between OX2, Under Ytan, Nemo Seafarms, RISE, and SLU, supported by Nordic Innovation and Mistra Co-Creating Better Blue, explored how offshore wind, low-trophic aquaculture, and ecological engineering can form the basis of a regenerative, multi-use business model. Over two field seasons, the project tested biodiversity-enhancing structures, developed biodiversity credit frameworks, and modelled nutrient and ecosystem benefits.

Offshore wind energy is expanding rapidly across the Nordic region, becoming central to achieving a fossil-free energy system, yet it competes for limited sea space in the Baltic Sea, one of the world's most stressed marine ecosystems. Europe faces urgent climate and biodiversity crises, and solutions are needed to deliver renewable energy while restoring ecosystems, enhancing food security, and increasing societal acceptance.

Multi-use and multifunctional offshore infrastructure offer a promising approach. By enabling structures to serve multiple purposes, such as biodiversity enhancement, low-trophic aquaculture, and environmental monitoring, multi-use concepts can reduce spatial conflict, improve ecological outcomes, and generate economic value. Low-trophic aquaculture provides nutrient removal and habitat creation benefits, while supporting Europe's food security. Current business models rarely capture these benefits, leaving nature undervalued and creating a biodiversity funding gap.

Field pilots in the Åland Sea and Björkskär showed that engineered surfaces accelerated colonization by habitat-forming species, particularly blue mussels, creating reef-like communities and significantly higher species richness compared to standard foundations. Mussel colonization also provides measurable nutrient removal, demonstrating tangible ecological value. These findings support a biodiversity crediting approach and highlight the potential for multi-use designs to combine ecological and economic benefits.

The project developed a proof-of-concept business model combining biodiversity credits, "dark green" electricity premiums, and low-trophic aquaculture revenues. Biodiversity-positive offshore wind can unlock new revenue streams, reduce regulatory and environmental risk, improve access to ESG-aligned financing, and enhance competitiveness in future concessions.

Overall, Nordic BioBuz shows that regenerative offshore wind is technically feasible, ecologically beneficial, and economically promising. By integrating biodiversity enhancement and low-trophic aquaculture, offshore wind farms can become multifunctional ecological assets, supporting climate goals, improving marine biodiversity, and creating new economic opportunities in a socially accepted and resource-efficient way.

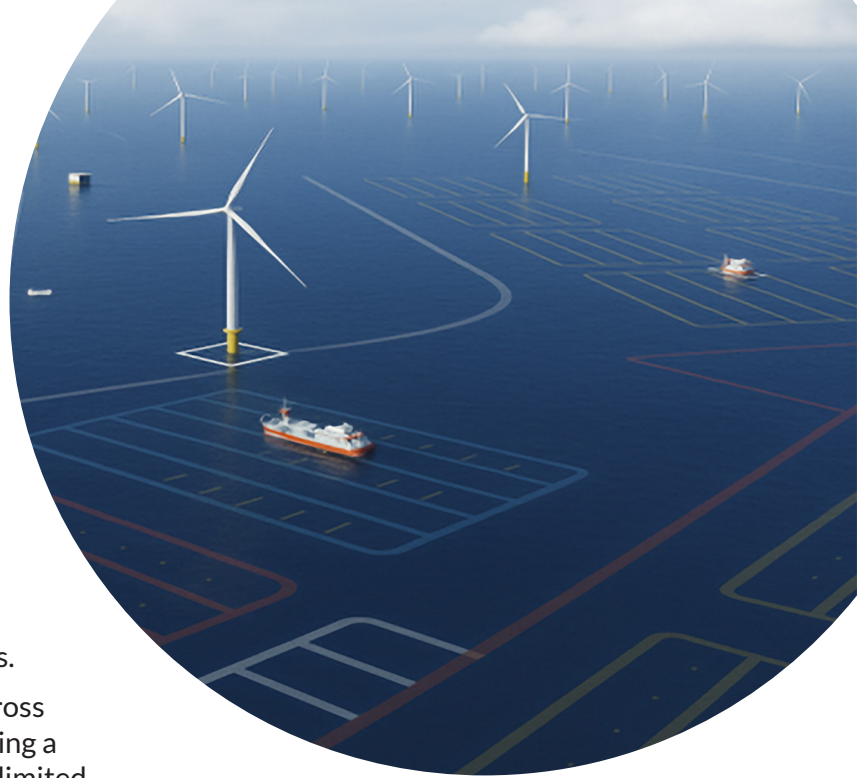


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Introduction

Glossary

Multi-use - The intentional joint use of marine space by multiple activities in proximity, designed to enhance synergies and reduce spatial conflicts.

Multifunctionality - The capacity of a structure, system, or area to deliver multiple benefits or services beyond its primary intended purpose, for example for a wind park to be designed for multiple purposes.

Low-trophic aquaculture - Aquaculture of species low in the marine food web (e.g. mussels, seaweed) that do not require external feed inputs and can provide ecological benefits.

Low-trophic species - Organisms that occupy lower levels of the food chain, such as algae or filter-feeding invertebrates, which obtain energy directly from sunlight or detritus.

Artificial reefs / Reef structures - Man-made structures placed in marine environments to promote colonization by marine organisms and enhance local biodiversity.

Biodiversity enhancement measures - Design interventions or practices intended to increase habitat quality, species richness, or ecological functioning within an area.

Bladderwrack (*Fucus vesiculosus*) - A brown macroalga common in the Baltic Sea and North Atlantic, often used as an indicator species for coastal ecosystem health.

Blue mussel (*Mytilus edulis*) - A filter-feeding bivalve common in the Baltic Sea and North Atlantic, that contributes to improved water quality and habitat complexity by forming dense reef-like aggregations.

Anthropogenic pressures - Human-induced impacts on natural ecosystems, including pollution, resource extraction, habitat alteration and climate change.

Ecosystem-derived values / Nature-derived values - The economic or social benefits that arise from ecosystem services, often not captured in conventional financial accounting systems.

Ecosystem restoration / Nature restoration - The process of assisting the recovery of degraded ecosystems to restore their structure, function, and capacity to provide ecosystem services.

Ecosystem services - The benefits humans obtain from nature, including provisioning (food, materials), regulating (climate, water quality), cultural and supporting services.

Eutrophication - The excessive enrichment of water bodies with nutrients, leading to algal blooms, oxygen depletion and loss of aquatic biodiversity.

Offshore Wind Farm (OWF) - A group of wind turbines installed at sea to generate renewable electricity. These farms take advantage of stronger, more consistent ocean winds to produce large amounts of clean energy.

Marine Spatial Planning (MSP) - A policy and management process for organizing human activities in marine areas to balance ecological, economic and social objectives.

Benthic data - Information collected from the seafloor, including the organisms, habitats, and physical conditions found there. It helps describe the state of marine ecosystems and how they may be affected by human activities.

Biodiversity credits - A certificate that represents a measured and evidence-based unit of positive biodiversity outcome that is durable and additional to what otherwise would have occurred.

Biodiversity credit markets - Emerging financial systems that enable the trade of biodiversity credits to channel private and public investments into ecosystem restoration and conservation.

Carbon and nutrient compensation - Carbon and nutrient uptake by marine organisms (e.g. algae, mussels) from the environment, that can be quantified and contribute to compensating carbon and nutrient loads.

Business model - How an organization creates, delivers, and captures value, economically, socially, and environmentally.

Circular business model - Business approach that minimizes waste and resource use by closing material and energy loops, emphasizing reuse, recycling, and regeneration.

Regenerative business model - A business approach that goes beyond sustainability by restoring and enhancing natural and social systems while generating economic value.

Project Björkskär - A cooperation project initiated in 2023 by OX2, Under Ytan and Nemo Seafarms developing techniques for the integration of low-trophic aquaculture and biodiversity enhancing services with offshore wind energy. Knowledge and data from project Björkskär were utilised in the Nordic BioBuz project.

Background

As offshore wind energy expands across the Nordic region it is becoming a cornerstone of the transition towards a fossil-free energy system (GWEC 2024; Wind Europe 2024). Yet, the acceleration of marine infrastructure development also increases pressure on limited sea space (Christie et al. 2014; Crona et al. 2021), and already heavily anthropogenically pressured marine and coastal ecosystems. Climate change and biodiversity loss are two of the central ongoing global environmental crises (IPCC 2023; Sacre et al. 2025). Nature protection and restoration as well as urgent phasing out of fossil fuels are essential to mitigate these crises (Bouman 2020, IPCC 2023, Edwards & Cerullo 2024; Sacre et al. 2025). The Baltic Sea is one of the most heavily impacted marine ecosystems in the world, suffering from eutrophication, biodiversity loss, and climate-related stressors (HELCOM 2023).

In response, the concept of multi-use and multifunctionality has emerged as a potentially promising approach to better balance economic, social, and environmental objectives at sea. Multifunctionality refers to the capacity of structures and facilities in marine environments to serve several diverse purposes beyond their original intent, such as biodiversity enhancement (Xylia et al., 2023).

To reduce conflicts between various societally important marine activities, several EU countries are currently considering opportunities to integrate multi-use into their maritime spatial plans (EU 2021). Marine multi-use is generally defined as the intentional joint use and sharing of marine resources in close geographic proximity, as an approach to facilitate successful coexistence of different types of industries and technical activities in the same marine area (e.g. fishing, aquaculture, nature conservation, other types of energy production) (Buck et al. 2008, Christie et al. 2014, Schultz-Zehden et al. 2018, Bocci et al. 2019, Van Hoey et al. 2021, Tamis et al. 2024). Since such multi-use parks can provide increased livelihood opportunities, they could also improve societal acceptance for offshore wind energy production (EU 2021, Van Hoey et al. 2021). If multi-uses are planned so that they contribute to ensuring a sufficient share of unused marine areas, multi-use could also contribute to conservation targets and give stronger readiness to address yet unknown needs that may arise in the future, e.g. in relation to climate change or future socioeconomic development (Bocci et al. 2019). As also highlighted by the Renewable Energy Directive (Directive (EU) 2023/1824), promoting marine multi-uses has been identified as a promising catalyst for the sustainable and resilient blue economy and central for achieving European and national goals for marine renewable energy in parallel with other central sustainability objectives (Buck et al. 2008, EU 2021, Van Hoey et al. 2021).

Among different types of multi-uses, low-trophic aquaculture (farming of low food-chain species like seaweed and shellfish that need little or no feed) has been shown to provide ecological benefits, with the potential to mitigate some of the environmental challenges faced by the Baltic Sea. Combining offshore wind energy with low-trophic aquaculture can therefore be a particularly impactful multi-use scenario for the Baltic Sea, offering opportunities for both environmental restoration and resource efficiency by the potential to mitigate some of the environmental challenges faced in the region (Ma and Salauddin 2025).

Increased aquaculture production of aquatic foods, such as fish, macroalgae, crustaceans and mussels, would also improve EU's food security and reduce the current high reliance on aquatic food imports (Christie et al. 2014; IMPAQT 2021; EUMOFA 2024). Today, the total European production from capture fishery and aquaculture combined is the third highest worldwide (including both EU and non-EU countries), with the largest share in the EU coming from fisheries (76% in 2022). The EU is still a net importer of aquatic foods, with an overall self-sufficiency (i.e. capacity to meet demand through own production) of only 38% in 2022 (EUMOFA 2024). Moreover, aquaculture can contribute with feed, raw materials, and biofuels (Christie et al. 2014, IMPAQT 2021). However, suitable areas for aquaculture are becoming increasingly scarce in many coastal areas (Buck et al. 2008, Buck and Langan 2017, Bocci et al. 2019, EC 2024), partly due to expansion of other marine activities such as offshore wind farms. Since combining aquaculture with offshore wind energy may alleviate spatial conflicts, aquaculture in combination with OWFs is seen as one of the most promising multi-uses in European seas (Bocci et al. 2019), and is growing in Europe (Buck et al. 2008, Buck et al. 2018, Przedzimirska et al. 2018, Van Hoey et al. 2021). Integrating aquaculture

with offshore wind farms could facilitate its development further offshore, including more wind- or wave-exposed areas than would otherwise be possible (Buck et al. 2008, Buck et al. 2018, Van Hoey et al. 2021). This could increase its potential capacity, and reduce the risk of conflict with coastal human activities. In some cases, moving offshore could also lower the activity's exposure to pollution, decrease risks of negative environmental impacts from the aquaculture itself, provide more favourable conditions for certain farmed species, reduce the risk of diseases among the cultivated species (Buck and Langan 2017). Combining OWF with aquaculture could also reduce overall costs, considering that marine infrastructure is expensive. The European Green Deal emphasizes that special attention should be given to the development of aquaculture with a lower environmental impact such as farming of low-trophic and non-fed species like mussels and macroalgae (EC 2024).

However, today's business models are largely shaped by short-term profit maximization and shareholder value. Even when activities generate positive environmental effects, these benefits are often not directly captured in financial terms. This creates a structural dilemma: businesses are fundamentally dependent on ecosystem services from healthy ecosystems for their long-term sustainability, with more than half of the world's gross domestic product depending on healthy and functional ecosystems (EU Green deal, 2020). Yet the value of nature remains largely invisible in conventional economic evaluation. Because ecosystem benefits are shared among multiple stakeholders and often treated as a "common good," it becomes difficult to trace and quantify the nature-derived economic value they generate. For biodiversity in particular, there is a global biodiversity funding gap of US\$700–900bn/year, corresponding to about €602.35–€772.65 billion EUR (Deutz et al. 2020).

To address this gap, the International Advisory Panel on Biodiversity Credits (IAPB) has launched a global framework for high-integrity biodiversity credit markets, marking an important step towards a functioning nature finance system. Biodiversity credits aim to quantify and track conservation and restoration outcomes, incentivize nature-positive practices, and channel financial flows towards effective biodiversity enhancement (Ducros & Steele, 2022).

Against this backdrop, the project partners OX2, Under Ytan, Nemo Seafarms, RISE and SLU, supported by Nordic Innovation, formed an interdisciplinary collaboration to explore how synergies between offshore wind energy, low-trophic aquaculture, and ecosystem-enhancing ecological designs in the Baltic Sea could form the basis for a new business model. Developing a method for creating marine biodiversity credits and conducting scenario analyses of different market configurations have been among the project's main achievements. Through experimental trials, modelling, and cross-sectoral collaboration, Nordic BioBuz has taken important steps towards a new paradigm for marine development: one where renewable energy, aquaculture, and ecosystem restoration co-exist and mutually reinforce each other.

The findings highlight how desired biodiversity outcomes, achieved through carefully designed biodiversity-enhancing measures, can strengthen the business case for offshore wind, transforming it from a conventional to a regenerative business model where value is created through the restoration of nature. The project contributes directly to the Nordic Council of Ministers' Vision 2030, supporting a green, competitive, and socially sustainable Nordic region.

Structure of the project

The project was structured into five interlinked work packages (WPs) executed over an 18-month period, encompassing two consecutive field seasons.

WP1 – Project Management: Led by RISE, this WP coordinated activities among partners, facilitated communication with Nordic Innovation, and ensured alignment and coherence across all WPs. Governance was maintained through a steering group with representation from all WP leads. Deliverables included formal reports to Nordic Innovation, a project handbook, and the final project report.

WP2 – Regenerative Business Model built on multi-use: Led by RISE with support from SLU, Under Ytan, Nemo Seafarms, and OX2, this WP developed a scenario for a multi-use based business model integrating both biodiversity credits, selling energy with a biodiversity premium and bio-based marine activities. Using methodologies Double Diamond framework and Value Case Methodology, aligning ecological, economic, and social values across stakeholders, producing a proof-of-concept detailed through a circular business model canvas, calculations on possible new revenue streams and guidelines for developing regenerative business models built on multi-use.

WP3 – Prototype Testing - Artificial Reefs: Conducted by Nemo Seafarms, Under Ytan, OX2, and SLU, WP3 tested biodiversity-enhancing materials and structures on offshore wind foundations and free-standing reefs. Techniques for promoting settlement of key species (blue mussels and bladderwrack) were evaluated through pilot deployments, monitored via underwater imaging and occasional diver inspections. Data from WP3, as well as data from pilots earlier deployed within “Project Björkskär”, informed the business model and biodiversity assessments in WP2 and WP4.

WP4 – Biodiversity and Nutrient Compensation Models: Led by SLU with partner support, this WP quantified ecosystem impacts and validated biodiversity credit systems for the Baltic Sea. Using field data from WP3 and literature sources, it modelled biodiversity credits and estimated nutrient and carbon uptake by aquaculture species. Deliverables include biodiversity credit models, nutrient and carbon compensation estimates, and guidelines for integrating these values into multi-use business concepts.

WP5 – Communication: Managed jointly by OX2, Under Ytan, Nemo Seafarms, and RISE, this WP developed project communication strategies, stakeholder engagement, and public dissemination. Activities included media visits, online content, newsletters, social media updates, and presentations at Nordic and EU conferences, ensuring visibility and knowledge transfer throughout the project.

Project Björkskär and Nordic BioBuz

Björkskär is a small island in the northeast corner of the Åland Islands archipelago located approx. 30km from OX2’s planned wind energy park Noatun North. In 2023, OX2, Under Ytan and Nemo Seafarms initiated “Project Björkskär”. Based on the island and the surrounding water area, Project Björkskär develops and tests nature inclusive designs and low-trophic aquaculture systems compatible with offshore wind energy infrastructure. The surrounding water area offers both open-water environment as well as sheltered shallow bays, ideal for in-situ tests.

