OCEAN MULTI-USE ROADMAP



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1 Introducing ULTFARMS

UNITED Project 2020 - 2023

ULTFARMS builds on the outcomes of UNITED, a Horizon 2020 project that demonstrated how co-locating offshore wind, aquaculture and tourism can create economically viable, socially beneficial and environmentally sustainable multi-use solutions for Europe's maritime sector and coastal ecosystems.

UNITED Project website

Coordinated by Deltares, it ran five pilots across **Belgium, the Netherlands, Germany, Denmark, and Greece,** organised around five pillars: technology, economy, legal and governance, society, and environment. Two of its pilots, in Belgium and Germany, are direct predecessors to ULTFARMS' own sites.




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While UNITED demonstrated the potential of multi-use at sea, ULTFARMS took the next step by focusing specifically on low-trophic aquaculture in offshore wind farms and testing how such systems can be planned, operated, monitored and scaled under real offshore conditions.

Ocean Multi-Use Commercialisation Roadmap

UNITED's outputs, notably the UNITED Blueprint for Offshore Site Operation and the Ocean Multi-Use Commercialisation Roadmap, laid the foundation for addressing licensing, governance and business model challenges associated with ocean multi-use. **The following sections highlight how ULTFARMS builds on these achievements and advances the state of practice.**

Blueprint for Offshore Site Operation

ULTFARMS Objectives

Optimising Low-Trophic Aquaculture in Challenging Offshore Conditions

- **The Mission:** Advance seaweed and shellfish (mussel and oyster) production systems within offshore wind farms across the North and Baltic Seas.
- **The Approach: Bridge engineering, ecology, and biology** to build a fully sustainable production chain.

Project Overview

Timeline: 46 Months (2023-2026)

Lead: Deltares

Network: 25 partners from 9 countries



6 Offshore Pilots

Belgium: Belwind
Germany: FINO2 Platform
Germany: FINO3 Platform
Denmark: Samsø Offshore Wind Farm
Denmark: Anholt Offshore Wind Farm
Netherlands: Depth-Adjustable Submersible Mussel Farm in Borssele III

5 Associate Regions

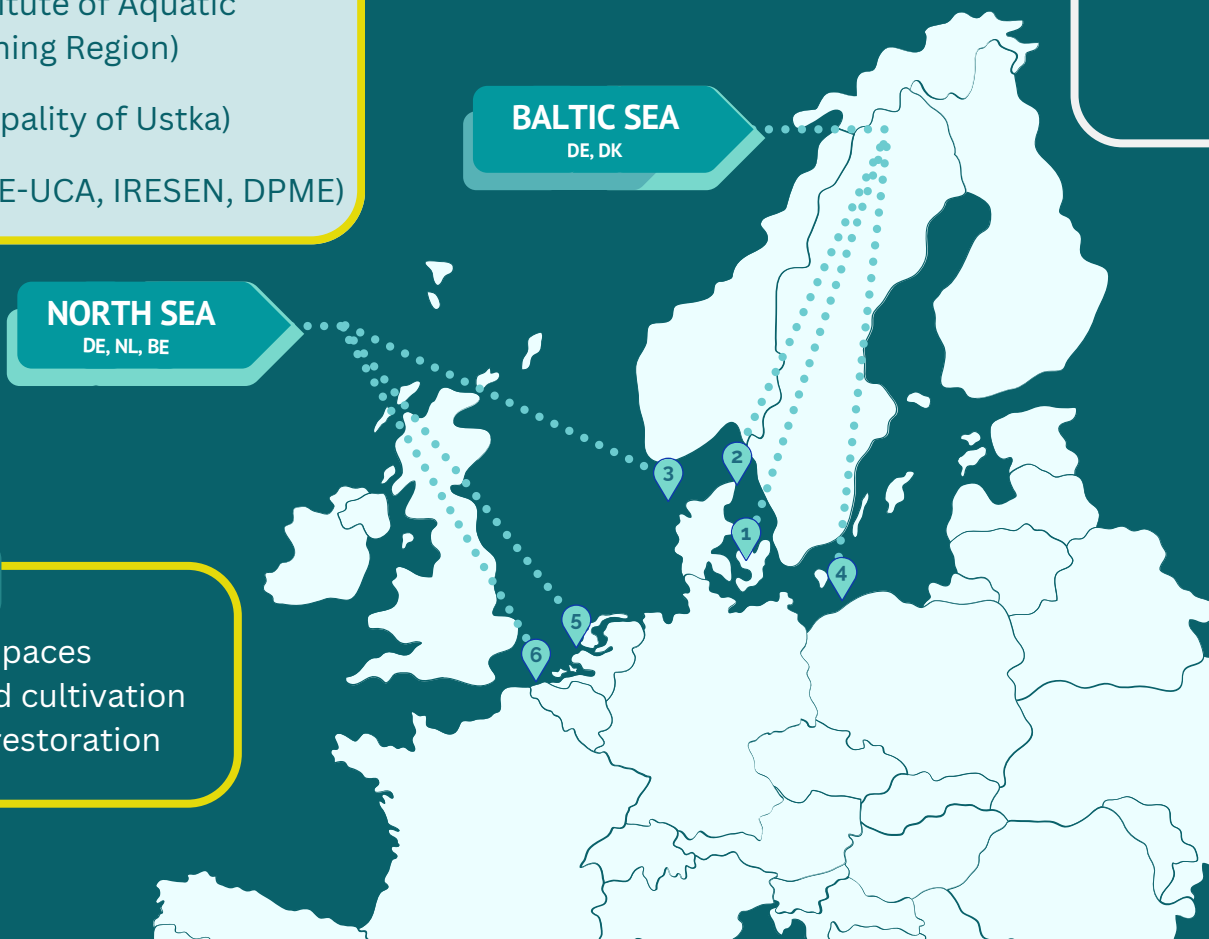
Wales, UK: CoSARIS (Bangor University)

Tunisia: SELIMA (INSTM, SEA-GUST, MEDORA)

Latvia: SymbioSea Baltic (Riga Technical University, Latvian Institute of Aquatic Ecology, Kurzeme Planning Region)

Poland: ULTAN (Municipality of Ustka)

Morocco: FLOWM (ESTE-UCA, IRESEN, DPME)



Core Focus

- multi-use ocean spaces
- bivalve & seaweed cultivation
- nature-inclusive restoration

Creating Legacy & Impact

- **Knowledge Hub:** Generated comprehensive data on sustainable, low-trophic aquaculture.
- **Actionable Assets:** Translated findings into practical guidance and strategic recommendations.
- **The Goal:** Lower market entry barriers and deliver immediate "keys to success" for short-term replication.

Innovation Testing

- Submersible cultivation trials for harsh environments.
- Advanced sensors and cameras for remote offshore monitoring.

Building Viable, Sustainable, and Innovative Outcomes

The project developed practical solutions and guidance for low-trophic aquaculture within offshore wind farms, aiming to optimise the use of marine resources, reduce environmental footprints, and monitor impacts on marine ecosystems.

This roadmap translates those lessons into standalone thematic roadmaps to support follow-up, upscaling and replication.



Who is this for?

Policymakers:
To streamline complex regulatory and licensing processes.

Industry Stakeholders:
To inspire cross-sector collaboration and commercial investment.

Research Institutes:
To promote and build upon sustainable marine practices.

How to Read This Roadmap

The roadmap provides detailed insights and recommendations for advancing sustainable low-trophic aquaculture practices. It is structured into standalone sections covering: licensing, operations and maintenance, finance and funding, monitoring and indicators, upscaling & commercialisation, advancing eco-friendly productivity, lessons learned, and the way forward.

Read all project details on the website

2 Licensing

Introduction

This thematic roadmap summarises ULTFARMS' licensing insights.

The Core Requirement: Low-trophic aquaculture in licensed offshore wind farms requires clear agreements or permissions on roles, safety and environmental conditions.

Safety & Compliance: Each added use (such as seaweed or mussel farming) must be authorised to protect safety, nature, and day-to-day wind farm operations.

Roadmap Focus:

- Why structured licensing matters
- Common bottlenecks that slow down projects
- Practical solutions that help in reality
- A concrete example that reduces uncertainty for applicants and authorities alike

Why This Matters

Determines project viability: licensing decides whether multi-use projects can proceed at all.

Reduces risk: predictable rules let developers plan investment with less risk and administrative burden.

Ensures consistency: clear frameworks help authorities assess applications consistently.

The cost of inefficiency: fragmented or lengthy permitting delays or discourages multi-use investment.

The big picture: improving licensing unlocks co-location at sea without lowering safety or environmental standards while reducing avoidable administrative effort.



Pathways

Overcoming lengthy processes: Multi-use projects can face slow, complex licensing when several authorities and licences are involved.

- *Example*: In one German pilot, obtaining the necessary licences took 6 years and involved 26 people across 5 licensing agencies. This points to a wider challenge: the wind farm, the aquaculture activity and any additional installations often each need separate licences.

The "one-stop-shop" solution: Giving applicants a single lead contact allows authorities to coordinate their input through one joined-up process.

- *Example:* Denmark uses a coordinated process where several authorities provide input together, simplifying administration and boosting developer confidence**.**

Standardising Evidence Requirements: Authorities need proof that multi-use projects are safe and environmentally sound, but developers often cannot tell what evidence is "sufficient" for these new combinations, and authorities are often unfamiliar with them too

- *A practical fix:* the lead licensing authority co-develops a shared checklist with developers, wind farm operators, aquaculture operators and assessors, updated as more sites are assessed.

Simplifying Site Rules: early project development is often time-consuming and costly because requirements vary wildly by country and site.