Nordic BioBuz builds upon the experience and knowledge gathered by the Project Björkskär team. The Nordic BioBuz prototypes were deployed in the same open water area as some of the pilots from Project Björkskär, offering comparable data from a longer time period. Therefore, data gathered from pilots deployed as early as spring 2023, has been used to strengthen the results for Nordic BioBuz, especially regarding analyses and calculations for biodiversity credits.



Prototype testing artificial reefs

The primary objective of this work package was to design, deploy, and monitor pilot-scale prototypes for biodiversity-enhancing techniques applicable to offshore wind infrastructure in the Baltic Sea. The methodology was divided into two distinct development tracks targeting different components of wind turbine installations, specifically:

1. **Foundation enhancement:** methods for increasing biodiversity on and around the wind turbine foundation
2. **Integrated artificial reefs:** methods for increasing biodiversity on scour and cable protections through artificial reef structures.

The field trials were conducted in a wave-exposed offshore area with a depth of 18-20 meters near the island Björkskär, north of the Åland Islands. The area is located approximately 30km from the planned area of OX2's Noatun North offshore wind energy project.

The prototypes designs and materials were chosen based on earlier own experience in project Björkskär as well as other published scientific findings. Through Project Björkskär, Under Ytan, Nemo Seafarms and OX2 have developed and tested various materials, structures and methods for both artificial reefs and biodiversity enhancement on foundations. Based on results from these, the Nordic BioBuz prototypes was designed to include both natural rocks and concrete structures, as well as more novel materials such as wood (ash, pine, birch). Inspiration for the wood structures was drawn from archaeology, and the fact that wrecks of old wood ships are well preserved in the Baltic Sea due to its low salinity and the lack of wood worms that lead to the rapid decomposition of wooden structures in fully marine areas (Ruuskanen, 2015).

By introducing new hard substrate, different types of marine infrastructure can attract new marine taxa and habitat-forming species (Werner, 2024). The purpose of WP3 was to further evaluate the existing pilots, and to test if biodiversity can be induced and increased in a controlled manner. Thus, in combination with varying the material and structures of different setups, active inducement of key stones species was trialed by transferring individuals (blue mussels, bladderwrack) onto the foundation and reef structures.

Prototype design and construction

In Nordic BioBuz, following the finalization of the prototype blueprints in May 2024, two sets of pilot structures were constructed and prepared for offshore deployment. These consisted of four different Foundation pilots and two Artificial reef pilots:

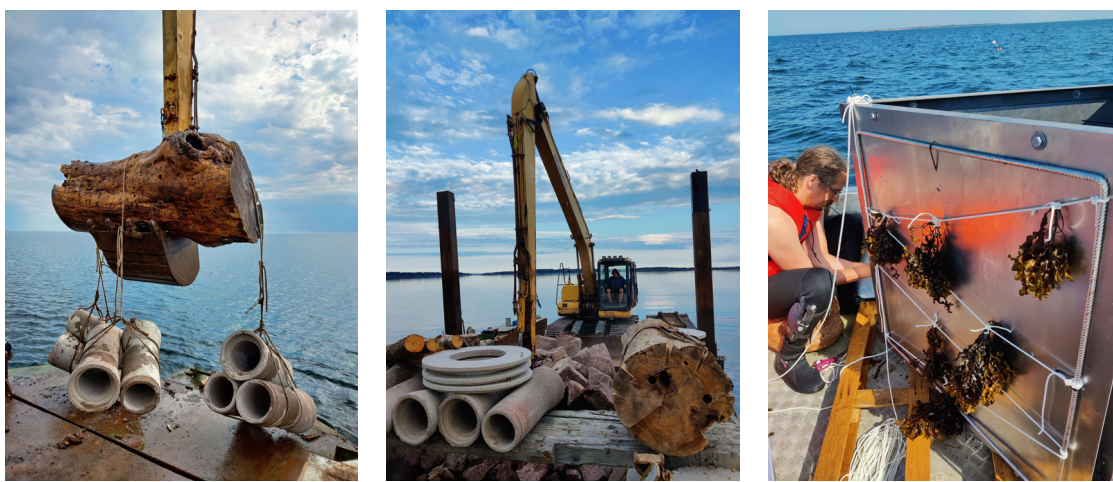
- A. **Foundation pilot:** Methods to actively promote the settlement of specific aquatic species were tested, using a total of four floating structures. The basis for each structure was a triangular prism, which provided three distinct surfaces for observation. The structures were moored to position at a water depth of 4-8 meters. The trials focused on promoting two Baltic key habitat-forming species; blue mussel (*Mytilus edulis*) and bladderwrack (*Fucus vesiculosus*). The four configurations of the pilot were:
 1. **Control:** A bare steel surface to monitor a "reference" settlement on the material, representing a default approach in industrially engineered wind farm foundations.
 2. **Mytilus trial:** A steel structure onto which approximately 15 kg (wet weight) of blue mussels were attached using nets, ropes and wire cages.
 3. **Fucus trial:** A steel structure with fertile bladderwrack plants attached using nets and ropes (see fig. 2.1).
 4. **Combination trial:** A steel structure with both blue mussels and bladderwrack (net, rope, wire cages), for observing potential interaction effects.
- B. **Artificial reef pilot:** To simulate biodiversity-enhancing scour and cable protection, structures were deployed directly on the seabed at a depth of 18-20 meters. These pilots were designed to

test how different materials, textures, and levels of complexity influence species colonization. The deployed materials included:

1. **Reference site:** A mound of natural rocks of varying sizes (30-100 cm), representing standard scour protection.
2. **Test site:** A complex reef combining natural rocks, large logs (Ash, Pine, Birch) with pre-drilled holes, and concrete elements (circular reefs and pipes) (Fig. 2.1). Three cages containing blue mussels were also placed on this reef to "seed" colonization.

Figure 2.1 Left and middle: Structures and materials for artificial reef building. Right: Foundation, *Fucus* v. (bladderwrack) trial.

The BioBuz-specific pilots were monitored between May 2024 and September 2025 and were complemented with corresponding data from structures installed during summer (May to August)



2023 within "Projekt Björkskär". The nine Björkskär installations, called "beds", are built inside a larger aluminium frame consisting of four smaller frames positioned in different angles (0°, 30°, 60°, 90°; Fig 2.2 left). Each smaller frame includes eight plates with different materials/substrates (untreated steel, painted steel, steel-net, steel+steel-net, gravel, leca, stainless steel, best-grade steel; Fig. 2.2 centre). The beds were installed at a water depth of 10 m (4 beds) and 20 m (4 beds), and one bed in a shallow coast environment.

Figure 2.2 Photos of the "beds" installed at different water depths in the Åland Sea at Björkskär, showing the different sides and angles (left), a close-up of the different used surface materials before installation (centre), and an exemplary installation with attached aquatic species (right).



Deployment and monitoring

The pilot structures were deployed in late May 2024, specifically on May 29 (Foundation pilots) and May 30 (Artificial reef pilots), using a specialized vessel to ensure precise placement. A systematic monitoring scheme was initiated in June 2024, with inspections one to two times per month during the ice-free season, using a combination of free diving (GoPro) and a Remotely Operated Vehicle (ROV). The monitoring focused on:

- structural integrity of the pilot structures and mooring systems
- settlement and growth of the target species (*Mytilus edulis*, *Fucus vesiculosus*)
- colonization by other aquatic sessile species
- overall habitat development

In addition to GoPro and ROV monitoring that was focusing on sessile species, a pilot study was conducted to design, build and test a low-cost monitoring system to also observe mobile species, such as hyperbenthic fish and invertebrates using Baited Remote Underwater Video (BRUV) technology combined with AI-based image analysis. The work aimed to assess whether affordable consumer hardware could support scalable, continuous biodiversity monitoring around offshore wind farm installations (Fiorina & Obst, 2025). The specific objectives were to:

- Develop and field-test a robust, low-cost BRUV system suitable for Baltic conditions.
- Train and evaluate object detection models (YOLOv8 and RF-DETR) for species-level recognition.
- Quantify key ecological variables such as species richness, abundance and behavior of the observed species.
- Integrate the analytical workflow into the Swedish Platform for Subsea Image Analysis (SUBSIM) for efficient data processing.
- Validate the system's operational efficiency and its ability to reduce manual analysis time.

Results

BioBuz pilot installations

The field trials yielded observational data on the efficiency of the tested biodiversity-enhancing techniques from June 2024 to August 2025 (Table 2.1). Data collection and monitoring are still ongoing and will continue beyond the project timeline, but the initial results obtained during the project duration provide a strong proof-of-concept. The data gathered from these pilots were relayed to WP 4 for integration into biodiversity- and nutrient compensation models.

Table 2.1 A summary of key observations from the field diary.

Date	Pilot type	Key observations	Status notes
June 2024	Foundations	Mussels on <i>Mytilus</i> and <i>Combination</i> pilots appear healthy and securely attached. <i>Fucus</i> on <i>Combination</i> pilot is in good condition.	<i>Fucus</i> pilot structure had sunken down to 20m but was later recovered.
	Artificial reefs	Initial dive confirms that all concrete structures, mussel cages, and the large ash log are in place.	The smaller pine and birch logs could not be located, possibly shifted during deployment.
August 2024	Foundations	<i>Mytilus</i> have spread from nets/ropes directly onto the steel surface. The <i>Combination</i> pilot hosts a diverse community, including shrimp.	<i>The Control</i> steel shows minor settlement of barnacles.
September 2024	Foundations	Several pilots lost.	Critical Issue: Loss of marker buoys resulted in the temporary loss of the <i>Control</i> , <i>Mytilus</i> , and <i>Combination</i> pilots. This created a significant gap in the data
April 2025	All Pilots	Spring ROV survey successfully located and marked the lost foundation pilots and confirmed that the reef structures were intact after the winter ice.	Monitoring resumed. <i>Fucus</i> pilot shows some white macroalgal growth.
July 2025	Foundations	<i>Control</i> and <i>Combination</i> pilots were successfully lifted and re-deployed. The <i>Combination</i> pilot continues to support healthy blue mussel colonies.	One anchor rope on the <i>Combination</i> pilot broke during the lift, highlighting material stress under the offshore conditions.
August 2025	Foundations	<i>Combination</i> pilot's blue mussels remain in good condition.	The <i>Fucus</i> plants are in very poor condition. The <i>Control</i> (steel) pilot was not found, likely due to another lost marker buoy.

A comprehensive photographic record documenting the pilots' development over time is available and recommended for inclusion as an annex, serving as a visual progress diary.

Complementary installations in Björkskär

The existing installations from "Project Björkskär" had been in the water since summer 2023 and could hence support the data from the BioBuz installations with relevant and more long-term information.

During the monitoring period from installation in August 2023 until May 2025, the Björkskär installation at 20 m depth was either not colonized by sessile organisms, or only colonized with barnacles, irrespective of the surface structure (Table 2.2, unit RE_20_S_15). While the example shown in the table had relatively low coverage, other designs (angles and sides) were more heavily covered by barnacles (not shown here).

On the two installations at 10 m depth, clear and pronounced differences in maximum coverage of blue mussels were observed across different types of surface structure (Table 2.2). In unit RE_10_S_6, the surfaces with leca, gravel, as well as the steel net, had nearly full coverage of blue mussels. None of the steel surfaces had blue mussels throughout the monitoring time period (May 2023 to May 2025). The steel structures were instead colonized by native filamentous algae. In unit RE_10_S_9, leca was the surface structure most colonized by blue mussels. Like in the other 10-m unit, the steel surfaces out of steel had less blue mussels than the other substrate types, or no blue mussels. In unit RE_10_S_6, barnacles also colonized the leca and gravel surfaces as well as one steel surface, co-existing with blue mussels. Only one of the surface structures (i.e. steel net with back) had a few barnacles on RE_SE_10_9. Most surfaces in the two 10-m units also had some degree of coverage

of filamentous algae. Generally, surfaces that had a lower coverage of blue mussels had higher filamentous algae coverage (Table 2.2).

Table 2.2 Maximum coverage with sessile organisms observed at exemplary installations in the Åland Sea (data from “Project Björkskär”), that were monitored three times during the first two years after installation in the water in May 2023 (monitoring in July 2024, October 2024 and May 2025), per place, surface structure, and species or organism group. Here, the plates facing up and with an angle of 60° were used as representative example. Given are also exemplary “weights” for biodiversity value calculations in row 1*, and the resulting exemplary biodiversity values (see equation 1 below). The structure that would reach the exemplary highest biodiversity value is indicated in bold style. Results for the reference structure are indicated in italics#. These were subtracted from the biodiversity values of the other structures

Unit ID	Water depth (m)	Surface structure	Blue mussel (<i>Mytilus edulis</i>). Weight: 10*	Barnacle (<i>Balanus improvisus</i>). Weight: 3	Filamentous algae. Weight: 2	Example biodiversity value (see Equation 1, page 24)*
RE_20_S_15	20	Best-grade steel	0	0.05	0	0.15-0.15 = 0
		Gravel	0	0.1	0	0.3-0.15 = 0.15
		Leca	0	0.05	0	0.15-0.15=0
		Painted steel	0	0.05	0	0.15-0.15=0
		Stainless steel	0	0	0	0
		Steel net	0	0.05	0	0.15-0.15=0
		Steel net with back	0	0	0	0
		Untreated steel#	0	0.05	0	0.15
RE_10_S_6	10	Best-grade steel	0.1	0	0.9	1+1.8-2.5=0.3
		Gravel	0.85	0.6	0	8.5+1.8-2.5=7.8
		Leca	0.85	0.8	0	8.5+2.4-2.5=8.4
		Painted steel	0.05	0	0.8	0.5+1.6-2.5=-0.4
		Stainless steel	0.1	0	0.95	1+1.9-2.5=0.4
		Steel net	0.9	0	0	9-2.5=7
		Steel net with back	0.05	0.3	0.3	0.5+0.9+0.6-2.5=-0.5
		Untreated steel#	0.2	0	0.25	2.5
RE_10_S_9	10	Best-grade steel	0	0	0.9	1.8-1.82=-0.02
		Gravel	0.15	0	0.2	1.5+0.4-1.82=0.08
		Leca	0.75	0	0.1	7.5+0.2-1.82=5.88
		Painted steel	0	0	0.45	0.9-1.82=-0.92
		Stainless steel	0	0	0	0
		Steel net	0.05	0	0.75	0.5+1.5-1.82=0.18
		Steel net with back	0.15	0.05	0.1	1.5+1.5+0.2-1.82=1.38
		Untreated steel #	0	0	0.91	1.82

*These “weights” are indicative values based on the relative importance of the encountered species for enhancing biodiversity in the respective ecosystem.

#Untreated steel is currently the industrially most common steel used in constructing offshore wind farm monopile foundations and was used as a reference in the biodiversity value calculations.

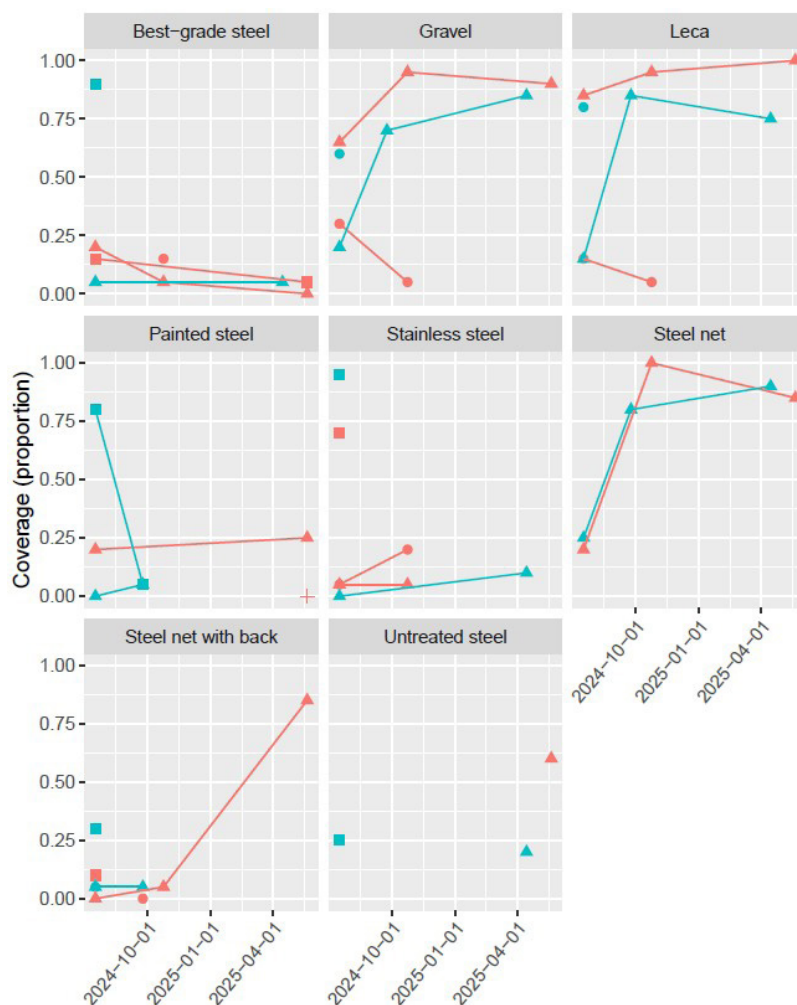
Figure 2.3 shows an example of how the coverage of attached aquatic organisms developed over time on the different surface structures on one of the installations at Björkskär (RE_10_S_6, 60° angle).

On the downward-facing plates, surfaces with leca and gravel, blue mussels had reached a coverage exceeding 60% already by the time of the first monitoring occasion in July 2024, or 14 months after the structured was deployed in the water. The coverage increased further over time, reaching nearly full coverage of blue mussels after two years. At the steel net and the steel net with steel back, blue mussels had lower coverage in comparison 14 months after installation but also reached coverages around or exceeding 90% during the following eight months.

On the painted steel, stainless steel and best-grade steel surfaces, blue mussels reached at most a coverage of 25% within the monitored time period up until two years after installation. Only a few data points from the untreated steel surface were available, which suggested that blue mussels had reached a coverage around 60% on untreated steel by the time of the last monitoring (Figure 2.3, red triangles).

On the upward-facing plates, the coverage of blue mussels was generally similar or somewhat lower than on the downward-facing ones. The coverage across surface structures were generally similar to the downward-facing plates (Figure 2.3, blue triangles). Some of the surface structures with low blue mussel establishment had slight coverage of filamentous algae (Figure 2.3, squares).

Figure 2.3 Development of observed coverage over time for blue mussels (triangles), barnacles (circles), filamentous algae (squares) and an undetermined bivalve (other than blue mussel; cross) at one of the installations at Björkskär (RE_10_S_6, 60° angle), for the different surface structures. Red and blue symbols show the coverages at the downward- and upward-facing plates, respectively. No invasive species were observed.



AI-Assisted Benthic Monitoring at Artificial Reefs

The automated AI-analysis produced nearly 1 million detections, documenting eight taxonomic groups across several trophic levels, including *Saduria entomon* (Baltic isopod), *Gobiidae* (Gobies), *Perca fluviatilis* (European perch), *Zoarces viviparus* (Viviparous eelpout), *Mysida* (Opossum shrimps) and *Aurelia aurita* (Moon jellyfish). The RF-DETR (Fiorina & Obst, 2025) model achieved high detection performance (mAP@50 = 88.8%, precision = 87.9%, recall = 89.1%). The benthic community was dominated by *S. entomon* (58.5%) and *Gobiidae* (37.5%), together accounting for 96% of all detections. Mean Shannon diversity, which measures both the number of species and their evenness within an ecosystem, ($H' = 0.52$) and evenness ($J' = 0.28$) indicated moderate richness but strong numerical dominance.

The findings suggests that the artificial reef at Björkskär supports a functionally benthic community, with primary, secondary, and tertiary consumers all represented. The BRUV system proved particularly suitable for monitoring complex three-dimensional reef structures where traditional methods (e.g. trawling or ROVs) are impractical.

Discussion

BioBuz pilots

Despite facing significant operational challenges due to the strong exposure from waves and winter ice in the offshore conditions, the pilots support the core hypothesis of this project, specifically that biodiversity-enhancing methods can accelerate the establishment of species and organisms on offshore infrastructure.

The most successful outcome was obtained from the seeding of blue mussels onto steel structures. Observations from August 2024 and throughout 2025 indicated that mussels actively migrated from the seeding nets and ropes and colonized the bare steel, more rapidly creating a complex, habitat-forming reef structure that attracts other species. The difference was especially apparent when comparing the results with the control pilot, i.e. bare steel, where almost no blue mussel settlings were visible. This provides a clear, actionable pathway for enhancing the transformation of passive infrastructure into ecological assets. Although the trial seeding with *Fucus vesiculosus* initially looked promising, ensuring its viability at these depths requires further investigation, as evidenced by the deteriorating condition of the plants in late 2025.

The primary source of error and data loss stemmed from equipment failure in the marking and mooring systems. The repeated loss of surface marker buoys is a critical lesson learned whether due to weather, material failure (such as water ingress in foam buoys), or potential theft. Future deployments would need to invest in more robust, potentially sub-surface, marking and tracking systems to ensure data continuity.

These results lead to several key recommendations for future innovation:

1. **Material innovation:** There is a clear need for research and development of biodegradable nets or other temporary attachment materials for mussel seeding. The ideal material would secure the mussels for 3-5 years before biologically degrading, leaving behind a self-sustaining colony directly on the foundation.
2. **Biodiversity enhancing:** Further developments need to be conducted into biodiversity enhancing methods, both from a technical as well as an environmental perspective. Scaling up solutions requires more robust structures and operational efficiency. Species composition and survival need to be validated through long term data from more replicas in conditions equivalent to the area of the offshore wind energy park.
3. **Biological optimization:** Further studies should investigate the optimal and maximal depth and minimal light conditions for enhancing macroalgae like *Fucus* to ensure their long-term survival and growth.

In conclusion, this work package provides a proof-of-concept for including biodiversity enhancement in the business model development of offshore wind farms. The demonstrated techniques for establishing foundational, habitat-forming species on the structures also create a tangible basis for the parallel development of biodiversity credit and nutrient compensation models. While operational setbacks underscore the challenges of working with infrastructure offshore, the successes provide a clear, innovative direction for building a sustainable and regenerative blue economy in the Nordic region.

Complementary Björkskär installations

The Björkskär installations illustrated the crucial importance of installation time as factor influencing which species may first colonize and establish on or at a newly installed artificial underwater hard structure. The unit installed in August 2023, at 20 m depth, was installed after the main blue mussel recruitment period was over for the year, while barnacle recruitment was still ongoing. The structure got heavily covered in barnacles. The units that were installed somewhat earlier also showed some barnacle recruitment, however, they co-occurred with blue mussels, the latter often dominating. The importance of taking the season of installation into account, based on the specific aquatic ecosystem and the recruitment characteristics of local species, has also been reported in many other studies of colonisation at artificial underwater structures (Reubens et al. 2014, Komyakova et al. 2019, Cardoso et al. 2020). The effect of the ecological engineering measures can therefore be enhanced by timing the deployment of artificial substrates to known key recruitment periods of the targeted species (Perkins et al. 2015).

Studies have also given support to the active “seeding” of key desired species as a way of giving competitive advantage to habitat-forming taxa (such as bivalves or canopy-forming algae) or other species identified as facilitators for the establishment of further species, such as also tested in the BioBuz project. This involves transferring reproductive propagules or fertile individuals of target species to the structure or their vicinity to facilitate their initial more rapid introduction and establishment (Browne and Chapman 2011, Perkins et al. 2015, Firth et al. 2016, Sherrard et al. 2016, Strain et al. 2018, Burt and Bartholomew 2019, Schoonees et al. 2019). In addition to adding habitat complexity, habitat-forming species may cause other desired effects such as contributing to carbon and nutrient sequestration. However, achieving successful establishment of the desired species can be challenging, e.g. when grazing pressures are high, or water quality is poor (Strain et al. 2018).

Results from the two units installed in Björkskär at 10 m depth showed that the colonization of blue mussels can differ strongly depending on the type of surface substrate. The surfaces with higher spatial complexity (leca, gravel and steel net) were generally colonized more quickly and heavily by blue mussels, compared to the different types of smooth steel surfaces which reached no or only little coverage with blue mussels during the study period. This finding is also supported by research on ecological engineering and artificial reefs, showing that increasing the complexity and heterogeneity of artificial underwater structures, for example by adding crevices, extrusions and diverse surface structures, generally stimulates reef formation and biodiversity (Charbonnel et al. 2002, Hunter & Sayer 2009, Claisse et al. 2014, Cardoso et al. 2020, Kraufvelin et al. 2023).

Given that natural reefs are generally more complex than traditional artificial underwater structures, which typically have more smooth and even surfaces, successful ecological engineering methods are commonly those that aim to increase the surface area and roughness of the added structure, as well as to enhance the complexity and heterogeneity (Perkins et al. 2015, Firth et al. 2016, Burt and Bartholomew 2019, Schoonees et al. 2019). However, overall, the composition and abundance of organisms that are attracted to an underwater structure will depend on how well the structures match the habitat requirements of the different species, in terms of e.g. requirements for shelter, food, and preconditions for reproduction (Glarou et al. 2020). If the goal is to obtain communities that resemble those on natural reefs in the area, the artificial structure should be similar to these in structure. For example, fish communities around concrete reef-simulating modules were more similar to fish communities at natural rocky reefs, than to fish communities around shipwrecks (Lemoine et al. 2019). Hence, mimicking natural surfaces can be a successful strategy for enhancing biodiversity (Vivier et al. 2021).

Biodiversity and nutrient compensation models

Biodiversity credits

Biodiversity credits are market-based mechanisms to accelerate private finance towards biodiversity conservation and restoration, intended to facilitate and accelerate conservation actions and biodiversity outcomes (Antonelli et al. 2024; BCA 2023,2024a,b,2025; Manez and Clifton 2025; Wunder et al. 2025). Specifically, a biodiversity credit is a “certificate that represents a measured and evidence-based unit of positive biodiversity outcome that is durable and additional to what otherwise would have occurred” (BCA 2023; 2024b). In this context, a positive biodiversity outcome is defined as an improvement in measures of biodiversity, a reduction in threats to biodiversity, or prevention of an anticipated decline in measures of biodiversity (BCA 2023; 2024b).

The purpose of biodiversity credits is to quantify and track biodiversity conservation and preservation efforts and outcomes, incentivize nature conservation and restoration, and channel financial flows towards effective biodiversity conservation (Ducros and Steele 2022). To ensure that biodiversity credit schemes provide both economic and environmental benefits to an ecosystem and people, they must provide additional value to the community and ecosystem they are working to improve. Typical classes of biodiversity credits include biodiversity credits for avoiding biodiversity loss, for improving biodiversity, or for successfully managing intact habitats and ecosystems (BCA 2024b; Ducros and Steele 2022; Maczik et al. 2024). Defining a biodiversity credit also requires identifying the duration over which the biodiversity credit will be maintained. Finally, biodiversity credits are also used for other ecological values apart from biodiversity, such as valuable ecosystem services (Ducros and Steele 2022).

One way to formalize a biodiversity credit is to determine species richness of the site, as well as the abundance of each of the species. The biodiversity metric is then calculated as the sum product between abundance of each species, weighted by a measure of “importance” in the ecoregion (Ducros and Steele 2022). The importance could e.g. be based on a measure of rarity of the species in the ecoregion (see Henriksson et al. 2016; Astudillo-Scalia and de Albuquerque 2019 for examples on how rarity can be used in biodiversity contexts), or, expressed in another way, the risk for the species (e.g. its threat status; Wallacea Trust 2023). This could also include consideration of how the new or restored habitat contributes to the delivery of ecosystem services, such as ways in which species in the habitat can support nutrient sequestration, productivity of fish or recreational values, for example (Cole et al. 2021). Also, a measure of connectivity could be used. Multiple weights can also be applied (e.g. measures for risk and connectivity), depending on the purpose of the biodiversity credit (Ducros and Steele 2022; Maczik et al. 2024).

Monitoring is needed throughout the project period to verify if the targeted outcomes are achieved, including the required additionality. For this, in addition to monitoring the actual sites for which the biodiversity credit should be determined, ecologically relevant reference sites need to be included and used as a baseline. The purpose of the baseline is to define what the long-term trajectory of biodiversity would be if no new action was taken, to determine additionality or net positive impact of the project. A suitable design of such a monitoring program is crucial. The complexity of biodiversity, with its diverse components and definitions, can make defining adequate and accurate biodiversity metrics and baselines challenging (Aide 2024).

Finally, prices need to be set. These might be based on step-wise approaches, where the price may increase from a starting price of the credit, e.g. when pre-defined “ecological milestones” are reached, that mark significant progress towards desired biodiversity outcomes such as a certain species composition, structure and function; or, when “management milestones” are reached, that enable the conservation of biodiversity and ensure the longevity of the conservation efforts (Ducros and Steele 2022).

Nutrient compensation and carbon storage potential

Some aquatic organisms have the potential to effectively bind nutrients, such as phosphorus and nitrogen, from the water column into their biomass. When the biomass is subsequently removed from the sea, this extraction could help to mitigate the common environmental problem of eutrophication (Hedberg et al. 2018; Kostamo et al. 2020; Kotta et al. 2020, 2022). This can be viewed as a type of “nutrient compensation”, that could for example be realized in low-trophic aquaculture with subsequent harvesting (Kostamo et al. 2020).

Low-trophic species suitable for aquaculture include macroalgae (seaweed), bivalve molluscs and sea urchins (Elvevoll et al. 2023). The nutrient removal capacity in low-trophic aquaculture depends on the size of the harvest, the time period between harvests, and the nutrient content in the harvested biomass (Hedberg et al. 2018). Here, we provide an example using blue mussels (*Mytilus edulis*).

The organisms also contain carbon in their biomass, which could contribute to the biodeposition of carbon to the seabed (Sea et al. 2022). However, the long-term net ecosystem role of these organisms as carbon source or sink remains debated (Filgureira et al. 2015; Aubin et al. 2018; Sea et al. 2022; van der Schatte Olivier et al. 2020; Hurd et al. 2022; Krause-Jensen et al. 2022). Estimates of how the species would contribute to carbon storage were therefore not included in this study.

Nutrient uptake by blue mussels

Mussel farming is suggested as a viable measure to mitigate Baltic Sea eutrophication, by a pathway where nutrients at sea are first fixed in the mussels and then removed from the system for consumption or other uses, such as feed, bioenergy production, or soil amendments. Blue mussels generally grow better at higher salinity levels, as their energy costs for osmoregulation increase in brackish conditions, but they can survive down to salinities of 4-5 (practical salinity units, which is lower than the typical salinity conditions at Åland). Their growth rates also depend on food availability. Depending on the site's productivity, mussels can usually be harvested 1-2 years after recruitment (Kotta et al. 2020).

Nutrient fluxes typically lead to that about 25% of the nutrients that are taken up by a blue mussel over the farming cycle can be removed at harvest. The remaining circa 75% of the nutrients are relocated and remain in the aquatic environment (Hedberg et al. 2018). For example, the blue mussels excrete feces and other particles not needed by the mussel, which contribute to biodeposition, as well as release nutrients during spawning and growth. The mussel's nutrient excretion is relatively higher at lower salinities, due to the higher energy need for osmoregulation. The nutrient fluxes around a blue mussel colony or farm can also affect local aquatic ecosystems (Hedberg et al. 2018), especially at relatively high amounts, farm sizes, and mussel densities (Wikström et al. 2020). The effects of the nutrient fluxes are also influenced by local conditions such as habitat type, water depth, bottom type and hydrodynamics. Further, when the carrying capacity of the system is exceeded, farmed mussels can become food limited, which can then also influence the natural mussel populations. For these diverse reasons, up-scaling from small-scale farming of blue mussels should be done with caution, to avoid unwanted negative environmental effects. It is recommended to conduct careful environmental mapping and modelling in connection to blue mussel farms, especially in restricted water bodies such as bays (Hedberg et al. 2018).

Nutrient uptake by macroalgae

Low-trophic aquaculture of macroalgae could, like in the example of blue mussels above, contribute to removing nutrients from the sea, while producing a resource that can e.g. be used as food or feed. Light, nutrient availability, temperature and salinity are key factors driving growth patterns of macroalgae, and the production potential of macroalgal farms is considered high in the Baltic Sea (Kotta et al. 2022).

Can bladderwrack contribute to nutrient removal?

Bladderwrack is a perennial macroalgal with poor dispersal capacity and low growth rate compared to many other groups of macroalgae in the Baltic Sea. Trials are ongoing for cultivating bladderwrack for commercial purposes, as compounds extracted from the algal biomass can be used in a variety of products. However, knowledge remains scarce about realistic amounts that can be harvested as well as methods to e.g. efficiently harvest and transport the algae (Kostamo et al. 2020). There is to date no commercial bladderwrack farm in the Baltic Sea, although it could be an attractive species for farming particularly in the eastern Baltic Sea (Kotta et al. 2022). One could potentially carry out similarly estimations for nitrogen and phosphorous uptake in bladderwrack as conducted in this study for blue mussels, although estimates from literature show considerable variability between studies. For the Western Baltic (Kiel Bight), bladderwrack was reported to contain about 1-6% phosphorous based on dry weight, and about 2-5% nitrogen based on dry weight (Schramm et al. 1988). In the outer archipelago near Askö, which is closer to Åland, the bladderwrack nutrient contents based on dry weight were around 0.1-0.3% phosphorus, and 1-4% nitrogen (Wallentinus 1979, in Schramm et al. 1988). There therefore remain strong development needs to understand how nutrient uptake could be enhanced by the culture of bladderwrack in the study area, and we did not conduct nutrient compensation estimations for that species.

Furthermore, bladderwrack has strong biodiversity values as a habitat-forming species and currently has a reduced distribution in many archipelago areas around Åland, due to the effects of eutrophication. Hence, even if it was enhanced by ecological engineering in the study area, it would make more sense to leave it growing in the system, where it can support biodiversity and ecosystem productivity, rather than to harvest it.