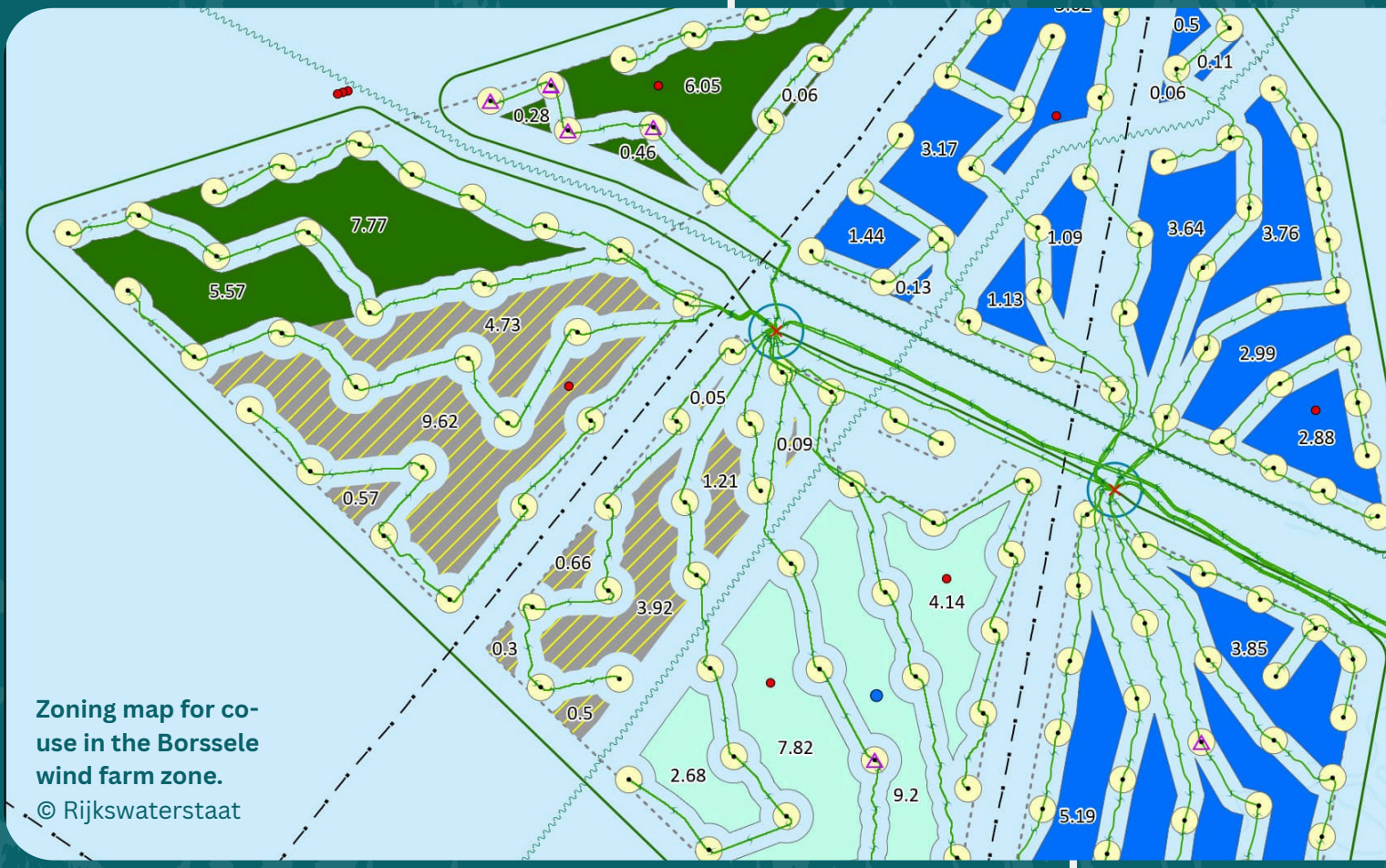
- *A practical fix:* This "early clarity check" is easiest when planning documents explicitly state:
  - Whether multi-use is allowed
  - Which activities are acceptable in principle
  - Which authority leads the permitting route

The Dutch "Area Passport" model:
The Dutch "Area Passport" maps a wind farm's layout, cables and safety zones to show where co-use is possible and which activities suit each area.

Example: The Depth-Adjustable Submersible Mussel Farm in the Borssele III wind farm used it as a shared basis for agreeing spatial preconditions, access rules and responsibilities before deployment, reducing uncertainty for both developers and assessors.



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Zoning map for co-use in the Borssele wind farm zone.
© Rijkswaterstaat

The Way Forward

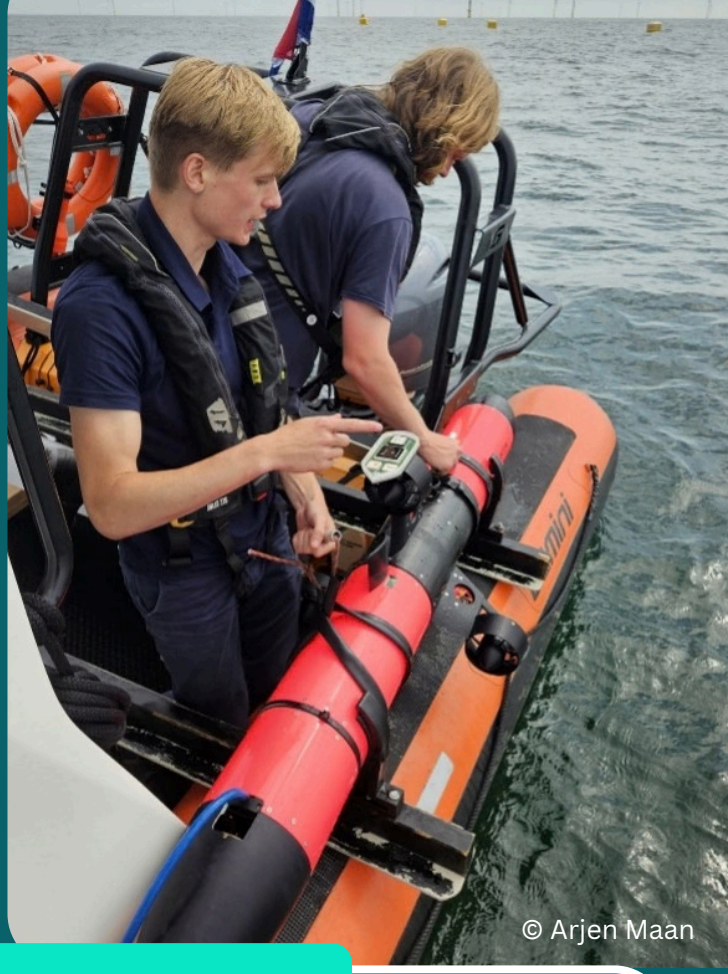
To strengthen multi-use licensing, policymakers need to move beyond general references in Maritime Spatial Plans and provide clarity on where multi-use is possible, under what conditions, and through which procedures.

1. **Make multi-use spatially specific:** Publish clear maps with zones for multi-use that show where it is encouraged, where it is possible with conditions, and where it is not allowed. These area-based assessments should identify key constraints and suitable options before applications start, so developers and authorities share a starting point.

2. **Make the route predictable:** Set one coordinated licensing route with a single lead authority or contact point, so applicants do not have to manage multiple parallel processes without guidance.

3. **Make evidence reusable:** Competent licensing authorities should allow relevant baseline data and earlier assessments to be reused where site conditions and risks are comparable, using shared templates so applicants do not rebuild the same evidence from scratch.

As countries update their Maritime Spatial Plans and licensing practices, these steps can be embedded early, including where new plans are being developed. This can help multi-use move from “possible in principle” to “clear in practice”. Taken together, they reduce uncertainty, maintain appropriate oversight, and make licensing for multi-use more efficient and supportive of the EU’s blue economy.



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Historical Note: Building on UNITED

ULTFARMS' co-management approach to licensing builds on findings from UNITED, and the German pilot carried over licensing experience and agency contacts first built during UNITED.
OLAMUR, a parallel Horizon Europe project on offshore multi-use aquaculture running to 2026, documented its own licensing routes for comparison, including a first-of-its-kind German application that required the licensing authority to establish a new legal basis before it could even be assessed.

Further Reading

ULTFARMS Deliverables:

- D4.2 Offshore implementation and process description
- D9.3 Governance bottlenecks to multi-use

OLAMUR Deliverables:

- D1.1 Offshore implementation and process description
- D2.2 Micro-siting criteria and mapping of co-location scenarios within pilots
- D7.2 Comparative report of governance systems in the Pilots

3 Operations & Maintenance



Introduction

Low-trophic aquaculture in offshore wind farms combines seaweed and/or mussel farming with renewable energy. Operations and maintenance keep people safe, equipment working, and day-to-day activities aligned with wind-farm access rules.

This thematic roadmap showcases the operations and maintenance insights learned during the ULTFARMS project by sharing:

- what needs to be organised
- what ULTFARMS pilots learned in practice,
- how needs differ by sea area,
- an example of how one pilot adapted after a setback.

Why This Matters

Offshore sites face wind, waves, currents, migrating bedforms, and limited access. Without regular checks and timely repairs, lines, anchors, and floats can fail, creating safety risks and downtime. Good planning operations and maintenance means:

- agreeing on access and safety rules with the wind farm operator,
- using suitable vessels and lifting gear,
- scheduling work inside available service windows.

Doing this well protects people and equipment, reduces downtime and builds trust between stakeholders.





Lessons learned

Routine operations and maintenance

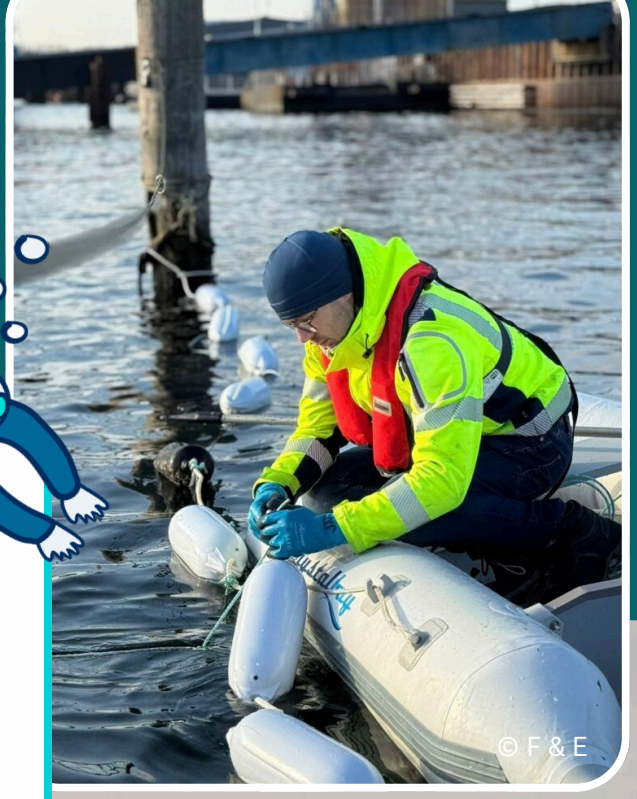
- Core tasks across ULTFARMS pilots: inspections (divers where allowed, or underwater drones), removing marine growth, and replacing worn parts.
- Offshore work needs a workboat with lifting gear and deck space, plus trained crews, clear work procedures, and bad-weather backup plans.
- Because site time is limited to wind farm service windows, joint trips should be planned early and vessels shared where possible to cut cost and delay.

Regional Strategies

- **North Sea:** higher waves and stronger winds call for sturdier equipment and tighter weather planning; German pilots used heavy anchors and strong mooring lines to limit movement and damage.
- **Baltic Sea and calmer basins:** smaller boats and lighter gear can be enough, allowing shorter, more frequent trips.
- Tasks are similar everywhere; the timing differs, from quick visits in calm water to fewer, carefully timed visits in rough seas.

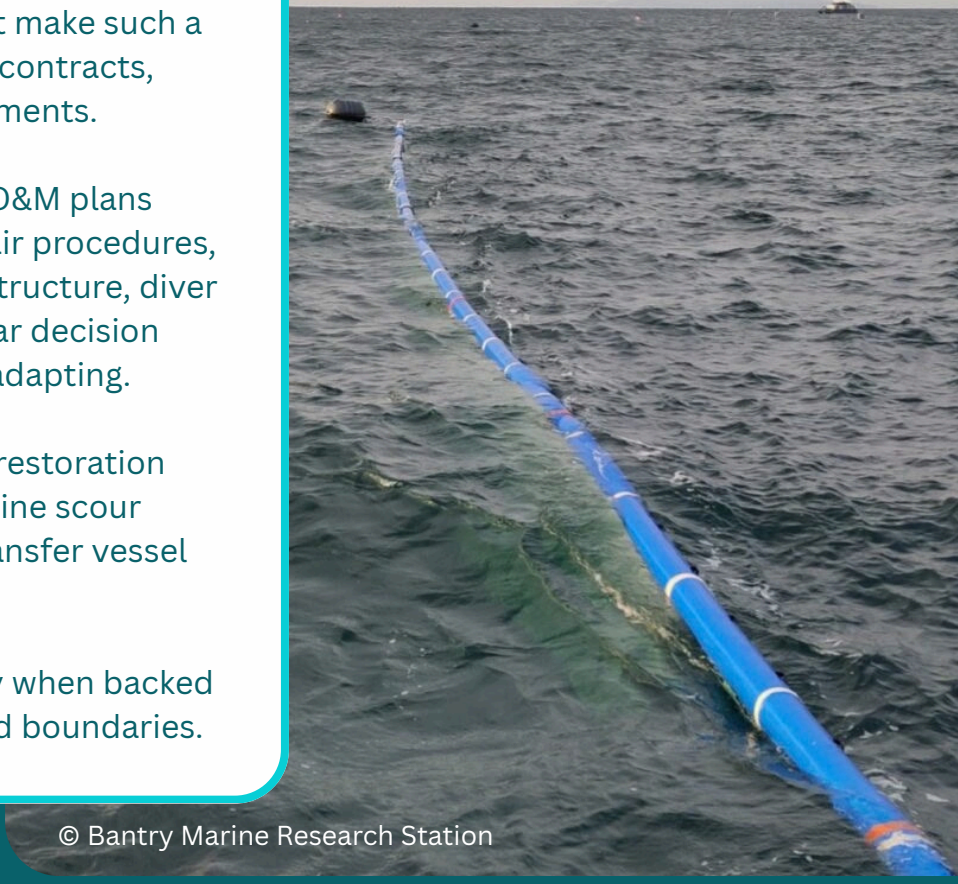


Lessons learned: Belgian Pilot Example



Contingency Planning

- A mooring failure at the Belwind site forced a move to the partly exposed Bantry Marine Research Station in Ireland, where the submersible longline survived several severe storms over the 2024 to 2025 winter.
  - A commercial farm could not make such a shift without prior planning, contracts, licences and market arrangements.
- Build contingency options into O&M plans before deployment: agreed repair procedures, alternative use of existing infrastructure, diver and vessel access rules, and clear decision points for pausing, repairing or adapting.
  - For the Belgian pilot, oyster restoration tables were installed on turbine scour protection, avoiding crew transfer vessel areas and cable zones.
- ***Key lesson:*** flexibility works only when backed by clear planning and pre-agreed boundaries.


© Bantry Marine Research Station

Historical Note: Building on UNITED

The submersible longline design used in the Belgian and German pilots was first developed and installed under UNITED; ULTFARMS adapted it for commercial-scale mussel and seaweed cultivation.

The Way Forward

Plan jointly, not separately

To scale up multi-use projects, operations and maintenance must become predictable and easier to organise across sites. This requires clear agreements between aquaculture and wind farm operators on access, safety, and responsibilities, so activities can be planned jointly rather than separately.

Reflect offshore realities

In practice, planning needs to better reflect offshore realities. Weather, long travel distances, and limited vessel availability often delay work, so projects need realistic time buffers and alignment with available service windows. At the same time, site layout and access must be considered from the start. Aquaculture systems should be designed in a way that keeps clear corridors for vessels to reach turbines, ensuring that wind farm operations are not affected.

Share resources, standardise procedures

Efficiency can then be improved by sharing resources and aligning schedules, for example, by using vessels that can support several tasks in one trip, such as inspections, small repairs, lifting, transport and monitoring. In parallel, standardising basic procedures – such as inspections, repairs, and safety checks – helps make operations repeatable and easier to scale.

Reduce the need for offshore visits

This will matter increasingly. Sensors, cameras and underwater devices can support inspections and remote monitoring, making operations safer and less dependent on short weather windows.

Further Reading

ULTFARMS Deliverables:

- D3.2 Design, numerical modelling of a submersible longline
- D3.3 Design and implementation of mariculture structures
- D3.4 Sensor technology design
- D4.1 Design, adaptations for deployment in offshore regions
- D10.2 Technical innovation for LTA implementation within OWF

OLAMUR Deliverables:

- D1.2 Guidelines for safe multi-use operations
- D5.2 Service tools delivery

4 Finance & Funding

Introduction

Low-trophic aquaculture in offshore wind farms combines food production and renewable energy in the same marine space. Growing this sector needs further development of farm systems, monitoring tools, data services, consultancy and environmental assessment methods.

This thematic roadmap looks at how finance and funding can help these innovations move from project-based development to uptake, scale-up and market readiness, matched to each innovation's maturity and potential.

Why This Matters

ULTFARMS' results range from market-ready innovations to non-commercial and policy-oriented tools, so no single funding model fits all. The four prioritised key exploitable results align with wider sustainability goals, strengthening their case for both public and sustainable finance.

Technical success alone is not enough. Scale-up depends on design guarantees, lower investor uncertainty and clear offtake conditions: who buys the biomass, at what volume, quality, timing and price. Without this clarity, even strong technology scales slowly.



UN SDG 9: Industry, Innovation and Infrastructure
ULTFARMS KER: Innovation

UN SDG 12: Responsible Consumption and Production
ULTFARMS KER: Responsible production

UN SDG 13: Climate Action
ULTFARMS KER: Climate Action

UN SDG 14: Life Below Water
ULTFARMS KER: Life Below Water

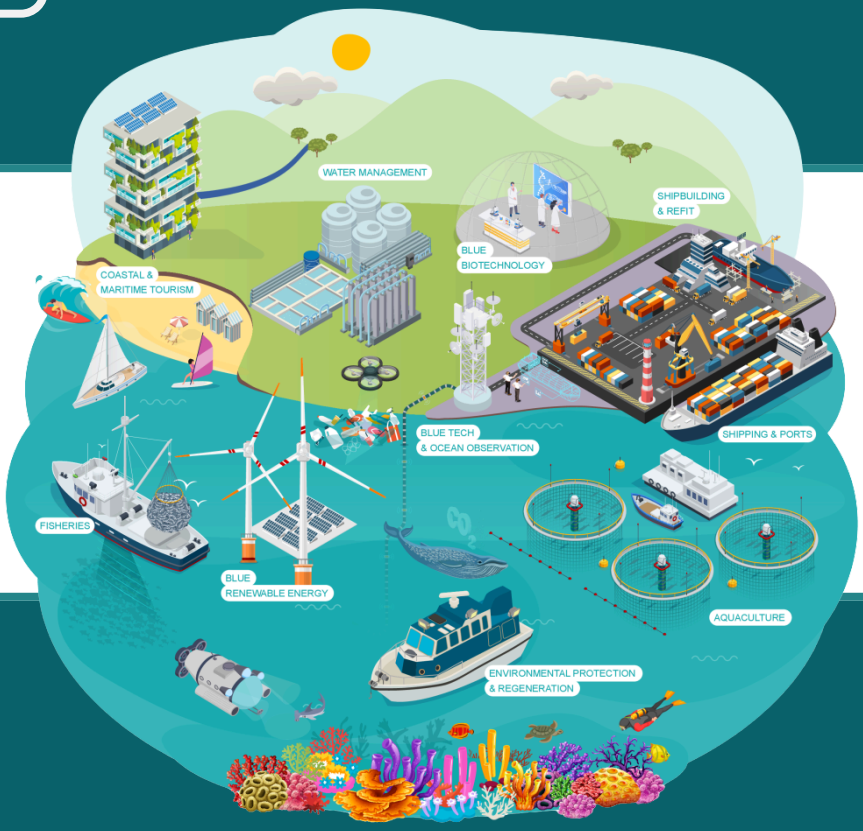
Pathways

Early stage: cascade funding
Also known as Financial Support to Third Parties, this model sees the European Commission fund a larger EU project, which redistributes part of its budget through open calls, usually to SMEs, start-ups and scale-ups. For offshore multi-use, it supports targeted testing, early digital tool use, small-scale validation and collaboration between developers and operational partners, making it well suited to early-stage proof of performance, users and value.

Later stage: diversified funding
In practice, scale-up follows a sequence: public funding to test and reduce risk first, then investment support and private finance for deployment, operation and replication.

Type of output	Likely funding route
Technologies/services with clear market potential	Innovation funding, investment support, private capital
Scientific knowledge, monitoring methods, environmental assessments, policy recommendations	Research, environmental and policy programmes

BlueInvest, a European Commission initiative, supports this transition through coaching, networking, matchmaking and market intelligence, helping blue economy start-ups and scale-ups build investment readiness.