Other macroalgae that could be relevant for low-trophic aquaculture in the Nordic region

Other macroalgal species that could be relevant for farming in the Baltic Sea include for example sea lettuce (*Ulva intestinalis*) and sugar kelp (*Saccarina latissima*) (Kotta et al. 2022). For sea lettuce, the western and southern Baltic Sea exhibited the highest farming potential, but promising farming areas were also identified in the eastern Baltic Sea. A typical deployment season for *U. intestinalis* in the Baltic Sea region would be from May to September. With one harvest cycle being around one month, it be harvested five times in a growing season (Kotta et al. 2022). For sugar kelp, promising farming areas are in the westernmost Baltic Sea, where salinity levels are sufficiently high. A typical deployment season for *S. latissima* in the Baltic Sea region would be from November to May, and the biomass would be harvested once at the end of the deployment period (Kotta et al. 2022).

In other Nordic countries, where sea areas have higher salinity than in the Baltic Sea, a more diverse range of aquatic species could be suitable for low-trophic aquaculture. Depending on site conditions these include for example macroalgae species such as dabberlocks (*Alaria esculenta*) and oarweed (*Laminaria digitata*) (Vincent et al. 2020). While blue mussel is the currently most farmed mussel species in Europe, another mussel species suitable for aquaculture in the Nordic region could include European oyster (*Ostrea edulis*) (Buck et al. 2010; CERES 2020; Joyce et al. 2013). Crucial issues to consider include the risk for contamination of the farmed organisms at certain sites (Jacobsen et al. 2023), and the effects of climate change on the farmed species, such as ocean warming and acidification, increased disease and pest susceptibility, and increased severity and frequency of heatwaves and storms (Veenhof et al. 2024; Torres et al. 2025).

Methods - the calculation approach

Focal species

Two species were chosen as focal to develop the concept; blue mussel (*Mytilus edulis/trossulus*) and bladderwrack (*Fucus vesiculosus*). Both species are common species on hard substrates in the Baltic Sea. Both species are also habitat-building, meaning that they form habitat conditions that are more complex and spatially diverse than the underlying habitat, which then typically attracts and supports

other aquatic species (Koivisto et al. 2011, 2011b; Koivisto and Westerbom 2010; Kristensen et al. 2015; Kotta et al. 2020). In addition to supporting biodiversity, these target species also provide important ecosystem services, such as improved water quality (Gentry et al. 2020; Alleway et al. 2023) (see also previous section).

In the Baltic Sea, blue mussels occur naturally on hard substrates down to around 30 meters depth. They are also common on some soft bottoms in the Baltic Proper. Blue mussel patches can form among the most species-rich habitats in the Baltic Sea, since they provide structure and shelter for other species. The diversity of associated macrofauna typically increases with the age and size of mussel patches. Blue mussel beds in the northern Baltic Sea have been associated with over 40 macrofaunal species, including crustaceans, molluscs and polychaetes. Blue mussels and macroalgae are commonly co-occurring, with mussels often providing a substrate for macroalgae colonization (Koivisto et al. 2011, 2011b; Koivisto and Westerbom 2010). The facilitating effects of mussels seem to produce advantages for different taxonomic groups in different successional stages (Koivisto et al. 2011).

Bladderwrack occurs naturally on hard substrates in the shallower waters, where light conditions are sufficient for their photosynthesis. They are also sensitive to sedimentation, as this disturbs the algae's chances to attach to the substrate (Berger et al. 2003), and against grazing from isopods and certain molluscs during the early life stages (Malm et al 2001). Unlike blue mussels, bladderwrack cannot move once it is attached. The species disperses from one area to the next by the means of its reproductive seeds (eggs), which have a limited dispersal range of a few meters from the mother plant. The fertilization is external in the water column, requiring that male and female plants are located close enough to each other at the time of recruitment. The fertilised eggs sink to the bottom and needs a smooth and clean substrate in order to attach. Like blue mussel, the macroalgae provide good habitat conditions for a wide range of aquatic species, supporting high biodiversity (Koivisto 2011; Koivisto and Westerbom 2010; Norling and Kautsky 2008; Kotta et al. 2020). For example, bladderwrack has been associated with over 30 macrofaunal species (Kautsky et al. 1992; Koivisto 2011).

Biodiversity estimation

Biodiversity credits can be used in different ways. Here, we conceptualized them for tracking potential increases in biodiversity indicators in relation to those of reference conditions (Ducros and Steele 2022). An “uplift” in biodiversity is defined as a “quantified change in one or more measures of biodiversity”, through habitat enhancement (BCA 2024b). Specifically, the biodiversity indicators were here compared for:

- 1) a scenario of offshore wind farm foundations with ecological engineering for biodiversity enhancement through higher structural complexity in the Baltic Sea, and
- 2) a scenario of reference wind farm foundations out of untreated steel with smooth surface, according to the current industrial standard, in the Baltic Sea.

For this, we used the sum of weighted species richness of sessile species as biodiversity proxy (Ducros and Steele 2022):

$$BI = \sum(\text{Weight} * \text{Coverage}_{EE}) - \sum(\text{Weight} * \text{Coverage}_{ref}) \quad (\text{eq.1})$$

where BI = Biodiversity index (dimensionless), Weight = Weight (dimensionless), EE = ecologically engineered, Coverage = coverage of the area with an epiphytic species or organism group (0-1), ref = reference. The sum is made over all monitored species.

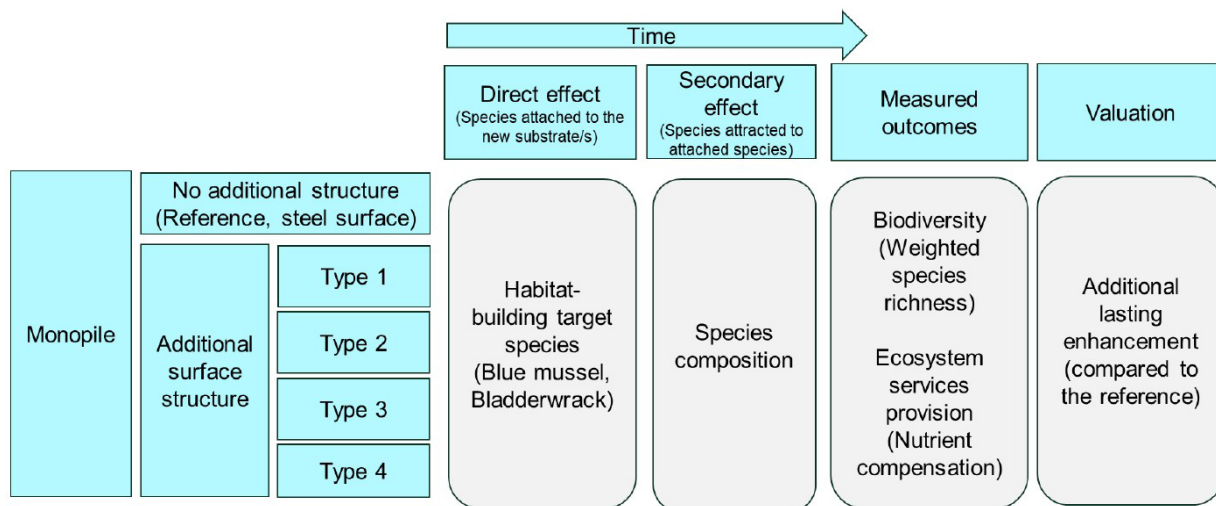
When it comes to biodiversity credits, the resulting biodiversity indicator can be multiplied with the area that is used for the ecological engineering. Here, we used the coverages of sessile species observed on different platforms as a basis for calculating the biodiversity index according to Equation 1. To calculate the biodiversity index, weights were given to each of the sessile organisms or organism groups observed at the structures. These weights are arbitrary at the moment and serve in this example to illustrate the chosen calculation method. They are, however, based on the relative

importance of the included species for enhancing biodiversity in the studied ecosystem (see Methods section “Focal species”).

Referring to key literature (also referred to in the section above), blue mussels were assigned the highest weight (10). Bladderwrack was considered for inclusion but did not recruit to the test structures during the two years of monitoring. Barnacles, which occurred frequently on some of the structures, were not targeted in the pilot but may increase the spatial rugosity of the substrate and thereby enhance the settling of other sessile species under certain conditions, including blue mussels (Bros 1987; Petraitis 1990; Köhler et al. 1999) In this study they were assigned a weight score of 3. Various filamentous algae also attached to the substrates. As no physical samples were taken, it was not possible to determine them to species, but most of them represented native filamentous red algae. This group was assigned a weight of 2, given that they contribute to biodiversity but do not form as stable structures as the other species and are not perennial.

Example calculations were made using two data types 1) the maximum coverages observed at three example Björkskär installations (Table 2.2) and 2) the change in observed coverage over time on the surfaces with leca compared to those with best-grade steel, which was used as reference (Fig. 2.3, Table 2.2).

Figure 3.1. Schematic to illustrate how the concept of biodiversity index and valuation was used in the BioBuz project.



Potential for nutrient removal

As another example, we estimated the potential uptake of nutrients (nitrogen and phosphorus) by blue mussel farms, based on nutrient contents given in the literature. Nutrient content in blue mussels in the Baltic Sea generally decreases with increasing salinity (Buer et al. 2020). Our estimations were mostly based on information synthesised by Hedberg et al. (2018). For blue mussel farms in the Baltic Proper, we considered the blue mussels (wet weight) to contain about 0,7% nitrogen and 0,07% phosphorous, a farming cycle of 19-30 months, and a harvest between around 10 and 30 tonnes wet weight per hectare and year (Jansen et al. 2021). We used these values for a rough estimation of the nutrient removal of mussel farms in the area, although they have substantial uncertainty (Hedberg et al. 2018).

Results

Biodiversity credit scenarios

Using the maximum coverage values of focal species at the example Björkskär installations as an illustration, the highest biodiversity index was observed at the surface structures with leca (at 10 m)

and gravel (at 20 m) (Table x). However, the installation at 20 meters depth was mostly covered by barnacles and may be less representative for this study, which had blue mussel colonization as the main objective. The sum of weighted species richness increased over time at the leca surface, while it varied at relatively lower values at the best-grade steel surface. The difference between both values gives the biodiversity index, which increased from the first to the second monitoring occasion, and then remained similar by the time of the third monitoring occasion (Table 3.1).

Examples of how to develop scenario estimates were built around assumptions as follows:

- Assuming that blue mussels and a related artificial reef would establish from the surface down to 20 m depth on a monopile with a diameter of 10 m, this would imply an areal reef coverage of around 600 m² per monopile.
- Assuming that ecological engineering to enhance mussel colonization, specifically to place a heterogeneous structure such as leca around the monopiles, would have been conducted for 100 wind turbines in the wind park, that would represent an area of 60,000 m².
- Assuming that the field study estimates of maximum coverage of blue mussels on this substrate (as observed after two years at one of the Björkskär installations) are representative, and based on the initial arbitrary parametrisations shown in our example, this would imply an example mean biodiversity index of 8.4, which when multiplied by the area subject to biodiversity enhancement (60,000 m²) gives an “area-based biodiversity index” of $8.4 * 60,000 = 504,000^1$.

The above example is based on a mean value, but in the same way, the rate (development over time) of the area-based biodiversity index can also be calculated to illustrate how its value may change over time (Table 3.1).

Table 3.1. Example calculation of a biodiversity index (BI, eq. 1) over time for one of the Björkskär installations (RE_10_S_6, 60° angle; Figure 2.3), calculated for the surface with leca and the surface with best-grade steel as reference.

Monitoring date	$\Sigma(\text{Weight} * \text{Coverage}_{\text{Leca}})$	$\Sigma(\text{Weight} * \text{Coverage}_{\text{Best-grade steel}})$	BI
17.07.2024	9.0	2.3	6.7
24.10.2024	9.7	0.1	9.6
21.05.2025	10.0	1.0	9.1

*Assuming the same dimensions and characteristics of wind park and biodiversity enhancements as described above for calculations.

Nutrient uptake in blue mussels in a multi-use scenario in the Åland Sea

We made rough scenario estimations for nitrogen and phosphorous content in blue mussels in a multi-use context with offshore wind farms, based on literature information and assumptions (Table 3.2). The presented values are to be seen as “order of magnitude” values to give a rough impression on the ranges that approximately could be expected, given the underlying assumptions made and the uncertainty in reported data, also including the fact that the literature data was from the Baltic Proper and not from the actual site. Hence, the values carry a considerable degree of uncertainty and should be treated accordingly.

¹to potentially be transformed to monetary units with a biodiversity credit value

Table 3.2 Literature information used, and assumptions applied, to make crude estimates of nitrogen and phosphorous contents in blue mussels in a multi-use scenario with a “scenario wind farm”.

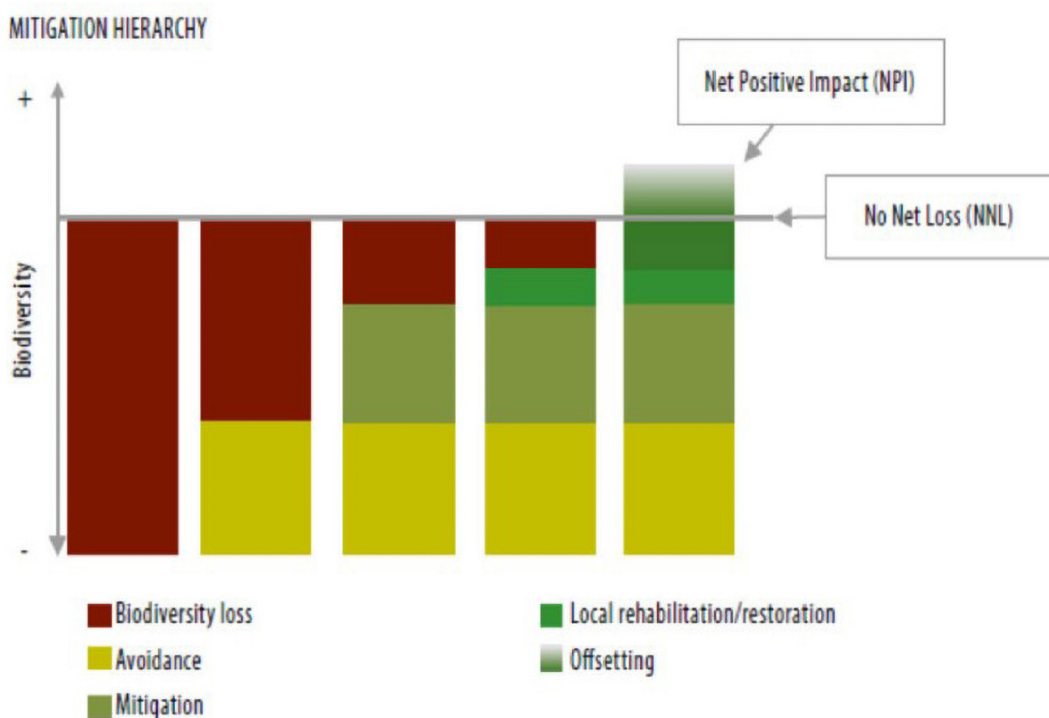
Variable	Unit	Minimum used	Maximum used	References
Annual harvest at blue mussel farm in Baltic Proper	Ton blue mussels (wet weight) per ha	10	30	Minnhagen 2017; Hedberg et al. 2018
Total nitrogen (TN) content per mussel	%	0.7	0.7	Hedberg et al. 2018
Total phosphorous (TP) content per mussel	%	0.065	0.065	Hedberg et al. 2018
TN content per mussel farm	t/ha-1 yr-1	0.07	0.21	Calculated from values above
TP content per mussel farm	t/ha-1 yr-1	0.01	0.02	Calculated from values above
Area of mussel farming in the scenario wind park	ha	3	12	Assumption
TN per scenario wind park and year	kg N/wind park-1 year-1	210	1260	Assumption, and calculated from values above
TP per scenario wind park and year	kg P/wind park-1 year-1	20	120	Assumption, and calculated from values above

We assumed that a mussel farming area of 3-12 hectares would be installed in the “scenario wind farm” (Table 3.2). With the literature values used and assumptions made, we then arrive at estimates of total nitrogen content in blue mussels ranging between 210 and 1,260 kg nitrogen per “wind farm” and year. The estimates for total phosphorous content ranged between 20 and 120 kg phosphorus per “wind farm” and year. These approximate annual estimates represent the amounts of nutrients that could be removed upon 100% harvest of the blue mussels. Assuming a life span of the wind farm and mussel farming of 40 years, that would amount to a removal of approximately 8 to 50 tons of total nitrogen, and of approximately 1 to 5 tons of total phosphorous.

Discussion

Biodiversity credit scenarios

When developing offshore wind farms, as in the general context of physical developments in nature, it is essential that the mitigation hierarchy is strictly and consistently applied, meaning that any biodiversity impacts or modifications are first and foremost to be avoided, thereafter minimised and remedied, and lastly compensated (Arlidge et al. 2018; Phalan et al. 2018; Maron et al. 2024; Wauchope et al. 2024; Figure 3.2). Hence, the development of biodiversity credits should build on the prerequisite of a full implementation of the mitigation hierarchy (Maron et al. 2024). Once the mitigation hierarchy has been fully applied, additional investment in conservation actions that benefit biodiversity can help to reach further “net positive impact”, or “nature positive” developments (Maron et al. 2024; Figure 3.2). Also, it is important to emphasize that ecological engineering measures, such as the ones studied here, can reduce ecological impact of artificial underwater structures, but not provide justification for avoidable degradation of natural ecosystems (Perkins et al. 2015, Firth et al. 2016). Rather, the measures should be seen as option to mitigate impacts and maximize potential ecological outcomes of unavoidable artificial underwater structures (Dafforn et al. 2015, Firth et al. 2016).

Figure 3.2. Illustration of the mitigation hierarchy. From Kostamo et al. 2020.

Furthermore, whether or not different types of ecological engineering approaches are wanted and suitable is case- and site-dependent. There may for example be cases where it is instead desirable to minimize the formation of an artificial reef with hard-substrate associated aquatic species, for example if underwater structures (such as an offshore wind farm) are constructed in a natural soft-bottom area where the promotion of hard-substrate-associated species is not desirable. Conversely, there may also be cases where it can be positive for nature to combine offshore wind energy (or other artificial underwater structures) with ecological engineering measures to promote and enhance artificial reefs. This may occur for example in areas where hard-substrate habitats were previously removed or degraded. Hence, the ecological engineering method studied here is not to be seen as a standard that renders positive outcomes in general, as this needs a case-by-case assessment.

The example developed in this pilot study refers to testing and evaluating the “high-level principle” cluster 1 of the biodiversity credit market, which is “verified positive outcomes for nature” (BCA 2025). The objective of the study was to find pathways for stimulating the establishment of habitat-building species, more specifically blue mussels and bladderwrack, as they may become the foundation for further development of biodiversity by attracting and supporting other species.

The field studies showed that, while bladderwrack was not observed at the pilot installations, blue mussels had preferentially established at the ecologically engineered surface structures with higher spatial complexity. The data also showed that positive changes, in the form of high blue mussel coverage, occurred additional to those observed at baseline, which was industrial standard steel surface. The changes observed lasted through the monitoring time of two years, verifying that biodiversity-enhancing surface structures can facilitate artificial reef development, pointing the way for promising positive outcomes for nature in the Baltic Sea.

At the Björkskär installations with biodiversity-enhancing designs (Ieca as surface structure), the estimated biodiversity index increased over time. This outcome was expected, and consistent with an observational study in the Northern Baltic Sea (Koivisto 2011). In that study, species richness as biodiversity indicator was also seen to increase with mussel biomass and with size of the mussels. Similarly, the biodiversity value of new blue mussel beds (for example as multi-use activity in offshore wind farms) could be expected to show an increasing trend from establishment to maturation of the mussel bed (Koivisto 2011).

There is currently no standardized approach for calculating biodiversity credits, but different methods for calculation and for weighing the different biodiversity components are promoted or tested (Maczik et al. 2024). Here, we followed the biodiversity indicator calculation approach outlined in Ducros & Steele (2022), where biodiversity is calculated as the sum product between abundance (in our case coverage) of each species or organism group, weighted by a measure of “importance” in the ecoregion. In our example calculations of the biodiversity indicator we used rather subjective values (“weights”) on an arbitrary scale, with the aim to reflect the relative value of the focal species for biodiversity in the studied ecosystem. Considering the differences in ecological function of the different species, a higher weight was given to more desired species, based on external criteria.

We only applied positive “weights”, as none of the encountered species was assessed as “unwanted”, as would be the case for example if non-indigenous or invasive species were to colonize. In the case that “unwanted” species would establish, these would be considered in the calculations by assigning them a negative “weight”, hence resulting in a decreasing biodiversity indicator. There is a risk that non-native or invasive species become dominant at new artificial hard structures, for example because they often have a competitive advantage during initial colonization of yet uncolonized hard structures (Dafforn et al. 2015, Firth et al. 2016, Burt and Bartholomew 2019, Brzana and Janas 2025). However, ecological engineering may be used to increase the probability of recruitment of local native species, for example by incorporating features that mimic their natural habitat (such as higher spatial complexity, as tested in this study), and/or by seeding the structures with native species. A higher diversity of native species may then offer resistance to settlement of non-indigenous, potentially invasive, species, thus decreasing the risk that they become dominant at the new artificial hard structure (Perkol-Finkel et al. 2018, Schoonees et al. 2019).

Facilitating the co-existence of activities in the same space through multi-use concepts can be central for marine planning, given the potentially high spatial competition between different human activities at sea. One example is combining offshore wind energy production and low-trophic aquaculture (Buck et al. 2008, 2018; Van Hoey et al. 2021). In the Baltic Sea, harvesting farmed mussels could also be a cost-effective complement to other measures needed to remedy the eutrophication problem in the Baltic Sea (Kotta et al. 2020, 2022). The internal loading of nutrients to the Baltic Sea is large. For example, nitrogen (N) fixation in the Baltic Proper has been estimated to about 399,000 tons per year (Olofsson et al. 2021), and the internal load of phosphorous (P) in the Baltic Proper was about 91,500 tons in 2005 (Stigebrandt et al. 2014). These estimates are for the whole Baltic Proper, and would, applying an area of 211,000 square km (Olofsson et al. 2021), very roughly correspond to average annual rates of around 0.02 tons N and 43 tons P per hectare. For comparison, the order of magnitude of nutrients that could be removed annually through mussel harvesting in one multi-use wind farm was about 0.1-0.2 tons N and 0.01-0.02 tons P per hectare and year, according to our rough and initial estimates (Table 3.2). This shows that mussel farming and harvesting could make relevant reductions of the internal nitrogen loading and contribute to reducing the internal phosphorous loading, even though to a minor proportion based on comparison of these rough and large-scale areal estimates and their underlying assumptions. The actual effect will vary depending on the location and spatial extent of the farming. In conclusion, combining wind energy with low-trophic aquaculture could be a useful measure to mitigate eutrophication, especially under large-scale establishment of wind farms (Wind Europe 2024), while at the same time producing aquatic foods or raw material for other products.

Business Model built on multi-use

This part of the project sought to develop a business model in which the regeneration of nature is integrated with the provision of renewable energy as a central value proposition.

Method

The proposed model responds to the growing recognition that traditional linear “take–make–waste”

business models are incompatible with the safe operating space defined by planetary boundaries (Rockström et al. 2009). With over half of global GDP—approximately €40 trillion—reliant on nature’s services (World Economic Forum 2020; Dasgupta 2021), it is vital that business find new models for operating that not only meets the “do no harm” criteria in the mitigation hierarchy, but actually starts having a positive impact on nature, such as through nature regeneration.

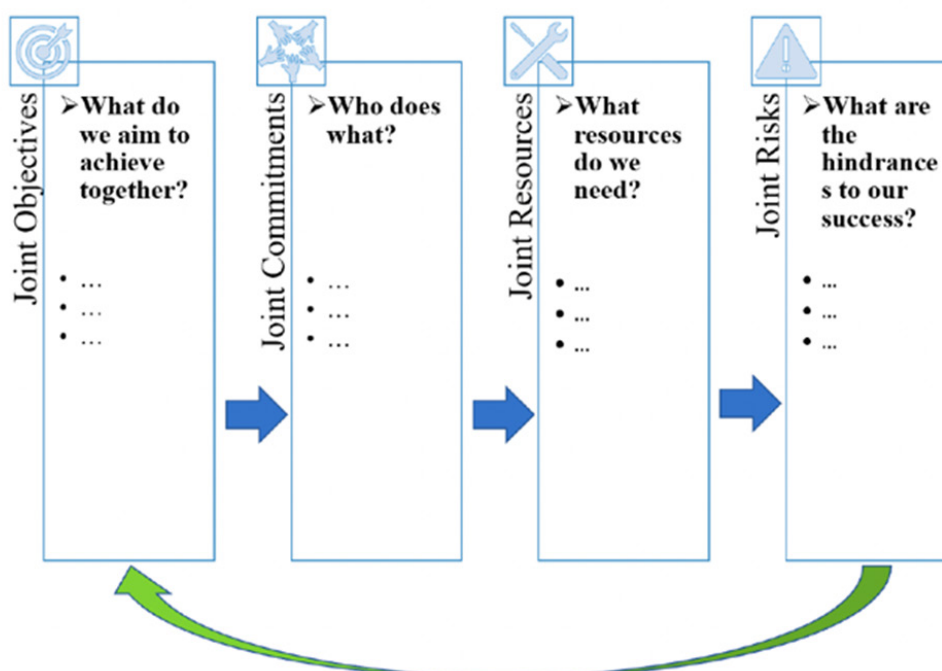
New business paradigms have emerged that seek to align economic activity with ecological resilience. Circular business models, which emphasize resource efficiency and material recirculation, have been proposed as a pathway to reduce environmental impact while maintaining economic viability (Ellen MacArthur Foundation 2013; Bocken et al. 2014; Geissdoerfer et al. 2017). However, to operate within the planetary boundaries and not only be resource efficient, it is vital to find business models and business operations that actually have a positive impact on nature. This project therefore extended beyond circularity towards regenerative or restorative business models (Fullerton 2015; Raworth 2017; Bocken & Short 2021), in which value creation is directly linked to the active restoration and enhancement of ecosystems. Such regenerative approaches reposition ecological regeneration not as a constraint but as a driver of innovation, competitiveness, and long-term business value within ecological and planetary limits (Dasgupta 2021; TNFD 2023).

To design this new regenerative business model, where one or multiple companies integrate to create a win-win scenario for both the companies and nature, various methods and models have been used but also redesigned to enable the creation of a regenerative business model.

Frameworks

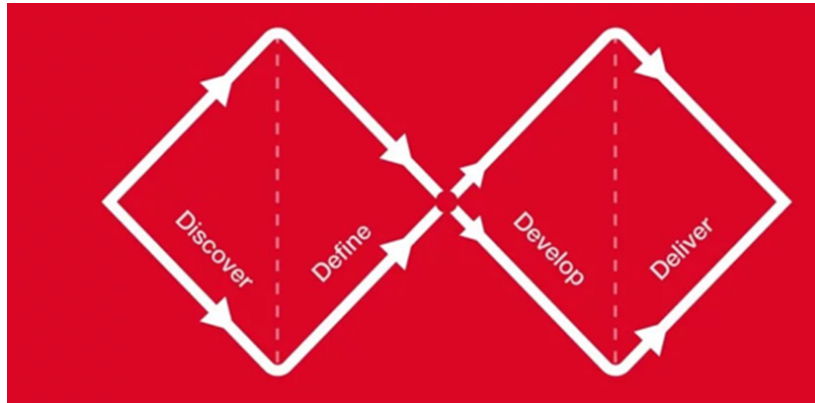
This study employed a multi-method design approach, combining strategic business model innovation tools with business ecosystem-oriented analysis. The Value Case Methodology served as the overarching framework guiding the research process. As described by Dittrich and Dijk (2013), this approach provides a structured means of identifying, assessing, and articulating the value of a project or innovation, particularly in complex multi-stakeholder contexts. It supports informed decision-making by systematically evaluating both tangible and intangible forms of value. In the present study, stakeholder mapping was carried out to identify relevant actors and their inter-relations, and the alignment map was adapted and redesigned to meet the specific needs of the project team (Fig. 4.1).

Figure 4.1: Alignment map



To structure the innovation process, the project adopted the Double Diamond framework developed by the UK Design Council (2005). This model divides the design process into four iterative phases—Discover, Define, Develop, and Deliver—enabling alternating cycles of divergent and convergent thinking (Fig. 4.2).

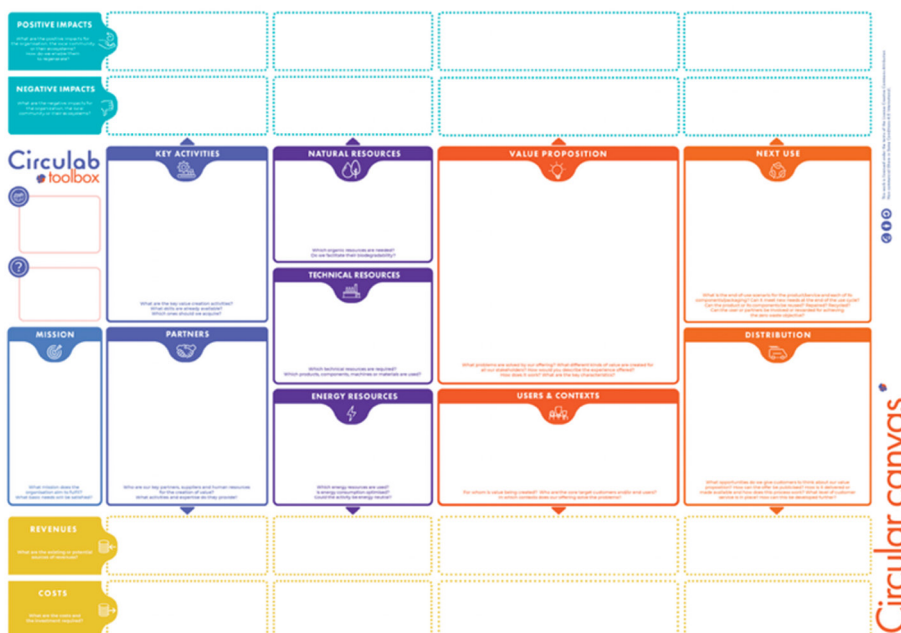
Figure 4.2: Double Diamond Innovation Framework



This process facilitated the exploration of challenges and opportunities, before progressively refining and implementing solutions. The iterative nature of this framework ensured a systematic approach to stakeholder engagement, problem definition and solution development. According to Design framework principles, a wide range of stakeholders should actively take part in designing the solution to make sure that the perspective of the ones who have the ability to act upon the business model is the one informing it, which is why multiple stakeholders outside the project took part in interviews.

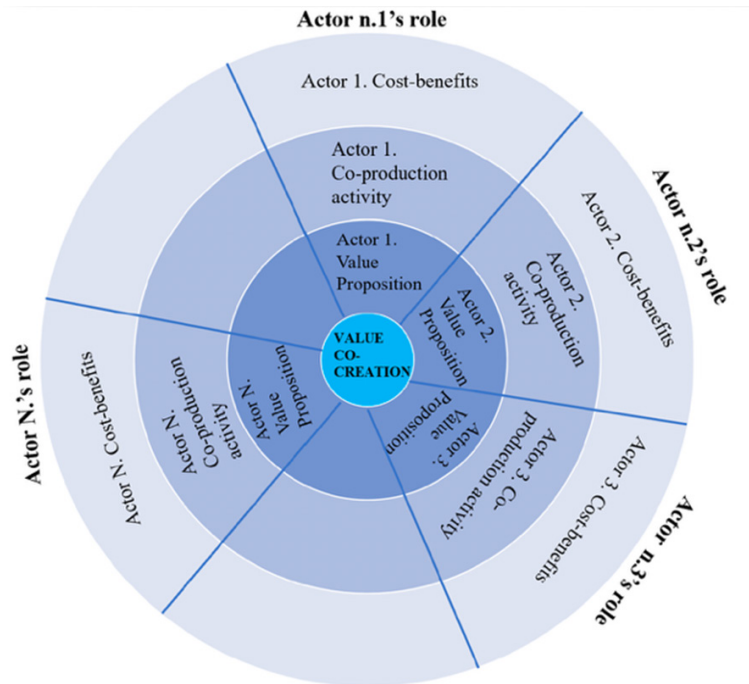
Building upon the outcomes from these design stages, the Circular Business Model Canvas, based on Osterwalder and Pigneur's (2010) original framework and redesigned through the Circulab toolbox, was employed to conceptualize and visualize the integrated business model. This tool enabled systematic mapping of core business elements—value propositions, customer segments, channels, revenue streams, key activities, resources, and partnerships—while embedding principles of circularity and resource efficiency. The use of this canvas supported the alignment between strategic objectives, operational design, and the potential economic value of multi-use offshore wind energy solutions (Fig. 4.3).

Figure 4.3: Circular Business model Canvas to depict a companies business model together with sustainability impact



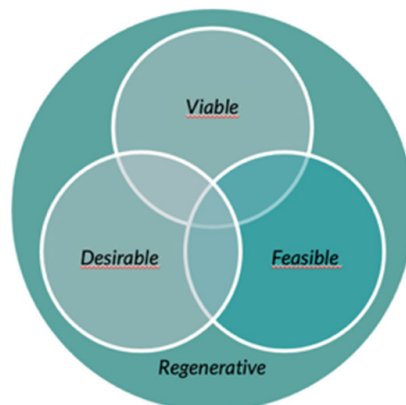
To capture the complexity of interdependencies between actors within the broader system, the Service-Dominant Ecosystem Map was applied (Fig. 4.4). Following Lüftenegger et al. (2017), this analytical tool was used to describe value co-creation processes at the ecosystem level, with specific attention to value propositions, co-productivity, and individual cost-benefit relations. This allowed us to identify where and how value was jointly created and shared across stakeholders in the multi-use context.