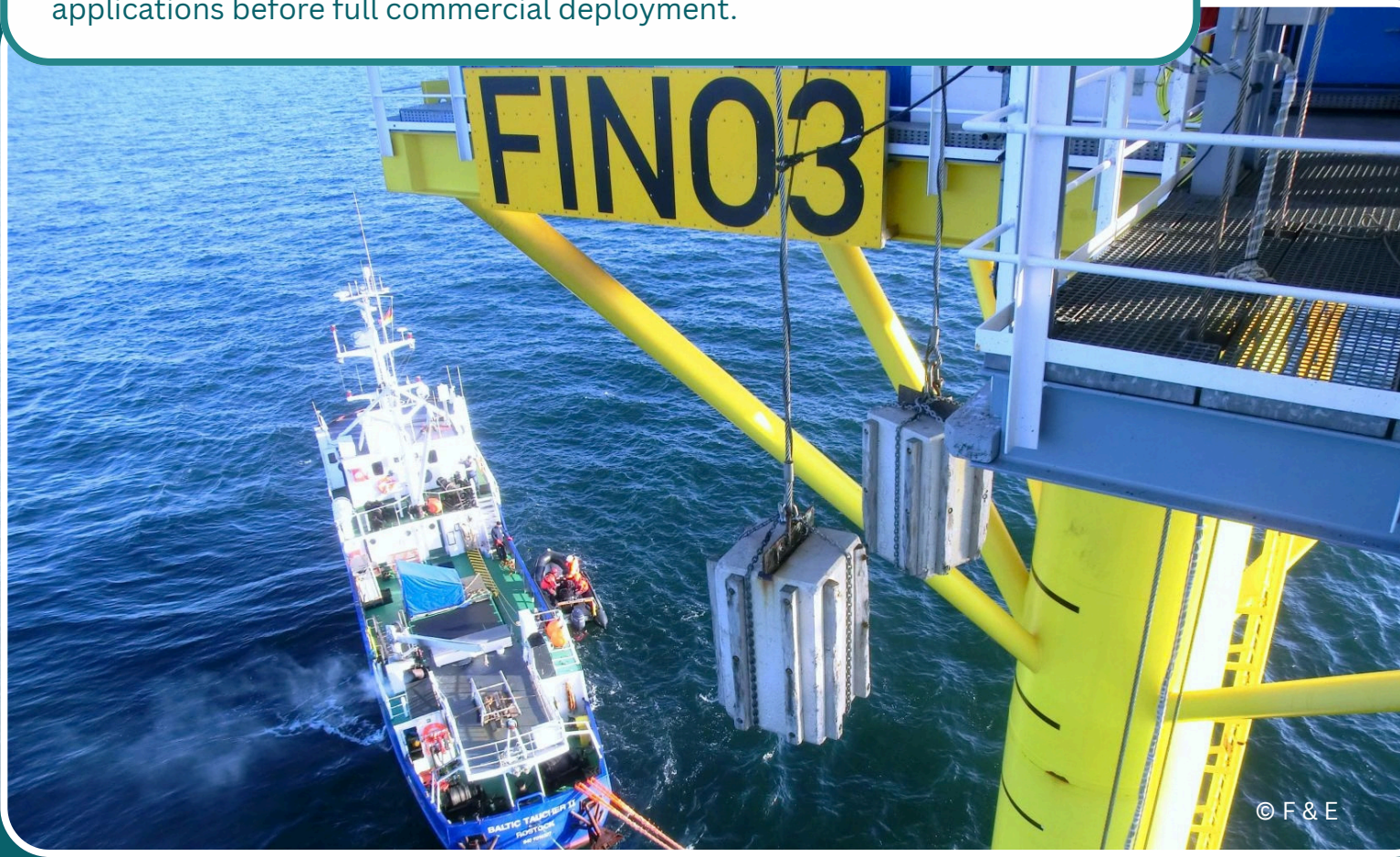


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A Working Example:

A useful example from the project is the development of offshore consulting services based on pilot experience. Expertise on farm design, anchor installation, vessel layout, environmental assessment, licensing, insurance and legal issues is being shaped into an integrated service for future developers, showing that research-based knowledge can already support new offshore applications before full commercial deployment.



Historical Note: Building on UNITED

The German pilot's business case builds on a feasibility study for commercial multi-use, first developed during UNITED and updated since; UNITED partners' market and licensing connections in Germany carried over directly into ULTFARMS.

The Way Forward

Blended finance and bankability:
Public support remains essential for innovation, testing and early uptake, but long-term replication needs this combined with finance suited to commercial growth.

What unlocks bankability:

- Clear ownership and reliable insurance arrangements
- Stronger design guarantees and better risk data
- Certainty on revenue models and market uptake
- Clear access rights and protection strategies for results, technologies, data and know-how; unresolved IP questions can delay licensing, investment and commercial agreements

What funding strategies should cover:
Not just physical infrastructure (cultivation lines, anchors, floats, moorings), but also monitoring, digital support, compliance, consultancy and environmental services, plus the arrangements needed to protect and use these results in practice.

What could strengthen investor confidence further:
Incentives linked to ecosystem benefits, and stronger integration of multi-use into planning and tenders.

The core message:
Finance and funding for offshore low-trophic aquaculture are not only about access to money. They are about creating the legal, commercial and operational conditions that make scale-up investable.

Further Reading

ULTFARMS Deliverables:

- D5.1 Exploitation and business plan
- D5.3 Final KERs business plans
- D7.3 Sustainability goals of business models

OLAMUR Deliverables:

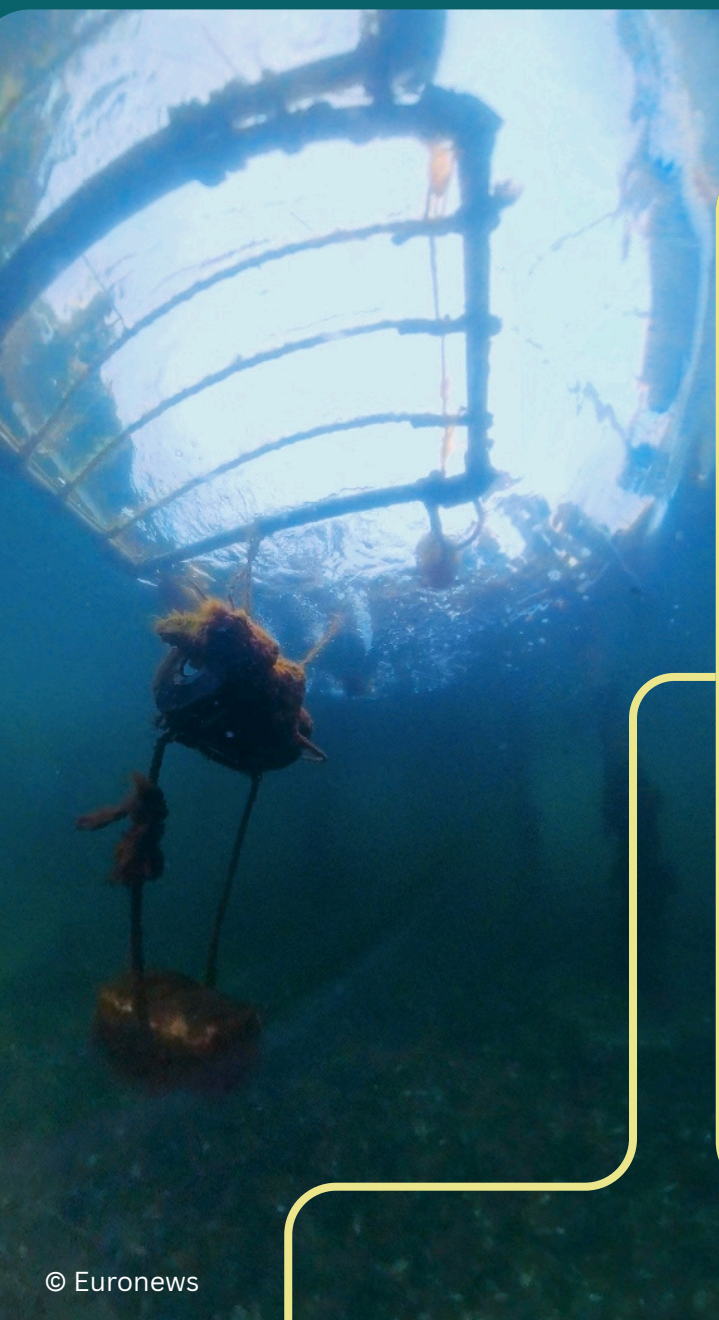
- D1.4 Economic data for investment & upscaling

5 Monitoring & Indicators

Introduction

Low-trophic aquaculture in offshore wind farms combines renewable energy and seafood production but needs careful monitoring to protect ecosystems and ensure farm performance. ULTFARMS implemented monitoring across pilot sites, covering environmental conditions (water quality, seabed ecology, biodiversity) and farm performance (growth, yield, equipment condition).

This thematic roadmap explains why monitoring and indicators matter, shares ULTFARMS' best practice, highlights regional differences, and gives a case study.



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Why This Matters

Robust monitoring is essential for responsible offshore low-trophic aquaculture. It supports sustainability evaluation, early warning for risks such as harmful algal blooms, timely operational response, food safety, and farm optimisation by linking environmental conditions to growth and yield. Without it, scaling offshore aquaculture responsibly, or building trust among policymakers, investors, operators and the public, becomes difficult.

Requirements also differ between countries: Denmark, for example, has no legal requirement for continuous monitoring of bivalve mollusc and macroalgae cultivation units, beyond reporting harvested amounts and organic-certification requirements where relevant. This variation creates uncertainty; greater harmonisation could reduce administrative burden, improve comparability, and strengthen the business case for offshore multi-use.

Pathways



A robust monitoring plan has **two steps**: baseline data collection before installation, to confirm site suitability and set a reference point, followed by monitoring throughout the farm's lifetime. ULTFARMS frames ongoing monitoring around three themes:

1. **Operation**: infrastructure condition and yield
2. **Product**: quality and food safety
3. **Environment**: how the farm affects, and is affected by, environmental conditions

ULTFARMS tested remote sensors, cameras and underwater vehicles to monitor biodiversity in harsh offshore conditions, with autonomous systems proving essential when weather limits human access. Data from instruments, satellites and models feed into platforms such as HiSea, giving a user-friendly, real-time basis for operational decisions.



Fluorescence-based tools such as **FluoroProbe** help detect phytoplankton groups linked to harmful algal bloom risk. Where feasible, monitoring should trigger alerts, combining model predictions with real-time sensor data against adjustable thresholds.

Offshore multi-use also benefits from shared monitoring approaches that let data, methods and lessons be compared across projects and sea areas, as reflected in the Netherlands' MONS programme.



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ULTFARMS Policy Brief
Environmental impacts & multi-use considerations



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The Way Forward

Scaling low-trophic aquaculture needs harmonised monitoring built on a small, shared set of indicators covering operation, product and environment, so results stay comparable across pilots despite local differences.

The next step is to move from data collection to integrated data systems: pooling data from multiple sources and using analysis and alert functions to support real-time decisions and long-term planning, not just storage. Data must also be usable for non-specialists, so managers and operators can act on sensor and sampling results directly.

Finally, monitoring needs to become part of governance, not a separate technical exercise. Sharing indicators, results and alerts through common reporting and dashboard systems can build trust among regulators, operators, investors and communities, provided roles, response times and decision records are clearly agreed.

Comparing notes across projects

Join the community!

The Ocean Multi-Use Hub, hosted on BlueActionMatch, and managed by SUBMARINER Network, is where practitioners share exactly this kind of cross-project monitoring experience, among many other multi-use topics.