Figure 4.4: Service. Dominant Ecosystem Map



Finally, the Feasibility–Viability–Desirability (FVD) Evaluation Matrix (Brown 2009) was employed to assess the maturity and potential success of the proposed solutions. Feasibility referred to the technical and operational practicality of the concepts; viability addressed the economic soundness and business case robustness; and desirability captured stakeholder acceptance and social relevance. To align with the project’s environmental objectives, a fourth criterion, regenerative potential, was added (Fig. 4.5). This ensured that the business model was evaluated not only for its economic and social merits but also for its capacity to generate measurable and durable positive biodiversity outcomes.

Figure 4.5: Redesigned Desirability, Viability and Feasibility Framework to include Regenerative criterias.



Discover Phase: Identifying Stakeholder situation, needs and Value Drivers

The initial phase involved a combination of individual interviews and desktop research to identify the needs of key stakeholders and the value drivers influencing the regenerative business model we sought to develop. Individual interview series with stakeholders provided an in-depth understanding of their specific needs, expectations and objectives. Internal interviews were held with SLU, OX2, Nemo Seafarms and Under Ytan. The interviews and seminars were complemented by desktop research, which focused on analyzing reports, and literature related to multi-functionality, nature credits and regenerative business models. The insights gained from these two approaches helped to identify the key stakeholders' priorities.

Following this, two collective online workshops were held with all project partners to refine and align the understanding of stakeholder needs and value drivers. These workshops provided a collaborative space for sharing perspectives and building consensus on the most critical elements that would drive the success of the proposed solutions. The service dominant ecosystem here was used as a way of understanding the stakeholders business ecosystem together with the circular business model canvas.

Outcome: Circular business model canvas for offshore wind owner and developer OX2 (Fig 4.6), stakeholder map (Fig. 4.7), dominant service ecosystem map (Fig. 4.8), and mapping of potential services on a multi-functional platform (Fig. 4.9).

Figure 4.6: Circular Business model Canvas for OX2

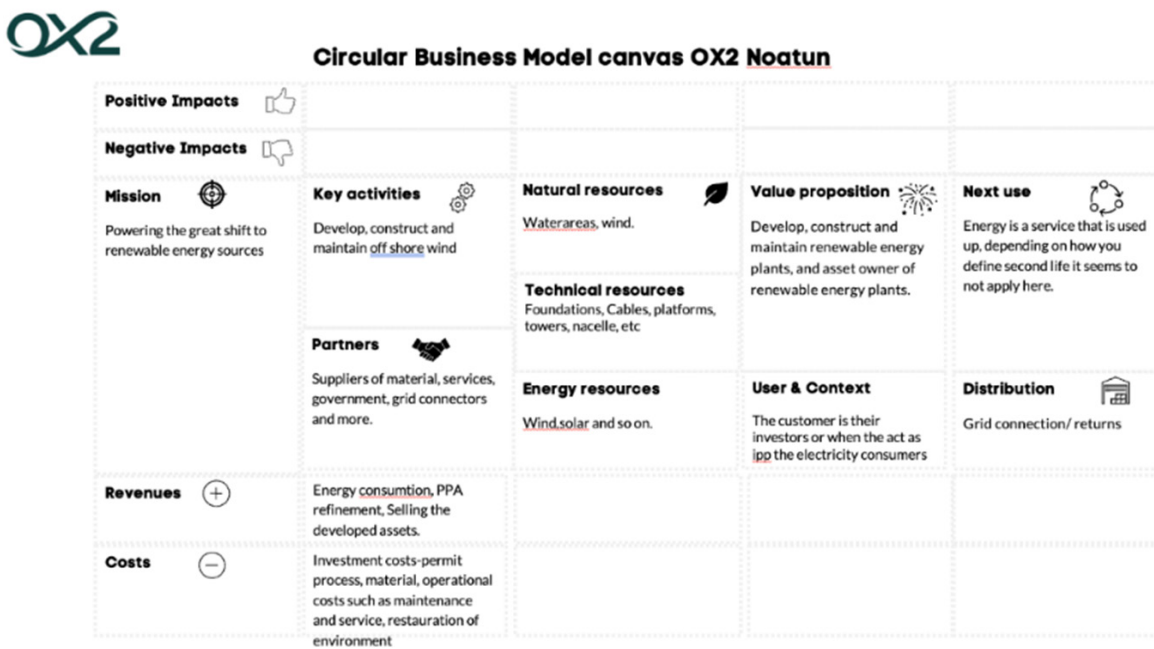


Figure 4.7: Stakeholder map

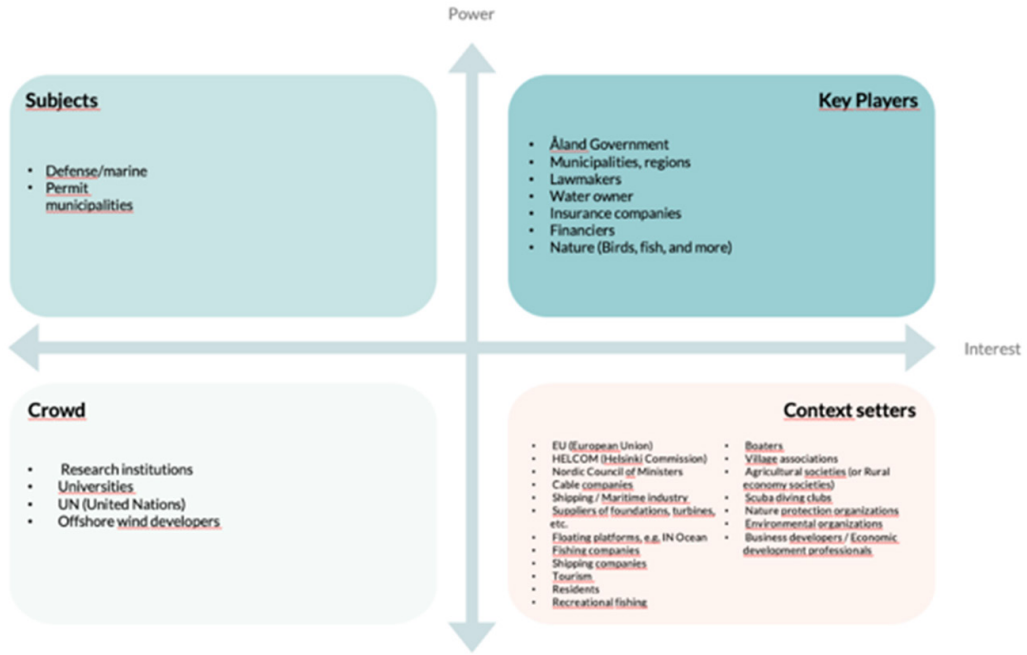


Figure 4.8: Service- Dominant Ecosystem for off shore wind

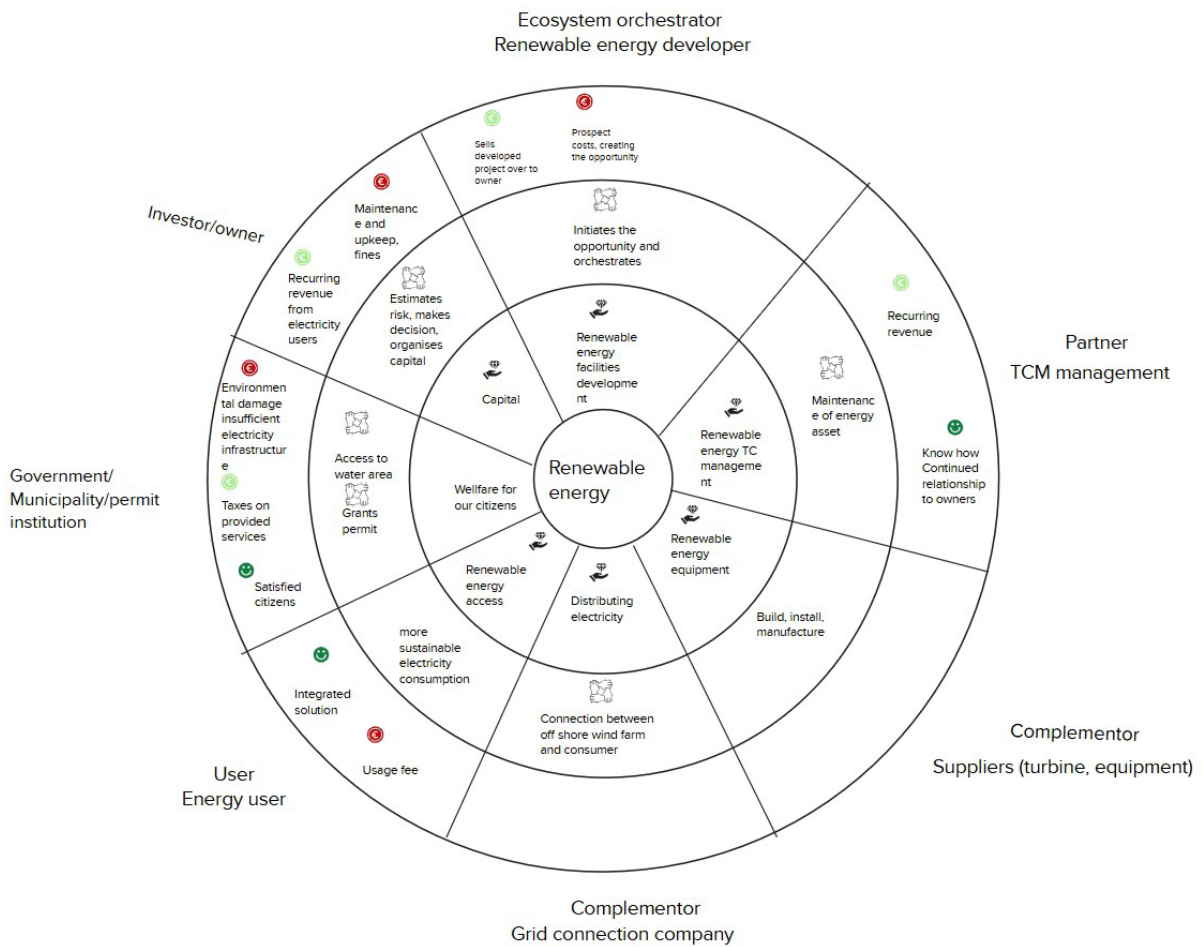
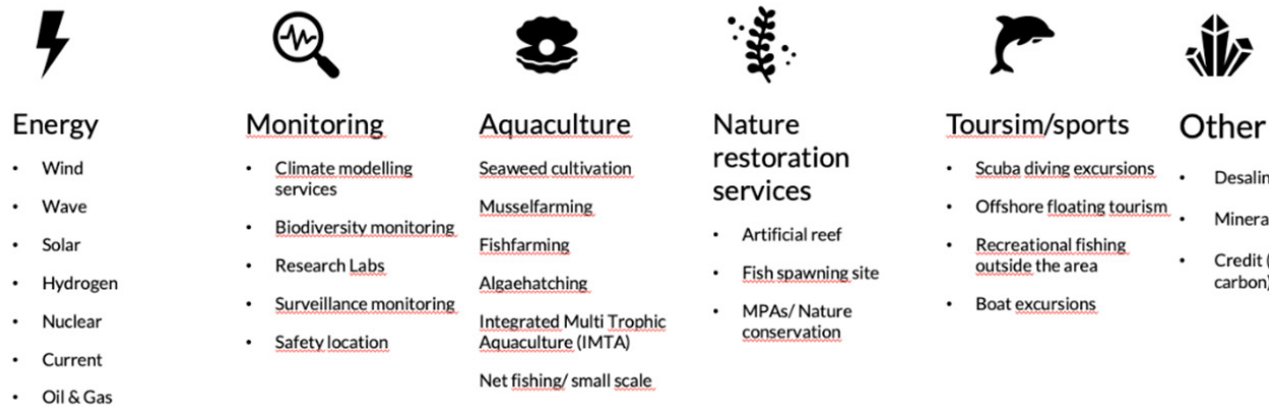


Figure 4.9: Mapping of potential services on a multi-functional platform

Define Phase: Defining collaboration, multifunctional set up, value criteria and alignment

In the next phase, the study focused on defining the challenge through further stakeholder interviews, to define the premises for the sought after collaboration and combination of actors and services on the multi-functional platform. Another collaborative workshop detailed the alignment map, redesigned for this specific need, see figures below. Through a workshop and continuous partner collaboration, the study co-created value criteria, focusing on how collaboration among the actors could yield a higher Internal Rate of Return (IRR) and lower Weighted Accumulated Cost of Capital (WACC). A redesign of the business ecosystem was created to visualize the potential new business ecosystem.

Outcome: Circular Business model canvas for start ups (Fig. 4.10). Alignment map for the 3 parties (Fig.4.11), redesigned dominant service ecosystem map (Fig. 4.12). Weighted Accumulated Cost of Capital (WACC) was the chosen assessment value criteria for the solution.

Figures 4.10: Circular Business model canvas for start ups

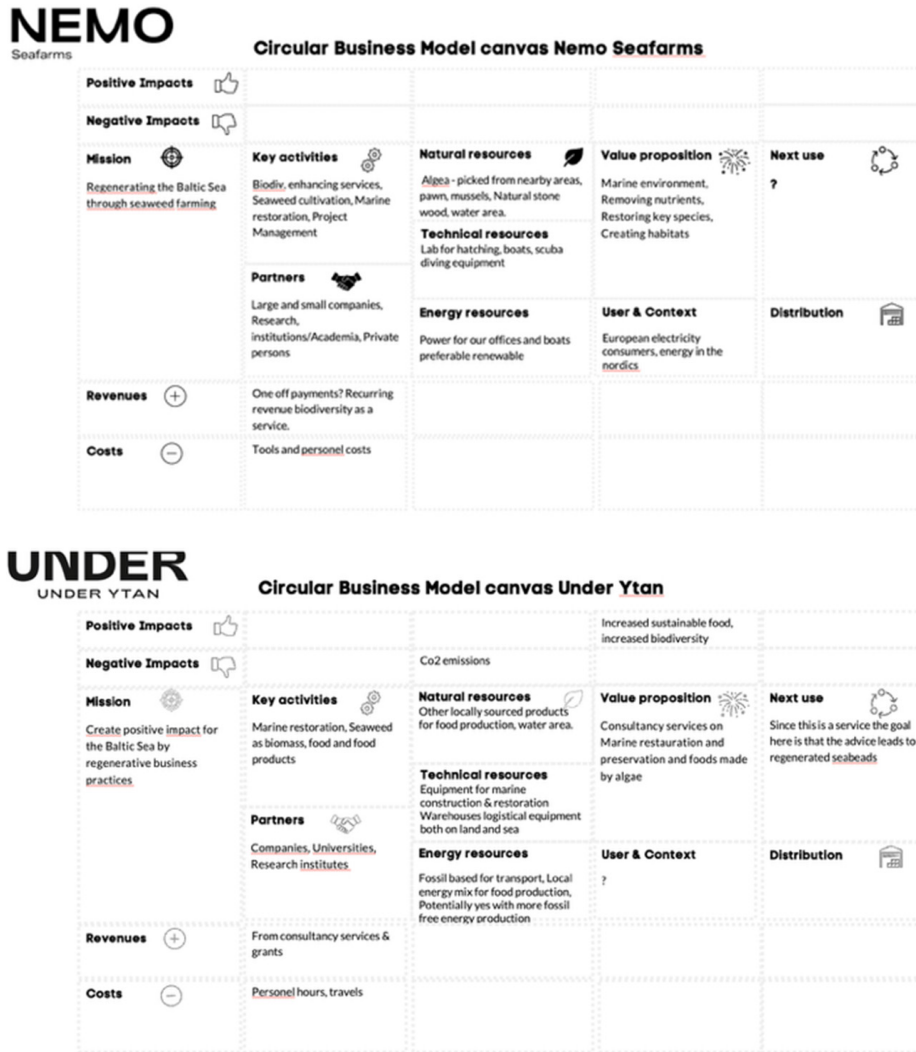


Figure 4.11: Alignment map for OX2, Nemo Seafarms & Under Ytan

Value alignment map

Synergies/conflicts for OX2, Nemo seafarms & Under ytan

Common needs: Water area, boats for technical service, water permits.

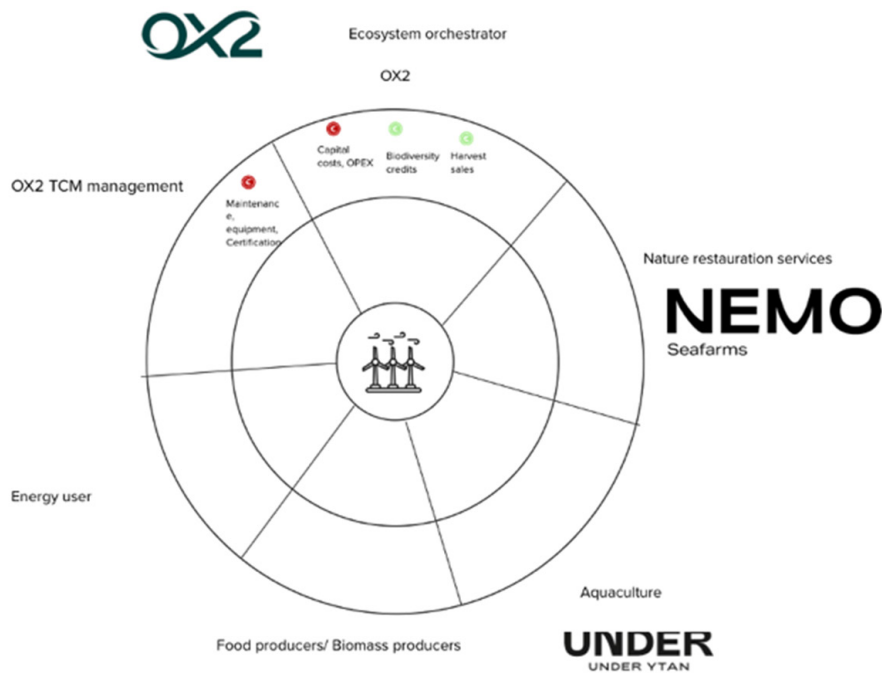
Synergi: The ecosystem services providers can help the offshore company mitigate their biodiversity impact and the off shore company can provide water area and vessles for the algaes to hatch.

Common stakeholders: Water owner, Financiers, Nature, Residents, Nature protect organisations and institutions

Common values: Regenerating nature/ biodiversity positive ambitions.

Challenge:
Financing ecosystem services
Measuring biodiversity

Customer: They don't service the same customers with their core value proposition

Figure 4.12: Redesigned dominant service ecosystem map

Develop phase: Ideating on how biodiversity enhancement impacts the business case

In this phase, we mapped out the possibilities for collaboration and multi-functionality, and evaluated how enhanced biodiversity potentially can have a positive impact on the business case. This process was facilitated through a co-creative ideation session where new revenue streams, potential for lowered costs and other benefits were characterized. The thereby defined 21 assumptions were then formulated into assumptions, and prioritized based on multiple criteria, such as: *What is most important to look into further? What do we think can make the biggest contribution? What is possible to find out? What is the time horizon? Is this important in other ways than adding financial value?* Subsequently, an interview plan was made to identify key actors and stakeholders who could feed into the process and on what key assumptions. Professionals possessing relevant expertise in sustainable finance, power development, and biobased business models were chosen to inform and serve as testers.

Outcome: 21 assumptions to be tested through interviews and desktop research (table 4.1).

Table 4.1: 19 ways increased biodiversity and collaboration could improve the business case for off shore wind

New income stream	Lowered costs	Other benefits
Selling biodiversity credits	Lowered lease for the use of a water area	Priority access to use the water area
Biomass production/harvesting	Reduced actions / costs for mitigating biodiversity loss	Brand goodwill – higher company valuation
Rent (arrende) for biomass productions/harvesting	EU subsidies	Certifications
Testsite for new sensors aimed at biodiversity measuring, R&D	Green loan benefits	Increasing the value of the lease
Patenting the method/process	Shared facilities, boats, UAVs, USVs for rent	
Services for Aquaculture, monitoring etc. Seed bank?	Avoiding compensation payments to fishers for lost income	
Shared facilities, UAVs, USVs, boats for rent for partners		
Fishers paying a higher price to fish in those waters		
Eco tourism paying a higher price to see the area		

Deliver Phase: Assessing our assumptions and re-designing the multi-functional offshore wind business model

Next in the process, our assumptions were validated or invalidated, respectively, through External Interviews. Interviews were held with Nordea, specialists on ESG and biodiversity finance, Ålandsbanken, fund manager, Natura Tua, a start up focusing on biodiversity restoration of forests selling Biodiversity units, and a Wind power owner in Europe on multiuse. Three seminars on biodiversity credits was attended, What opportunities are there with biodiversity credits (KSLA, May 2025), Biodiversity credit alliance Inputs for IUCN WCC Motion & EU Roadmap (BCA Secreteriat, 2025), Buyer perspective on biodiversity credits (Swedish Biocredit Alliance forum (SBA, October, 2025). These expert insights were crucial for understanding the potential benefits and risks associated with different solutions.

By combining expert interviews with a review of white literature, such as academic reports, grey literature, and attending seminars to gather information on market development of biodiversity credits, nature finance, and multi-use development it was possible to validate or invalidate potential financial savings or efficiency improvements.

The final phase also involved synthesizing these findings to deliver a concept for a new regenerative integrated multi-functional business model, offering insights into how business models and business ecosystems can be designed with an integrated focus on both nature and financial perspectives.

Outcome: Prioritized and validated/invalidated streams impacting the business case (table 4.2)

Table 4.2: Prioritized and validated/invalidated streams impacting the business case

What	Assumption + (assumption number #)	Validated/ Invalidated	How
Selling Biodiversity positive energy	Including positive biodiversity outcomes in the Power Purchase Agreement will allow for a price premium (1)	Validated	Interviews, power company + market research
Biodiversity credits/ Carbon credits +	Biodiversity credits can generate a new income stream for offshore wind developers (2)	Validated	Interview Market research, seminars https://www.cleantides.net , https://www.seatrees.com , https://ec.europa.eu/commission/presscorner/detail/nl/ip_25_1679 Interview carbon credit broker, Market research https://www.cleantides.net , https://www.seatrees.com , https://ec.europa.eu/commission/presscorner/detail/nl/ip_25_1679 , Seminars Biocredit alliance and KSLA
Aquaculture (Algae+ Mussels)	Providing aquaculture services can generate a new income stream for OX2 + Biomass can generate a new income stream for offshore wind developers (3)	Validated	Market research from adjacent project Marefine.com
Access to impact-focused investors and ESG funds	Including ecosystem-enhancing services could reduce the cost of capital for the wind power developer by providing them access to impact-focused investors and ESG funds (4)	Partially	Interviews Nordic banks
Improved interest rate due to lower risk assessment	Including ecosystem-enhancing services will improve the risk assessment due to reduced environmental risks (5)	Validated	Interviews Nordic Banks
Less actions/Lower costs to mitigate biodiversity loss	Including ecosystem-enhancing services could lower the restoration costs (6)	Partially	Interviews Nordic Banks
Lowered lease for the use of a water area	Including ecosystem-enhancing services could lower the lease for the water area (7)	Partially	Interview Power company, market research
Priority to use water area	Operating in a biodiversity positive approach will give priority to water use (8)	Validated	Market research https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act_en

Results

Based on the project findings, three main categories of factors were identified as having the greatest potential to significantly influence the Weighted Average Cost of Capital (WACC) for offshore wind projects integrating low-trophic aquaculture and biodiversity-enhancing measures. These categories were prioritized according to their market relevance, likelihood of realization within a 5–10-year time horizon, and their potential magnitude of impact on the business case.

Increased or New Revenue Streams

Several novel or expanded revenue opportunities were identified. First, the sale of **“dark green” renewable electricity**— (1) energy produced with demonstrable biodiversity benefits could command a price premium in power purchase agreements (PPAs). This development parallels the existing market for renewable energy certificates and guarantees of origin (GOO’s), which allow corporations to demonstrate compliance with sustainability and reporting requirements (Swedish Energy Agency, 2025). As biodiversity reporting becomes increasingly regulated through frameworks such as the EU Corporate Sustainability Reporting Directive (CSRD) and the Taskforce on Nature-related Financial Disclosures (TNFD), similar mechanisms could emerge for biodiversity-positive energy products.

Second, the generation of (2) **biodiversity credits** present a promising, though still emerging, income stream. Biodiversity credit markets are being developed globally to incentivize the protection and restoration of ecosystems (Biodiversity Credit Alliance, 2023; Ducros & Steele, 2022). Pilot initiatives such as SeaTrees and Treebula demonstrate that voluntary biodiversity credit trading is already occurring, while international bodies including the EU Commission and the United Nations are actively developing standards and governance mechanisms to ensure credit integrity (European Commission, 2024; UNDP, 2024). Although the market remains nascent, the growing number of initiatives suggests strong potential for scalability. Two possible scenarios are: First selling the credits as an option, by a contract enabling a purchaser the right to purchase for example Ex-post the impact of the credit can be measured, (ex-post referring to after the impact has been obtained); Or, the second scenario, could be a market for the credits similar to the GOO’s with a mandatory market setting the prices for the credits.

Third, additional revenue could derive from (3) **low-trophic aquaculture**, including the cultivation of mussels and seaweed. These activities provide direct economic returns through the sale of biomass while offering co-benefits such as nutrient uptake and habitat enhancement. According to estimates from Kulikowski et al. (2021), offshore seaweed farming can yield between €45 and €170 per kilogram of dried biomass, depending on species and market segment. This represents a potentially valuable diversification of income streams for offshore renewable developers.

Lowered Costs

Several mechanisms were identified through which multifunctional offshore platforms could reduce costs and improve access to capital. The first concerns (4) access to impact-focused investors. Offshore wind development is a capital-intensive sector, and small adjustments in WACC can significantly affect project viability. Integrating biodiversity-positive design could attract a broader pool of investors focused on environmental, social and governance (ESG) outcomes (Nordic Investment Bank, 2024). Interview data indicate that financial institutions view measurable biodiversity outcomes as a factor that could improve credit terms or attract new sources of green financing.

Second, incorporating biodiversity enhancement measures can reduce **perceived environmental and regulatory risk**, thereby improving loan conditions. Projects with verifiable strategies for mitigating biodiversity loss may achieve better risk ratings and lower interest rates, reflecting reduced exposure to fines, delays or remediation costs (European Investment Bank, 2023; KPMG, 2024).

Third, **lowered costs associated with environmental mitigation** could be realized over the project lifespan. By proactively enhancing rather than merely offsetting biodiversity impacts, developers may reduce the need for costly compensatory actions or environmental penalties (Bassen et al. 2019, Interview, financial institution, 2025).

Finally, **lowered lease costs for marine areas** could, in theory, serve as a powerful economic incentive for biodiversity-positive projects. In offshore wind developments, annual lease payments can amount to 20–30 million euros, representing around 10% of total investment costs. Even minor adjustments (e.g. a 2% discount) could significantly influence project economics. Although no concrete cases were identified in this study, this mechanism presents a potential policy lever for aligning public procurement and marine spatial planning with sustainability objectives.

Other Benefits

Beyond direct financial metrics, several strategic and regulatory advantages were identified. The forthcoming EU Net-Zero Industry Act proposes that environmental impact and spatial efficiency should serve as key criteria in the allocation of marine development rights (European Commission, 2024). In practice, this means that developers demonstrating positive biodiversity outcomes or multifunctional use of marine areas may gain a competitive advantage in concession auctions.

Calculated hypothetical additions to the business case

For the revenues we could get detailed with based on available data, these have been calculated as promising additions to the business case, where we can see that charging for “dark green energy” gives the highest result.

Electricity Revenue from PPA with Guarantees of Origin + Biodiversity Premium

Assumptions:

- Annual production: 19.5 TWh = 19,500,000,000 kWh
- Baseline PPA price: 50 €/MWh
- Additional premium for Guarantees of Origin + 3 €/MWh
- Additional premium for positive biodiversity credit/impact + 3 €/MWh

Table 4.3: Annual Revenue Scenarios for Offshore Wind Farm (19.5 TWh/year)

Scenario	Renewable (GO) Premium (€/MWh)	Biodiversity Premium (€/MWh)	Total Price (€/MWh)	Annual Revenue (€)	Annual Revenue (MEUR)	Increase vs Baseline (MEUR)
1. Baseline electricity	0	0	50	$19,500,000 \times 50 = 975,000,000$	975.0	-
2. Renewable electricity (with GO)	+3	0	53	$19,500,000 \times 53 = 1,033,500,000$	1,033.5	+58.5
3. Renewable + Biodiversity impact	+3	+3	56	$19,500,000 \times 56 = 1,092,000,000$	1,092.0	+117.0

Summary

- Baseline electricity sales: 975 MEUR/year at 50 €/MWh.
- Renewable (with Guarantees of Origin): adds +3 €/MWh -> +58.5 MEUR/year.
- Renewable + Biodiversity impact: adds an additional +3 €/MWh (total +6 €/MWh) -> +58,5 MEUR/year.
- This corresponds to an approximate 5.7% increase in annual revenue compared with selling Renewable Electricity only

The electricity price assumptions are informed by market outlooks from Baringa and Aurora Energy Research, both of which model long-term supply and demand dynamics in the European power market. Earlier projections indicated baseline wholesale electricity prices in the range of 45–50 €/MWh, excluding transmission costs. Prices are expected to rise over the medium term, reaching approximately 55–60 €/MWh within two years and 65–70 €/MWh within four years (Aurora, 2025).

In parallel, the market for Guarantees of Origin (GOs), which certify the renewable origin of electricity, operates independently based on supply–demand conditions and regulatory drivers. GO prices has fluctuated significantly, ranging from 1–2 €/MWh in periods of low demand to 7–8 €/MWh in tighter markets (European Investment Bank, 2022).

For the biodiversity premium, a similar market-based mechanism is assumed, with pricing expected to reflect the perceived value of verified positive biodiversity impacts. However, as this market is still emerging, price levels may vary considerably depending on future demand, certification standards, and policy incentives.

Potential Macroalgae Revenue

Assumptions

- Cultivation costs: €23,400 per hectare per year (Kulikowski et al., 2021)
- Yield: 1 t dried per hectare per year (\approx 10 t fresh/ha)
- Market price: €70/kg dried
- Baltic Sea market size: 2,400 t dried/year
- Realistic market share capture: 5–15 %
- Area use: Only a small portion of offshore area (100–360 ha) would be used initially

Table 4.4: Potential Revenue algaefarming by Market Share

Market share	Volume (t dried/yr)	Revenue (€M/yr)	Area needed (ha)	Net revenue (€M/yr)	% of total business case (€1,033.5 M)
5 %	120	8.4	120	5.5	0.53 %
10 %	240	16.8	240	11.2	1.08 %
15 %	360	25.2	360	16.8	1.63 %

Summary

- Macroalgae cultivation at €70/kg dried can provide a modest revenue stream.
- Even with only 5–15% market share, annual net revenue ranges from €5.5–16.8 M, using 120–360 ha of offshore cultivation area.
- Compared to the total business case (€1,033.5 M), this represents 0.5–1.6%, showing it is a supplementary rather than core revenue source, but with potential for growth as the market develops.

Table 4.5: Biodiversity Credit Revenue: Low vs High Scenario

Scenario	Total area (m ²)	Price per m ² (€)	Estimated Revenue (€)
Conservative / Low	75,400	10	754,000
Optimistic / High	75,400	45	3,393,000

1. Total area: 377 m² × 200 units = 75,400 m² eligible for biodiversity credits.
2. Price per m²:
 - a. Low scenario: €10/m² (derived from €95 per 100 ft² market reference).
 - b. High scenario: €45/m² (derived from €450 per 100 ft² market reference).

3. Revenue calculation: Total area × price per m².
4. Market context: Revenue depends on market formation:
 - c. In a regulated market, scarcity could increase prices.
 - d. In a voluntary market, uptake is limited today, making high-price scenarios less likely.
5. Unit conversion: Original pricing was per 100 ft²; converted to €/m² for clarity and ease of reporting.
6. Sources: Seatrees (link) and Wunder et al., 2025
7. The calculation is also assuming this is an annual revenue stream meaning customer would continuously pay for upkeep.

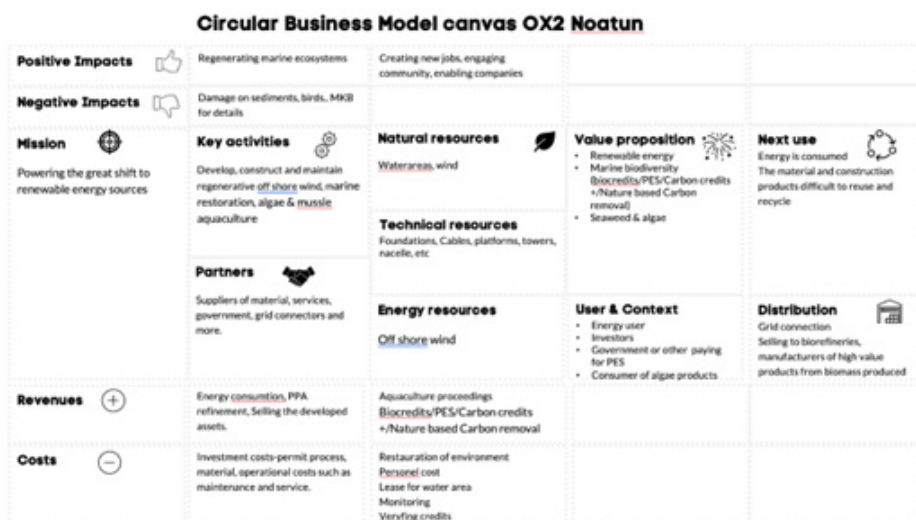
Overall takeaway:

- These three streams offer significant complementary revenue to the core offshore wind project.
- Early-stage revenue is modest but realistic, supporting medium-term business case assumptions.
- Phased development and market-linked scaling is recommended to align production with market demand and certification capacity.

The regenerative business model built on multi-use

This business model (Fig. 4.13) can serve as a framework to challenge and redesign traditional business models, incorporating the concept of multi-functionality, where two or more actors collaborate to generate greater profit while reducing environmental harm and potentially even contributing to positive biodiversity outcomes.

Figure 4.13: The new business model



Discussion

Conceptual Model and Synergies

Through innovative and interdisciplinary collaboration, combining restorative low-trophic aquaculture with offshore wind and biodiversity enhancing design we developed a conceptual integrated business model. The model demonstrates how synergies between two human activities

can produce both positive ecosystem outcomes and economic value.