Blue Action Match

Further Reading

ULTFARMS:

- D3.3 Design and implementation of mariculture structures
- D3.4 Sensor technology design
- D6.1 Review of the monitoring requirements and strategies
- D6.2 Description of data flows, manuals and training materials

OLAMUR:

- D2.3 Report on the basin-scale siting potential for multi-use of LTL aquaculture, OWFs, artificial reefs, and IMTA in the North Sea and Baltic Sea
- D3.1 Data on farming productivity for different scenarios
- D3.2 Report on assessment of carbon and nutrient uptake, and quantification of ecosystem services
- D5.1 OLAMUR database and service platform
- D5.2 Service tools delivery

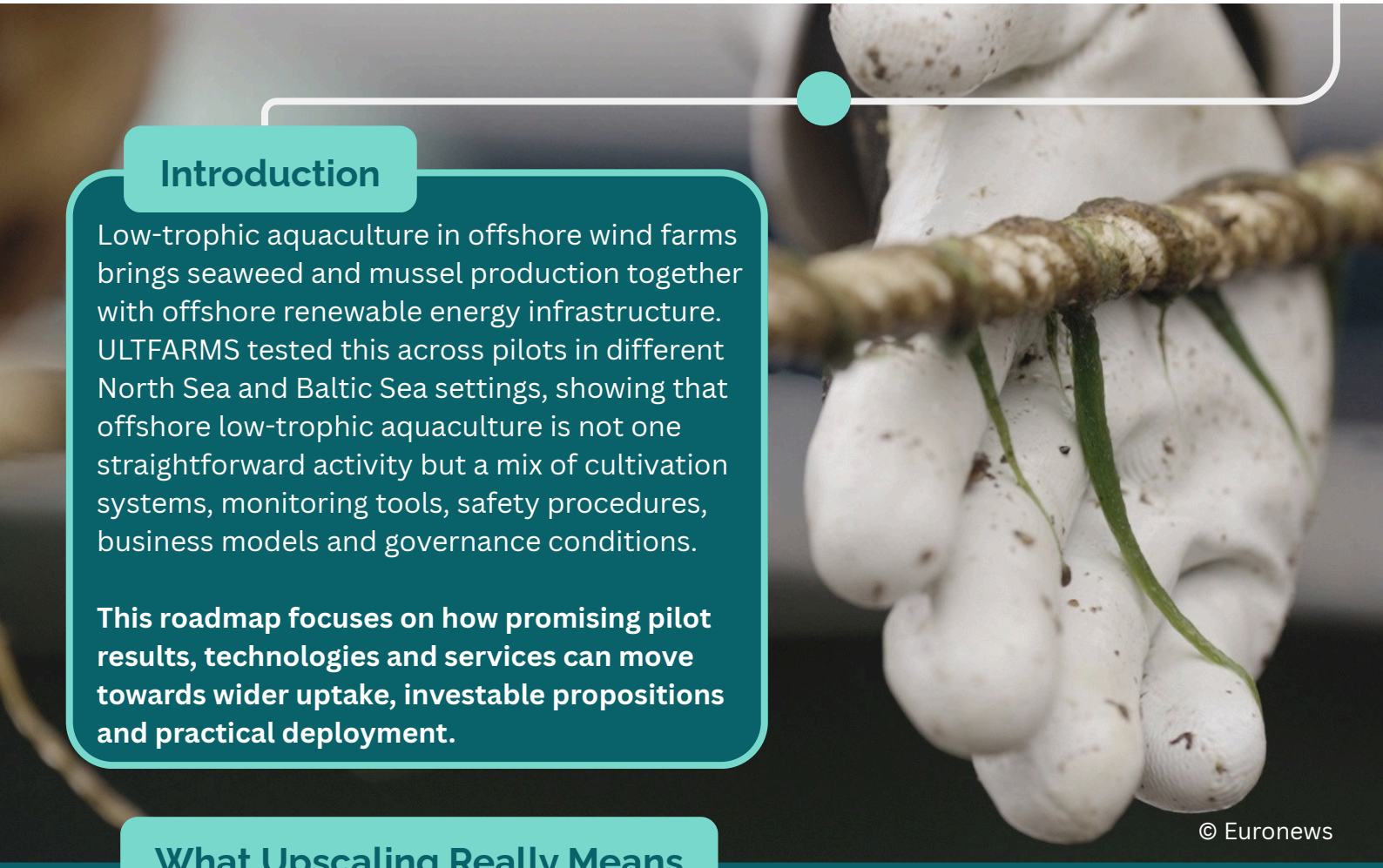


↑ Chlorophyll sensor ↓





6 Upscaling & Commercialisation



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Introduction

Low-trophic aquaculture in offshore wind farms brings seaweed and mussel production together with offshore renewable energy infrastructure. ULTFARMS tested this across pilots in different North Sea and Baltic Sea settings, showing that offshore low-trophic aquaculture is not one straightforward activity but a mix of cultivation systems, monitoring tools, safety procedures, business models and governance conditions.

This roadmap focuses on how promising pilot results, technologies and services can move towards wider uptake, investable propositions and practical deployment.

What Upscaling Really Means

Upscaling and commercialisation are not just about producing more biomass. They are about making offshore aquaculture reliable, safe, investable and acceptable, which requires:

- Cultivation systems that can operate in exposed conditions
- Clear monitoring of environmental and food-safety risks
- Better information on production volumes
- Practical business models that fit growers, wind farm operators, service companies and public authorities

Commercialisation should be understood as a staged process

ULTFARMS has identified promising exploitable results, but wider uptake still depends on further validation, clear ownership, reliable delivery models, and evidence that solutions can be repeated across sites.

ULTFARMS Policy Brief

Low-Tropic Aquaculture Value Chains

Why This Matters

Europe's expanding offshore wind creates both pressure on marine space and an opportunity to use it for more than energy. Low-trophic aquaculture can support more efficient use of that space, contribute to sustainable food, feed and biomass production, and create new roles for maritime companies, researchers and technology providers.

But commercial scale-up remains conditional. Offshore production faces harsh weather, high costs and strict safety requirements. Investors need confidence in robustness and risk management; authorities need confidence that environmental risks are controlled; consumers expect transparency and quality.

Upscaling cannot rely on technical performance alone: commercial success also depends on environmental performance, economic feasibility, licensing clarity, stakeholder acceptance and repeatable delivery.

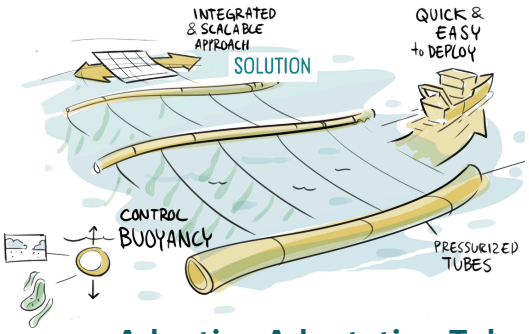
Pathways

ULTFARMS identified 18 key exploitable results (KERs); four were prioritised through Multi-Criteria Decision Analysis. These illustrate that upscaling isn not one linear route from pilot to market: it requires different validation steps, partners, business models and governance depending on the type of result.

Result	Developer	What it does	Commercial Route
Pressure Adaptive Cultivation Tubes	**Impact-9**	Makes offshore cultivation infrastructure more resilient, reducing biomass losses	Product development; needs design guarantees, standardisation, repeatable evidence
FluoroProbe	**BBE Moldaenke**	Automated in situ algae classification, including harmful algal bloom risk groups	Market uptake as a monitoring tool; supports food safety and harvest planning
Bivalve Biomass Quantification	**VLIZ**	Uses multibeam echosounder data to estimate biomass on dropper lines, reducing manual & diver inspection	Service-based, with potential for future software/dashboard development
Snap Your Algae	**F&E**	Image-based phenotyping for standardised macroalgae trait measurement	Strongest near-term value in research and breeding; wider commercial use depends on market development



Detailed overview of the 4 KERs above

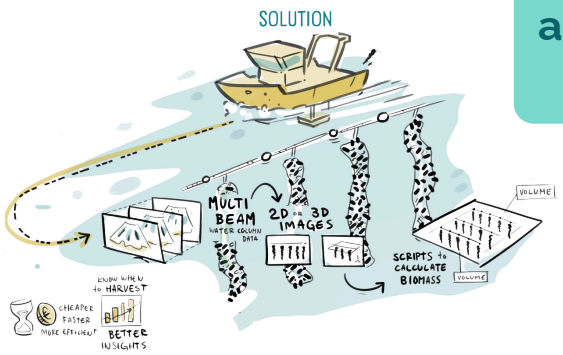


Pressure Adaptive Adaptation Tubes: offshore reliability evidence, integration routes with farm systems, protection via licensing and trade secrets for engineering know-how

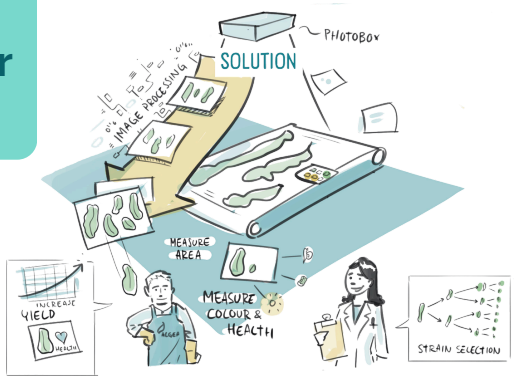


FluoroProbe: validation of the full monitoring workflow (not just the sensor), clear ownership and sales or service arrangements

A staged, IP-aligned path for each result



Bivalve Biomass Quantification: standardised, repeatable methods, service-based exploitation, clear agreements on data ownership and reuse



Snap Your Algae: continued refinement and partnerships, open access combined with copyright and attribution where research use is the main value

Illustrations © Tomas Pasma

The Pattern

Some results are closer to product development, others to services, advisory packages or data workflows. Each route needs different partners, revenue models and evidence before investors or customers commit.

The Way Forward

Targeted validation, not blanket scale-up: testing whether selected technologies and services work reliably offshore, whether users see their value, and whether delivery, support and maintenance responsibilities are clear.

No one-size-fits-all demonstration. Larger cultivation systems may need integrated demonstration sites testing technology, monitoring, business planning and governance together; smaller tools or data workflows may need more targeted validation with clear use cases. Either way, the same questions apply: who owns and operates the solution, who carries the risk, how is data used, how is safety organised, how are costs shared, how are benefits demonstrated.

Clear ownership across the board

Each result needs a lead partner, priority user groups, and short validation cycles updated by evidence and feedback. Integration-dependent delivery needs partners secured early; service-based delivery needs defined responsibilities; digital delivery needs maintenance, data handling and user trust built in from the start.

Enabling conditions at sector level

Regulatory frameworks for offshore multi-use, better integration of aquaculture into offshore wind planning and tenders, stronger market development for seaweed and shellfish, and greater investor confidence. Technical innovation alone won't be enough without these evolving in parallel.

ULTFARMS shows strong potential for low-trophic aquaculture in offshore wind farms, but large-scale deployment needs more than technology: robust systems, trusted monitoring, clear governance, viable business cases, supportive policy and growing market demand.

The broader lesson: Offshore low-trophic aquaculture belongs in Europe's long-term blue economy ambitions. The path forward is not just scaling individual technologies, but building the conditions for an entire sector to emerge and grow.



Further Reading

ULTFARMS Deliverables:

- D5.1 Exploitation and business plan
- D5.2 Economic analysis
- D10.4 Cross-thematic overall viability of LTA in OWF

OLAMUR Deliverables:

- D1.4 Economic data for investment & upscaling
- D6.2 Life cycle systems sustainability assessment
- D6.3 System value from growth positive targets, OLAMUR market entry scenarios

Historical Note: Building on UNITED

UNITED's Ocean Multi-Use Commercialisation Roadmap and the UNITED Blueprint already mapped much of the EU-level commercialisation pathway for marine multi-use. The exploitable results generated by UNITED provide the offshore, pilot-tested evidence base that ULTFARMS builds upon and extends, adding detailed technical, operational and business insights specific to low-trophic aquaculture.

7 Advancing Eco-friendly Productivity

Introduction

Eco-friendly productivity in offshore low-trophic aquaculture is not achieved through production alone. It depends on how aquaculture is designed, sited, operated, monitored and verified within offshore wind farms.

> In this thematic roadmap, eco-friendly productivity is understood as a practical direction of travel: from reducing negative impacts towards systems that can support ecological functions and, where evidence is strong enough, contribute to more restorative outcomes.

Low-trophic aquaculture is often promoted as inherently sustainable, but positive ecological outcomes can not be assumed simply because production is low-trophic or co-located with renewable energy. Ecological performance depends on site conditions, species selection, production intensity, infrastructure design, harvesting practices, monitoring and governance, as well as site-specific ecological carrying capacity: whether nutrient extraction and use stay within local ecosystem limits, which vary by region depending on nutrient availability, water exchange and ecological conditions.

This thematic roadmap treats eco-friendly productivity as an evidence-based concept, drawing on the Environmental Footprint Assessment, ecosystem-services feasibility screening, governance and certification mapping, and an analysis of wider ecosystem pressures and responses.

It connects ecological ambition with practical implementation and makes clear that stronger claims, such as habitat support, water-quality regulation, biodiversity benefits or restorative effects, require stronger evidence. Rather than prescribing one fixed model, this roadmap offers guidance for moving from responsible pilot activity towards eco-friendly productivity that is credible, verifiable and governable.

Why This Matters

Offshore wind farms are becoming a major part of Europe's marine space, with growing interest in combining energy production with low-trophic aquaculture. Such systems may improve space efficiency, support sustainable biomass production, and contribute to ecological functions such as nutrient uptake, habitat formation or support for marine life.

However, these outcomes remain conditional. Eco-friendly results do not automatically follow from multi-use: a mussel or seaweed system may reduce certain pressures while raising new operational, ecological or governance questions, depending on spatial planning, stocking density, infrastructure and harvesting. Excessive production intensity or unsuitable locations can affect nutrient availability and wider ecosystem functioning, and effects are highly site-specific.

Conventional sustainability approaches, focused on efficiency, impact reduction and compliance, are necessary but not always sufficient where ecological baselines have already shifted: doing less harm shouldn't be confused with demonstrating a positive contribution. There is also a governance gap, since certification schemes are generally better suited to recognising compliance than verifying restorative outcomes, risking overclaiming that can undermine trust.

Eco-friendly productivity is therefore more than a production activity. It needs a system-level view linking ecological performance, operational design, monitoring, governance and verification. The strongest evidence found relates to operational design, monitoring, risk mitigation, material suitability, circularity, decommissioning and stakeholder engagement. Wider claims about ecosystem services, nutrient cycling, water quality and restoration remain more conditional and need stronger, site-specific evidence.



Six Pathways for Eco-Friendly Productivity

1. **Establish a credible evidence base:** start from a clear ecological baseline. Structure evidence through indicators, confidence levels and transparent treatment of uncertainty; keep claims proportionate where evidence is limited.

2. **Move from reducing impacts to increasing benefits:** reducing harm, through better materials, responsible harvesting and equipment retrieval, is good practice but mainly demonstrates responsible operation. Stronger claims need evidence that systems actively support ecological functioning.

3. **Design for ecosystem-service outcomes:** consider potential outcomes (biomass production, nutrient regulation, habitat support, cultural value) during system design, not as an after-the-fact claim. Define expected benefits, possible negative effects and monitoring approaches before deployment.

4 **Strengthen monitoring, harmonisation and adaptive management:** assess operational performance and ecological outcomes over time using appropriate indicators. Sensors, cameras and biological sampling support evidence generation but do not by themselves demonstrate benefit; harmonised protocols improve comparability across sites.

5 **Keep valuation proportional to the evidence:** biomass production is easier to quantify than biodiversity or habitat support, which may be better represented through qualitative indicators. Apply monetary valuation only where evidence is robust; it should never replace ecological assessments.

6 **Embed evidence in governance and verification:** evidence should inform licensing, monitoring, reporting and certification, with ecolabels following robust assessment rather than preceding it. Mitigation-focused schemes may need a purpose-built framework for verified restorative claims.

Together, these pathways show eco-friendly productivity as a staged process, moving from responsible design towards more ambitious claims only where ecological performance can be demonstrated within site-specific limits.



The Way Forward

The next step is repeatable, verifiable practice: define ecological objectives early, agree shared indicators, monitor over seasonal and multi-annual timescales, build in adaptive measures, and communicate uncertainty clearly.

For policymakers, the priority is connecting ecological ambition to licensing and verification requirements. For industry, it is translating these into practical offshore operations. For researchers, it is improving methods to detect and attribute ecological effects in dynamic offshore environments.

Eco-friendly productivity can bridge science, policy and industry, but only if it stays evidence-based and transparent: establish baselines, monitor consistently, adapt when needed, and make stronger claims only when the evidence supports them.

ULTFARMS Policy Brief
Restoration & Nature Inclusive Design

Roadmap for Eco-friendly Productivity - *An integrated synthesis of D7.4*

Across D7.4, eco-friendly productivity is most credibly supported by evidence on offshore design, monitoring, risk mitigation and circularity, while wider ecosystem-service and restorative/regenerative outcomes remain conditional on stronger, longer-term, verifiable evidence.

A. What the roadmap may collectively enable

Evidence-conditioned environmental outcomes

- Responsible offshore / exposed production
- Eco-friendly productivity
- Ecosystem-service contribution
- Restorative / regenerative claims

B. Roadmap prerequisites

Values-based regenerative ambition

- Bottom-up ambition from stakeholder values and shared vision
- Regenerative principles and end-goals
- Social acceptance and motivation

Evidence-based differentiation

- Assessment of what can credibly be claimed
- Confidence, uncertainty and evidence gaps
- Pilot experience and *in-situ* insights

Governance, verification and certification architecture

- Top-down instruments, voluntary standards and labelling frameworks
- Existing ecolabel limits, auditability, and certification readiness
- Market implementation and feasibility

C. Evidence base for the roadmap

Literature review and input from external experts

- Scientific literature and targeted meetings with external experts
- Cross-project insights (UNITED, OLAMUR)

Pilot-generated evidence

- Reporting, field data and pilot lead input
- Operational and ecological evidence

Environmental Footprint Assessment

- Structured scoring framework
- Confidence and uncertainty tracked

DAPSI(W)R(M) system structuring

- Drivers to responses systematically mapped in matrix
- Causal pathways framed

Ecosystem services mind map and feasibility

- Interdependencies and trade-offs identified
- Assessment and ESs valuation feasibility summarised

Governance, standards and certification mapping

- Operational binding and non-binding instruments
- Verification and eco-label implementation pathways mapped

D. Integrated synthesis of D7.4 results

Strongest evidence base

- Operational design, monitoring and risk mitigation are consistently evidenced
- Materials, circularity, retrieval and decommissioning are well documented
- Stakeholder participation and demonstration value are consistently supported

Evidence base requiring substantiation

- Carbon, nutrient and wider regulating-service effects remain unevenly quantified
- Turbidity, water quality and habitat function warrant stronger causal evidence
- Long-term ecosystem effects and valuation robustness remain insufficiently verified

E. Six integrated operational roadmap pathways

1. Credible evidence and assessment basis

- Site-specific baselines, structured indicators & boundaries
- Communicate confidence and uncertainty transparently

2. From eco-efficiency to eco-effectiveness

- Distinguish reduced harm from ecological contribution
- Require site-specific evidence and ecological limits for progression

3. Design for ecosystem-service outcomes

- Define service objectives before deployment
- Link design choices to ecological functions

4. Monitoring, harmonisation and adaptive management

- Integrate monitoring into design and operations from outset
- Improve cross-pilot comparability, documenting interventions

5. ES valuation balanced & proportional to evidence

- Prioritise what can be measured accurately
- Avoid false precision

6. Implementation, governance, verification and certification

- Treat certification as an outcome, not a starting point
- Translate evidence into auditable governance pathways
- Consider a purpose-built framework where existing schemes remain mitigation-focused

F. Co-design foundation

Co-design underpins all evidence interpretation and roadmap development

Pilot engagement, expert consultation, iterative learning, context-specific adaptation and shared ownership and accountability.