We initially cast a wide net, exploring multiple pathways through which improved ecosystem health could generate revenue streams, reduce costs, and create other benefits. Subsequently, we prioritized the contributions most relevant to the business case. Biodiversity credits were identified early as a concrete mechanism to generate economic, societal and environmental value for developers, operators, entrepreneurs, and the Nordic region.

However, biodiversity credits are not the only benefit of enhanced biodiversity. Access to impact-focused investors, preferential allocation of water use, and improved loan terms also contribute meaningfully to the business case for biodiversity-enhanced offshore wind farms.

Potential Revenue Streams and Scale Considerations

Although the new revenue streams appear substantial in absolute terms, this scale is necessary to meaningfully impact the internal rate of return, given offshore wind power plants' estimated CAPEX of €14–30 billion. While some revenue sources are speculative, even conservative projections suggest they could meaningfully complement the financial viability of offshore wind projects.

Deriving financial value from biodiversity enhancements

Although a commercial company may have the capacity to make significant contributions to biodiversity, translating these benefits directly into the balance sheet is not straightforward. The impacts are often intangible, providing indirect benefits such as enhanced social license to operate or regulatory compliance.

For companies ability to manage natural resources sustainably, biodiversity-related initiatives need justification either through direct economic returns or through other benefits that ultimately generate financial value. In the absence of such direct links, initiatives typically depend on a chain of factors, such as:

Access to capital contingent on demonstrating best-practice sustainability, qualifying for high-rated sustainability investment funds, or attracting philanthropic investors (Wunder et al. 2025). These factors are influenced by legal requirements, environmental policies and other external incentives.

Desirability and Market Considerations

If revenue is closely linked to positive biodiversity impacts, the business model is regenerative in nature (Konietzko et al. 2023). Execution and feasibility are critical, requiring that all claims are substantiated and validated by third-party verifiers. Scaling the model to the full area planned for offshore wind, that is also suitable for low-trophic aquaculture and where biodiversity-enhancing design is a management goal, represents the most significant stress test, which cannot be fully assessed until further pilot projects and testing are conducted.

Market desirability insights can be drawn from literature and analyses (Wunder et al. 2025). Market growth is likely to be driven by regulatory requirements for biodiversity reporting, which will increase demand for verifiable biodiversity impact claims. Nevertheless, the future evolution of the biodiversity credit market remains highly uncertain, and different scenarios could significantly affect the ability of the business model to capture potential revenue.

A central question is: why would the private sector voluntarily pay for global public goods? (Wunder et al. 2025). The inclusion of biodiversity goals in corporate reporting, legislation, and the EU Nature Credit Scheme will significantly influence the business model's viability.

Table 4.6: Biodiversity Credits: Market and Business Case Implications

Aspect	Voluntary Market	Regulated Cap-and-Trade / PPA
Buyers	Companies, private individuals	Corporations with high biodiversity ambitions (e.g., Amazon, Microsoft, Google)
Motivations	Marketing, social license to operate, employer branding, sustainability commitment, philanthropic	Meeting regulatory targets, access to capital, reputational benefits, supply chain risk mitigation
Estimated Impact	Low, speculative	Significant, depending on regulation and uptake

Without clear regulation penalizing poor practices, best-in-class companies—those actively reporting on biodiversity—are most likely to pay premiums. Enhanced regulation targeting companies with poor practices and redirecting funds to those capable and motivated to generate positive biodiversity outcomes would strengthen the business case.

While some benefits remain intangible or speculative, they provide a strong rationale for continued pilot projects, phased implementation, and ongoing testing to maximize both environmental and economic outcomes.

Conclusions

The Nordic BioBuz project demonstrates that regenerative and multifunctional approaches to marine development are not only ecologically necessary but increasingly economically viable. By integrating offshore wind energy with low-trophic aquaculture and biodiversity-enhancing design, the project provides tangible evidence that nature-positive outcomes can reinforce, rather than compete with, commercial objectives.

Importantly, Nordic BioBuz has proven that the entire chain, from deploying multifunctional structures in the sea to incorporating biodiversity enhancement as an explicit component of the business model, can function in practice. The pilot installations verified that habitat-forming species such as blue mussels can accelerate ecological recovery on artificial structures, offering a replicable pathway for transforming passive offshore infrastructure into active ecological assets.

Through scenario analyses and business model development, the project identified multiple mechanisms through which biodiversity enhancement can generate financial value, —ranging from biodiversity credits and “dark green” energy premiums to diversified aquaculture revenues and improved access to impact-oriented investment. While many of these markets remain at an early stage, the findings indicate clear potential for multifunctional, biodiversity-positive offshore wind farms to strengthen long-term competitiveness, attract sustainable finance, and enhance regulatory positioning in a rapidly evolving blue economy.

At the same time, the work highlights that biodiversity measures must build on a rigorous application of the mitigation hierarchy and be context-specific to ensure genuine ecological benefit. Effective scaling will depend on transparent verification frameworks, coherent regulatory support, and strong collaboration between research, industry, and policymakers.

Ultimately, Nordic BioBuz points toward a new generation of marine business models that move beyond minimising harm to actively restoring ecological function. This regenerative paradigm aligns with the Nordic Council’s Vision 2030 and the European Green Deal, positioning the Nordic region as a frontrunner in developing a blue economy where renewable energy, aquaculture, and ecosystem recovery thrive together.

Recommendations for future research

- » How regenerative solutions can be scaled up and adapted across different marine contexts,
- » Testing different materials as scour protection for low-trophic aquaculture/reef building and at a larger experimental scale with more replicas, including more kinds of material and at more exposed conditions
- » Testing the biodiversity index on a longer time horizon, and iterate continuously for specific locations
- » Automation of underwater monitoring to make biodiversity assessment and verification more efficient and scalable.
- » Explore the dynamics of the nascent markets emerging around ecosystem services and biodiversity credits, aiming to design business models that are not only feasible and viable, but also desirable and regenerative.
- » By advancing both the technological and financial dimensions, future work can bridge the gap between experimental pilots and widespread implementation.

Appendix

Nordic Added value and recommendations for future investigations

The project explored nature-based solutions designed for integration with offshore windmill foundations and scour protection around both foundations, with the goal of enhancing positive impacts on local marine ecosystems. Based on the project's results, we have taken initial steps towards evaluating and developing a biodiversity crediting system adapted to the Baltic Sea context. The business model blueprint includes estimations of biodiversity credits generated through positive impacts from both algae and mussel farming practices, as well as how to incorporate positive enhancement effects in multiple ways into the business model. The validation and proof of concept of such a system and a business model incorporating biodiversity credits provides a foundation for further development in other Nordic regions. In this way, biodiversity and nutrient credits—and their various ways of being included in sustainable business models, can be, and needs to be, adapted to local ecological and regulatory contexts, and hopefully become mainstream practice depending on the nordic market development.

The added value of cross-Nordic cooperation lay in the pooling of resources, expertise, and transdisciplinary approaches. While the work could have been carried out within one country, we found that involving multiple Nordic nations created greater legitimacy, broader relevance, and stronger capacity to address shared environmental and industrial challenges. Collaboration across borders strengthened the consortium and increased the reach and uptake of project results.

Realization of Regional and Global Goals

The project contributed to fulfilling the three overarching goals of the Nordic Council of Ministers' Vision 2030:

A Green Nordic Region – by advancing knowledge on how to develop offshore wind with minimal environmental impact.

A Competitive Nordic Region – by piloting frameworks for innovative business models and exploring how offshore wind foundations can enhance marine biodiversity, strengthening Nordic leadership in this emerging field.

A Socially Sustainable Nordic Region – by fostering collaboration between Nordic countries and applying transdisciplinary methods that strengthened shared competence and capacity.

The project also supported the EU Mission “Restore our Ocean and Waters”, particularly Objective III: Making the sustainable blue economy carbon-neutral and circular, in alignment with the European Climate Law and the Sustainable Blue Economy Strategy. The project contributed by adopting a holistic systems perspective and by developing knowledge and tools to promote sustainability and regenerative business modelling within offshore industries.

Finally, the project primarily contributed to the following UN Sustainable Development Goals (SDGs):

SDG 7: Affordable and Clean Energy – by identifying ways to make offshore wind development more environmentally and climate-friendly while exploring new business models.

SDG 9: Industry, Innovation and Infrastructure – by supporting innovation in offshore infrastructure and the development of nature-positive business frameworks.

SDG 14: Life Below Water – by testing solutions with potential to increase marine biodiversity and enhance ecosystem services such as fisheries.

Communication

Goals and Purpose

At the beginning of the BioBuz project, the consortium developed a **Communication Plan** to

guide all external communication activities. The plan defined shared objectives, target audiences, responsibilities, and key messages, ensuring that all partners communicated in a coherent and coordinated way throughout the project. The communication activities were designed to ensure that the project's results and messages reached a broad range of audiences in an open, transparent, and inclusive manner.

The overall purpose of the communication work was to:

- align partners around common messages and coordinated external communication.
- raise awareness of the BioBuz project and its partners among relevant stakeholders across the Nordic and Baltic regions.
- share progress and results continuously throughout the project period.
- highlight the innovative potential of biodiversity credits and nature-positive business models.

The main messages of the BioBuz project were:

- BioBuz promotes actions to mitigate climate change, increase biodiversity, and reduce eutrophication.
- BioBuz develops innovative offshore multi-use business models, including the use of biodiversity credits.
- BioBuz builds new value chains from low-trophic aquaculture in the Baltic Sea.

Keywords: *#nordicinnovation #multiuse #BalticSea #offshorewind #biodiversitycredits*

Stakeholder Dynamics and Engagement

At the beginning of the BioBuz project, a stakeholder analysis was carried out to identify key external actors and to structure the project's outreach strategy. The analysis covered a broad spectrum of audiences from research institutions and public authorities to investors, NGOs, and local partners on Åland and across the Nordic region. This early mapping formed the basis for a targeted communication approach, ensuring that messages and channels were adapted to the needs and interests of each group. The initial stakeholder categories included:

- **Research and academia**, such as universities in Sweden, Finland, and Norway (e.g. SLU, Åbo Akademi, University of Gothenburg, RISE), with interest in nature-based solutions, biocredits and low-trophic aquaculture.
- **Local stakeholders and partners**, including Åland authorities, NGOs, private companies with focus on practical implementation, ecosystem restoration and social acceptance.
- **Policy makers and public officials** from ministries and agencies in Finland, Sweden, and Åland, engaged in marine spatial planning, environmental policy and regulation of multi-use marine areas.
- **Financial institutions and investors** exploring the potential of biodiversity credits and nature-positive business models.

As the project progressed, the stakeholder landscape broadened and matured. During 2024–2025, interest gradually expanded beyond the initial local and research networks to also include Nordic and European industry actors, innovation clusters and investors interested in scalable and measurable biodiversity solutions. BioBuz positioned itself as one of the first Nordic projects exploring biodiversity and aquaculture integration in a multi-use offshore wind context. Stakeholder engagement was thus both dynamic and reciprocal: the project continuously adapted its messages based on feedback and emerging interests, while stakeholders contributed with perspectives, data and visibility that strengthened BioBuz's relevance and impact.

Articles, Media, and Public Outreach

The external communication combined formal channels (articles, reports, conferences) with informal and public accessible formats (social media and storytelling), aiming to reach both expert and general audiences.

Articles and News Features

Selected articles and updates were published during the project period to highlight BioBuz activities, key findings and the broader context of biodiversity-positive offshore innovation.

- “Nordic BioBuz explores biodiversity credits in offshore wind” – published on **Carbon Pulse** (August 2024): [link](#)
- Articles and updates were also published on partner websites and LinkedIn, featuring the **Björkskär test site, low-trophic aquaculture, and multi-use business models throughout the project.**
- The project was presented in the **Björkskär Annual Report 2024**, which summarised the practical test results and their implications for future offshore projects.

Social Media Activities

Social media served as an effective and low-threshold platform for project communication, especially through **LinkedIn**. Regular updates were shared by the partners, highlighting fieldwork, results and partner achievements.

Delivered posts included:

- September 2024: Submariner Network mention and field season reflections
- October 2024: Fieldwork update
- November 2024: Continued fieldwork post
- December 2024 – January 2025: Arctic Frontiers and start of new season
- March 2025: European Ocean Days and Mission Restore our Oceans and Waters
- March 2025: Pioneering a multi-use ocean economy for a nature-positive future
- April 2025: Start of field season
- May 2025: Project results and partner highlights
- June 2025: Field work update
- July 2025: The now and the future of Nordic BioBuz
- October 2025: Wrap-up update and closing of data collection

These posts reached audiences well beyond the immediate project circle and helped position BioBuz within a broader Nordic innovation context.

Conference Presentations

BioBuz partners actively contributed to knowledge exchange by presenting the project in several Nordic and European forums:

- September 2024: Nordic Innovation’s Conference on Co-existence, Malmö
- October 2024: Cool Blue / Havshoest Nordic Network Meeting at Tvärminne
- October 2024: Submariner Network’s Members Assembly and 10-Year Anniversary in Berlin
- November 2024: ProMission BANOS Conference, Amsterdam
- Jan 2025: Beyond Borders Conference. Arranged by Arctic Frontiers. Tromsø
- April 2025: Att bygga affärer med regenerativa affärsmodeller. Biodiversity and Business Conference arranged by Dagens Industri and Aktuell Hållbarhet, Stockholm
- May 2025: Nordic BioBuz Project presentation at C2B2 Innovation Talks 2025, online
- May 2025: Havsvindsforum i Göteborg, Green Power Sweden, Göteborg
- October 2025: Ekosystemsbaserad Havsförvaltnings frukostseminarium online

- October 2025: Innovative business models for multi-use/Samexistens för ökad sjömatproduktion Innovatum Science Park Webinarium

These presentations focused on the role of BioBuz as a practical test platform and conceptual model for biodiversity enhancement and multi-use offshore development.

Final online seminar

The final online seminar of the Nordic BioBuz project was held on 20 November 2025 as an online event, gathering 70 partners and experts to present key results and reflections. The event highlighted how offshore wind, low-trophic aquaculture and ecosystem-enhancing measures can be combined to create regenerative value in the Baltic Sea. Presentations covered prototype testing by Under Ytan and Nemo Seafarms, biodiversity and nutrient compensation models by SLU, and business model development by RISE. Invited commentators, including experts from the Swedish Biocredit Alliance, Ålandsbanken and the University of Gothenburg, reflected on the potential of biodiversity credits and multi-use approaches to support a sustainable blue economy.

Visits to Björkskär

Field visits to Björkskär played a central role in the BioBuz project's communication and stakeholder engagement. The island served as both a symbolic and practical meeting point where partners, researchers, policymakers, and investors could experience the test installations and discuss the broader vision of integrating biodiversity into offshore wind and marine multi-use development.

Kick-off Meeting at Björkskär

The BioBuz project officially began with a kick-off meeting at Björkskär in the Åland archipelago in June 2024. The event combined presentations, workshops, and site visits to the first biodiversity test structures. Participants included representatives from the project partners OX2, Under Ytan, Nemo Seafarms, RISE, and SLU.

The purpose was to create a shared understanding of objectives. The visit helped align the project consortium and inspired many of the communication materials and visual storytelling used later in the project.

Stakeholder Meeting at Björkskär

In July 2025, BioBuz organised a stakeholder meeting at Björkskär. The event gathered around 20 participants, including representatives from Nordic Innovation, Ålandsbanken, Swedish Biocredit Alliance, Qarlbo Biodiversity, and the project partners.

The programme included boat transport to the island, a guided tour of the pilot installations, and presentations of findings from the different work packages. Discussions focused on the integrated business model for offshore multi-use platforms, biodiversity credit frameworks, and scaling up future cooperation and funding opportunities.

The atmosphere was open and forward-looking, with many participants expressing a strong interest in continuing collaboration beyond the BioBuz project. The visit was also covered in internal communication and partner channels, reinforcing the project's visibility across the Nordic innovation landscape.

Evaluation

Communication was an essential part of the BioBuz project, both for visibility and for creating dialogue between research, industry, and policy. The overall approach – combining scientific dissemination, public storytelling, and partner-driven social media – proved effective in reaching diverse audiences and stimulating discussion about biodiversity in offshore multi-use contexts.

The communication objectives outlined in the initial plan were largely met.

The project and its partners achieved strong visibility within the Nordic innovation ecosystem.

The Björkskär visits and conference presentations provided concrete opportunities for engagement and networking.

Regular social media updates helped maintain continuity and reach audiences beyond the consortium.

Continuation Beyond the Project

The communication work will continue after the end of the BioBuz project through:

- Partner channels, including websites and LinkedIn posts by OX2, Nemo Seafarms, and Under Ytan.
- The Björkskär platform, which remains active as a semi-offshore test site for biodiversity and aquaculture research.
- Follow-up initiatives, such as the planned BioBuz 2.0 development and continued exploration of biodiversity credits in offshore wind contexts.
- Public dissemination, including preparation of scientific papers and contributions to Nordic and EU conferences.

In this way, BioBuz communication will not end with the formal project closure but will evolve into a continuing story of collaboration, learning, and innovation across the Nordic blue economy.

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