Further Reading

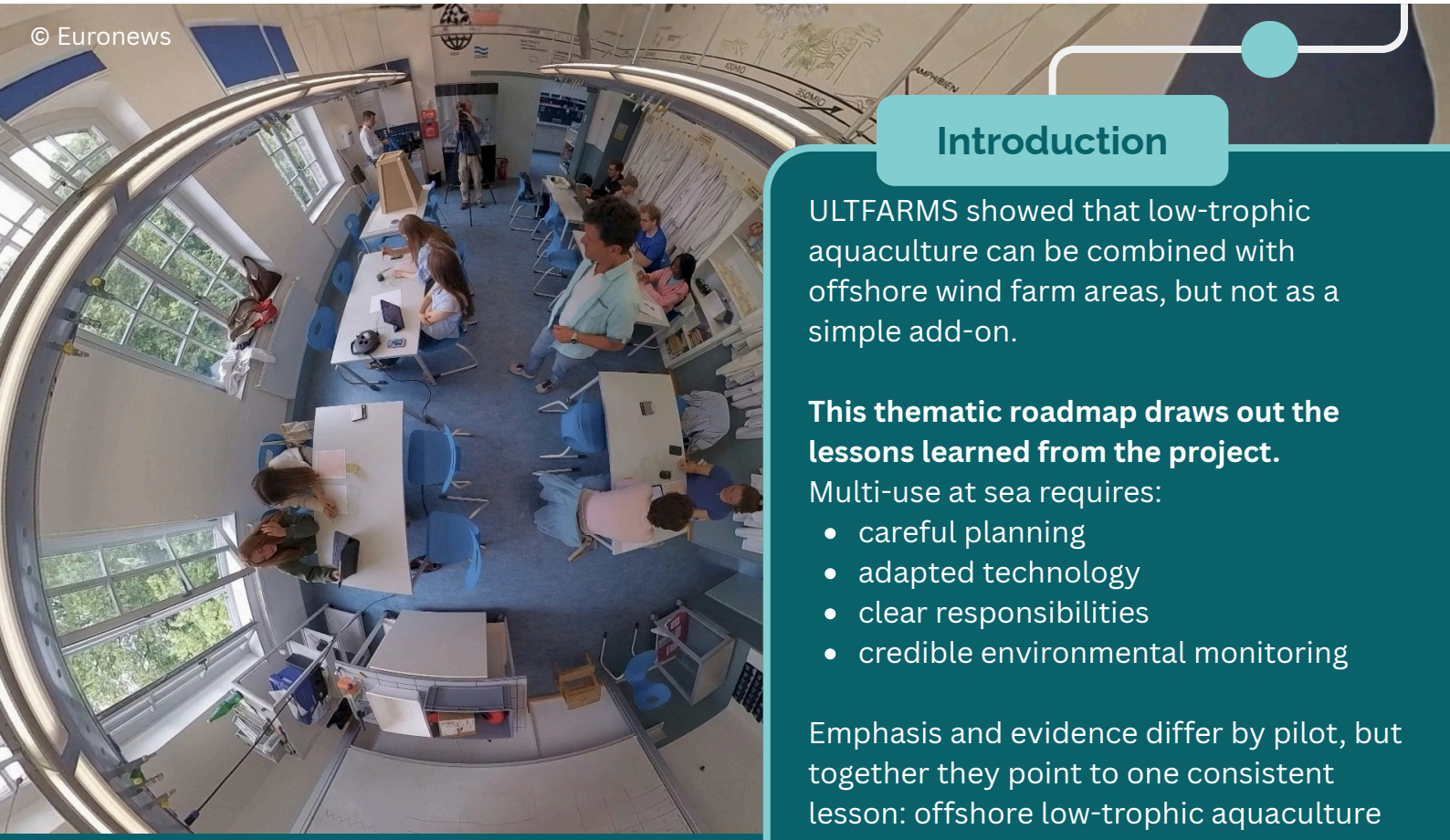
ULTFARMS Deliverables

- D7.3 Sustainability goals of business models
- D7.4 LTA aquaculture in OWF and eco-friendly approach

ULTFARMS Scientific Publications

- *Nature Inclusive Design in Marine Infrastructure (abbr.)* - ICES Journal of Marine Science

8 Lessons Learned


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Introduction

ULTFARMS showed that low-trophic aquaculture can be combined with offshore wind farm areas, but not as a simple add-on.

This thematic roadmap draws out the lessons learned from the project.
Multi-use at sea requires:

- careful planning
- adapted technology
- clear responsibilities
- credible environmental monitoring

Emphasis and evidence differ by pilot, but together they point to one consistent lesson: offshore low-trophic aquaculture must be designed as an offshore activity from the start, not a copy of nearshore practice. For policymakers, industry and science, this means treating multi-use as a system challenge, developing technical design, licensing, safety, monitoring, business conditions and stakeholder trust together.

Why This Matters

Combining aquaculture with offshore renewable energy makes more efficient use of marine space. It can support seafood and biomass production without claiming separate sea areas, while contributing to climate and food-system objectives. Low-trophic aquaculture may also provide environmental benefits, such as water-quality regulation or habitat support, but these can not simply be assumed: they depend on species, site conditions, farm design, production intensity and the quality of monitoring before and during operation. This is why ULTFARMS' lessons matter beyond the six pilots: they help define what must be arranged before multi-use can be replicated responsibly.

Lessons learned

The ten lessons below bring together insights from the ULTFARMS pilots and thematic roadmaps. They show that successful multi-use depends on organising the technical, environmental, regulatory, operational and social dimensions as one connected challenge.

1 Planning

Plan multi-use before offshore wind deployment, not after problems arise. Considering aquaculture requirements early, such as where it can fit within the wind farm layout, as well as how vessels can safely access the site, which licenses are needed, and who is responsible for safety, operations and maintenance are all important. This also reduces uncertainty for authorities, developers and operators.

2 Co-design is essential

Practical solutions need early collaboration between engineers, aquaculture operators, wind farm operators, regulators, researchers and local stakeholders. This improves technical alignment, identifies safety and licensing constraints early, and builds trust across sectors that normally work under separate rules and risk cultures.

3 Offshore systems must be adapted to offshore conditions

Harsh weather, waves, currents and limited access create different requirements from nearshore aquaculture. Systems need robust designs, clear maintenance procedures, and contingency options. Designs, configurations and routines may need adjusting through iterative testing before wider application.

4 Operations and maintenance must be realistic and pre-agreed

Future projects need clear arrangements for inspections, repairs, vessel access, safety procedures and responsibilities, defining what happens when equipment is damaged, access is restricted, or activities need to pause.

5 Monitoring is key

Environmental and operational monitoring is key to responsible offshore aquaculture. Water quality, seabed conditions, biodiversity, farm performance and equipment condition need to be assessed before and during operations. Monitoring supports adaptive management, helps prevent negative impacts, and makes sustainability claims more credible for authorities, investors and the public.



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6 Environmental benefits must be demonstrated, not assumed

Low-trophic aquaculture can be designed to support marine ecosystems, for example through habitat structures or native shellfish restoration. However, positive effects depend on local conditions and farm design. ULTFARMS' Nature-Inclusive Design work and sustainability pathway show that broad claims about ecological benefits should be avoided unless supported by monitoring data and clear indicators.

7 Licensing and governance remain decisive for scale-up

Technical feasibility alone is not enough. Clear regulations, predictable licensing routes and well-defined responsibilities are needed before multi-use can move from pilots to wider application. Policy can help by clarifying where multi-use is allowed, which conditions apply, and how evidence on safety and environmental performance should be assessed.

8 Social acceptance and trust must be actively built

Multi-use projects need support from stakeholders and society. Trust depends on transparent communication about benefits, risks, monitoring results and responsibilities. Engagement should not only explain the concept, but also show how environmental impacts are managed and how lessons from pilots are used to improve future projects.

9 Scale-up depends on an integrated package

Replication needs workable operations, credible monitoring, clear governance and licensing, realistic business models and strong cooperation between science, policy and industry. Weakness in any one element makes scale-up slower and riskier.

10 Sea-basin cooperation must feed into national decisions

Platforms such as the Greater North Sea Basin Initiative, HELCOM-VASAB, the North Seas Energy Cooperation, OSPAR and EU-funded projects help align approaches across countries. But ULTFARMS showed that cooperation alone doesn't deliver multi-use: without routes from regional guidance into national maritime spatial plans and permitting, progress stays slow and uneven.



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Taken together, these ten lessons show that offshore low-trophic aquaculture can move beyond pilot-scale experimentation only when planned, operated and governed as an integrated offshore system. Technical feasibility is necessary but not sufficient: future projects also need predictable licensing, robust safety and maintenance arrangements, transparent monitoring, realistic business conditions and sustained stakeholder confidence.

Historical Note: Building on UNITED

UNITED reached a parallel conclusion across its own five pilots: that multi-use needs technology, economy, legal, social and environmental strands managed together, not solved in isolation. It produced its own cross-pilot synthesis report (D7.7) and a dedicated report on stakeholder involvement and trust-building (D5.5), both feeding into its Ocean Multi-Use Commercialisation Roadmap. ULTFARMS' ten lessons extend this same integrated approach specifically to offshore low-trophic aquaculture.

The Way Forward

Future offshore low-trophic aquaculture projects should build on ULTFARMS by moving from pilot learning to structured implementation. Policy should provide clear spatial and licensing pathways; science should support shared indicators, monitoring methods and evidence standards; industry should focus on robust designs, safe operations and realistic business cases. Together, these steps can make future projects easier to permit, safer to operate and more credible to scale.

Further Reading

ULTFARMS Deliverables

- D2.1 Stakeholder engagement strategies for pilots
- D3.1 Co-design of production-related activities
- D7.2 Nature-inclusive designing of offshore multi-use infrastructure
- D8.1 Harmonized recommendations for production systems
- D10.3 Guidance catalogue for offshore multi-use developments

ULTFARMS Policy Briefs

- Lessons learned, Knowledge Gaps and Outlook from All Pilots
- Role of Associated Regions and Transferability

OLAMUR Deliverables:

- D2.1 A protocol for multi-use for stakeholders
- D2.2 Report on micro-siting criteria and mapping of co-location scenarios within pilots
- D5.4 KPI monitoring report
- D6.1 Life cycle sustainability assessment of OLAMUR systems and associated restorative food production and supply systems

9 The way forward

Introduction

This chapter sets out the way forward for low-trophic aquaculture in offshore wind farms. ULTFARMS has shown that such systems can be developed offshore and can support more sustainable, efficient use of marine space. But success depends on much more than technical feasibility: governance, licensing, operational logistics, monitoring, stakeholder acceptance and commercial viability all decide whether concepts move beyond pilot scale.

No Single Solution
There is no single fix that unlocks large-scale deployment. Progress depends on coordinated action across policy, industry and research: technologies must mature, regulatory frameworks must evolve, and business models must prove their value under real conditions. Environmental benefits and impacts should be demonstrated through evidence, not assumed.

A Phased, Evidence-Based Path Forward
The lessons gathered across the ULTFARMS pilots offer a practical foundation for future development. Low-trophic aquaculture can become part of a sustainable blue economy, provided investment is matched by proper planning, monitoring and collaboration. The way forward is not rapid expansion at any cost, but building confidence and capability step by step.

Continuing the Conversation

The way forward depends on stakeholders continuing to talk to each other once ULTFARMS ends. As a legacy tool, ULTFARMS created the Ocean Multi-Use Hub, a community for ocean multi-use professionals, stakeholders, NGOs, researchers and blue career practitioners to keep exchanging knowledge and showcasing new developments.

The Hub is hosted on BlueActionMatch, a community platform for action across the blue, and managed by SUBMARINER Network. The Hub provides a lasting home for ongoing discussion and expert engagement beyond the project's own lifetime. It is open to anyone working on integrated, sustainable and inclusive use of Europe's marine spaces.



Join the community!

Key Messages

More than a technical fit
Low-trophic aquaculture can become part of future offshore activity, especially alongside offshore wind, but only with early planning, clear governance and solutions built for offshore conditions from the start, not adapted from nearshore practice.

Scale-up needs more than good technology
Cultivation technology and infrastructure are not enough on their own. Regulatory certainty, efficient operations, monitoring and stakeholder engagement carry equal weight in determining whether pilots can grow.

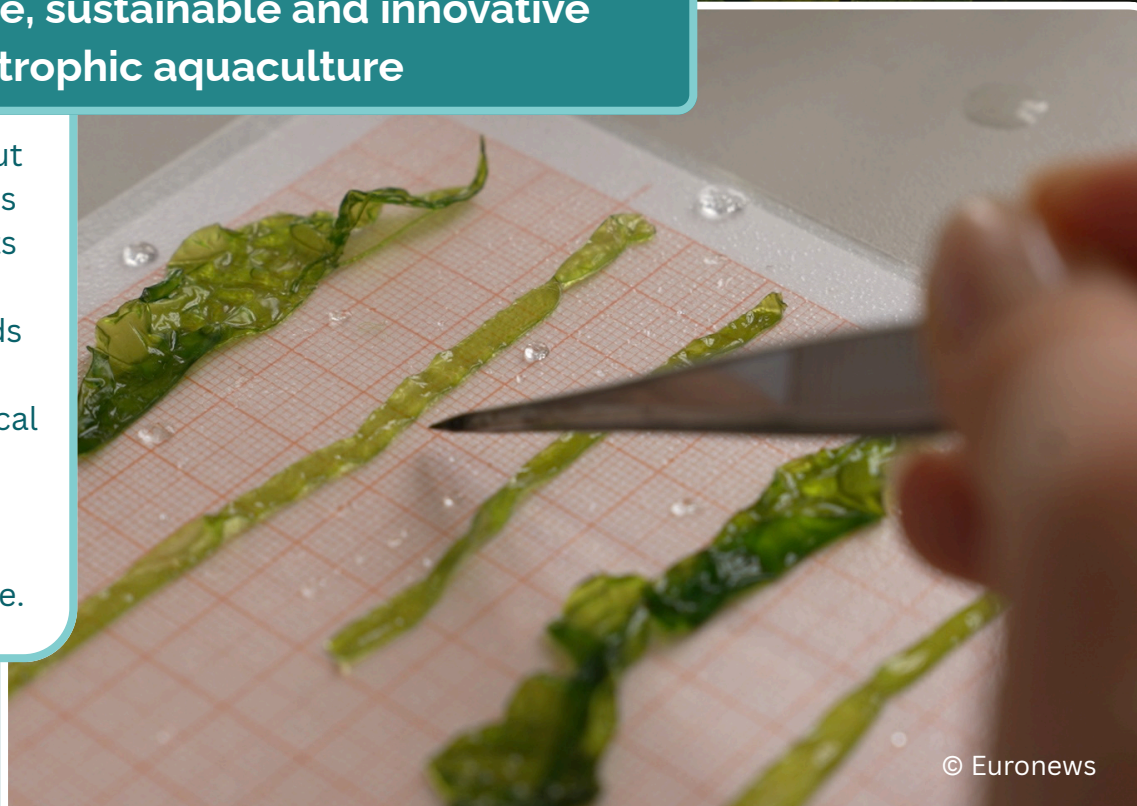
Reduce uncertainty to enable investment
Progress depends on practical pathways: giving investors and operators more certainty, improving coordination across sectors, and building reliable evidence on both environmental and economic performance.

Trust depends on evidence
Environmental claims must be backed by monitoring and transparent reporting. As expectations for evidence-based decision-making grow, the sector's credibility will rest on the quality of that evidence.

Growth is a shared responsibility
No single actor can deliver this alone. Offshore wind operators, aquaculture producers, technology developers, regulators, researchers and local stakeholders all need to help create the right conditions.

Towards viable, sustainable and innovative low-trophic aquaculture

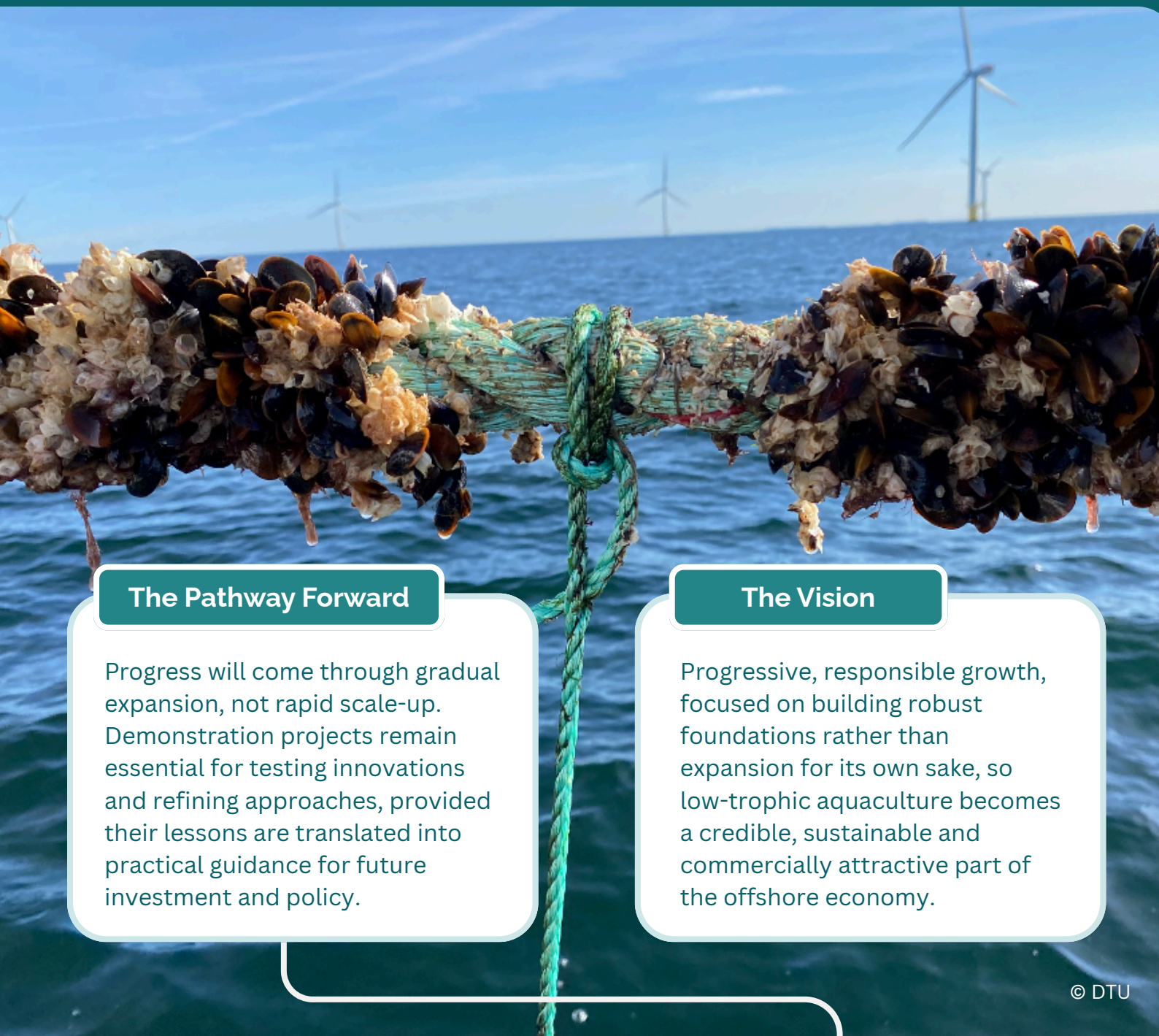
The next phase is about creating the conditions for promising concepts to move from demonstration towards wider adoption, combining technological innovation, practical implementation experience and supportive governance.



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Three Dimensions of Progress

	What is needed
Operational	Systems designed to withstand harsh weather, limited access and high offshore costs, with continued innovation in cultivation, monitoring, maintenance and planning to improve reliability.
Environmental	Low-trophic aquaculture can support food production with low resource inputs, but benefits vary by site and system; consistent monitoring and transparent assessment are needed to understand real impacts.
Economic	Business models that reflect offshore realities, with shared infrastructure, coordinated logistics and integration with existing offshore activities to cut costs, alongside new products and services that create commercial opportunities.



The Pathway Forward

Progress will come through gradual expansion, not rapid scale-up. Demonstration projects remain essential for testing innovations and refining approaches, provided their lessons are translated into practical guidance for future investment and policy.

The Vision

Progressive, responsible growth, focused on building robust foundations rather than expansion for its own sake, so low-trophic aquaculture becomes a credible, sustainable and commercially attractive part of the offshore economy.

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Key recommendations

Six recommendations, spanning technical, regulatory, operational, environmental and commercial dimensions, set out the conditions needed to move from pilots to wider, responsible implementation.

1 Plan for aquaculture from day one

Build aquaculture into offshore planning, design and licensing from the earliest stage, not as an afterthought. Early coordination between planners, licensing authorities, wind developers and operators avoids constraints on space, access, safety and infrastructure later on.





2 Create clear governance frameworks

Predictable licensing and clear responsibilities are essential for investment. Better coordination between authorities can cut administrative complexity and support innovation while maintaining safety and environmental standards.

3 Invest in offshore-ready technology, together

Public programmes should fund early-stage testing and shared monitoring; LTA developers should improve their own systems; offshore wind developers should contribute where value is shared (logistics, monitoring, tenders); private investors will follow once reliability and revenue models are clearer.




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4 Build a shared evidence base

Treat onitoring as a strategic investment, not a compliance box to tick. Harmonised approaches and shared lessons strengthen confidence in the sector and support better planning, investment and regulation.

5 Design collaborative business models

Identify value across the whole offshore ecosystem, aquaculture, wind, technology and services, and encourage shared infrastructure and logistics. Governments can help through tender criteria, funding incentives and risk-sharing instruments.


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6 Scale up in phases, not leaps

Treat early scale-up as a shared public responsibility until commercial viability is proven. A competent public authority or mandated multi-use platform should coordinate the process, with public bodies ensuring continuity and alignment with marine spatial planning, and the LTA community defining technical needs and standards.

Conclusion

Low-trophic aquaculture in offshore wind farms offers a promising route to sustainable food production, offshore innovation and more efficient use of marine space. Realising this will take continued collaboration between policymakers, researchers and industry, backed by robust evidence and realistic business pathways, moving the sector from demonstration to an established part of the EU's blue economy.

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