SEAMARK
Seaweed-based Market Applications

THE SEAMARK JOURNEY:
DEMONSTRATING SCALABLE, INVESTABLE SEAWEED VALUE CHAINS PROVIDING INFORMED GUIDANCE FOR POLICYMAKERS

THE **FINAL SEAMARK MEETING**, MAY 20TH, 2026, LIMASSOL, CYPRUS

Co-funded by the European Union

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SeaMark - Seaweed-based Market Applications:
"Unlocking the potential of macroalgae for a thriving European blue bioeconomy"

Welcome to the Final SeaMark Meeting

OLAVUR GREGERSEN, CEO, OCEAN RAINFOREST
THE **FINAL SEAMARK MEETING**, MAY 20TH, 2026, LIMASSOL, CYPRUS

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Project objective

SeaMark will demonstrate how to **scale up** innovative seaweed cultivation and processing into **price-competitive product applications,** making the entire supply chain attractive for **commercial investments.**

Project lifetime

Today

Project Start
July 2022

Project End
June 2026

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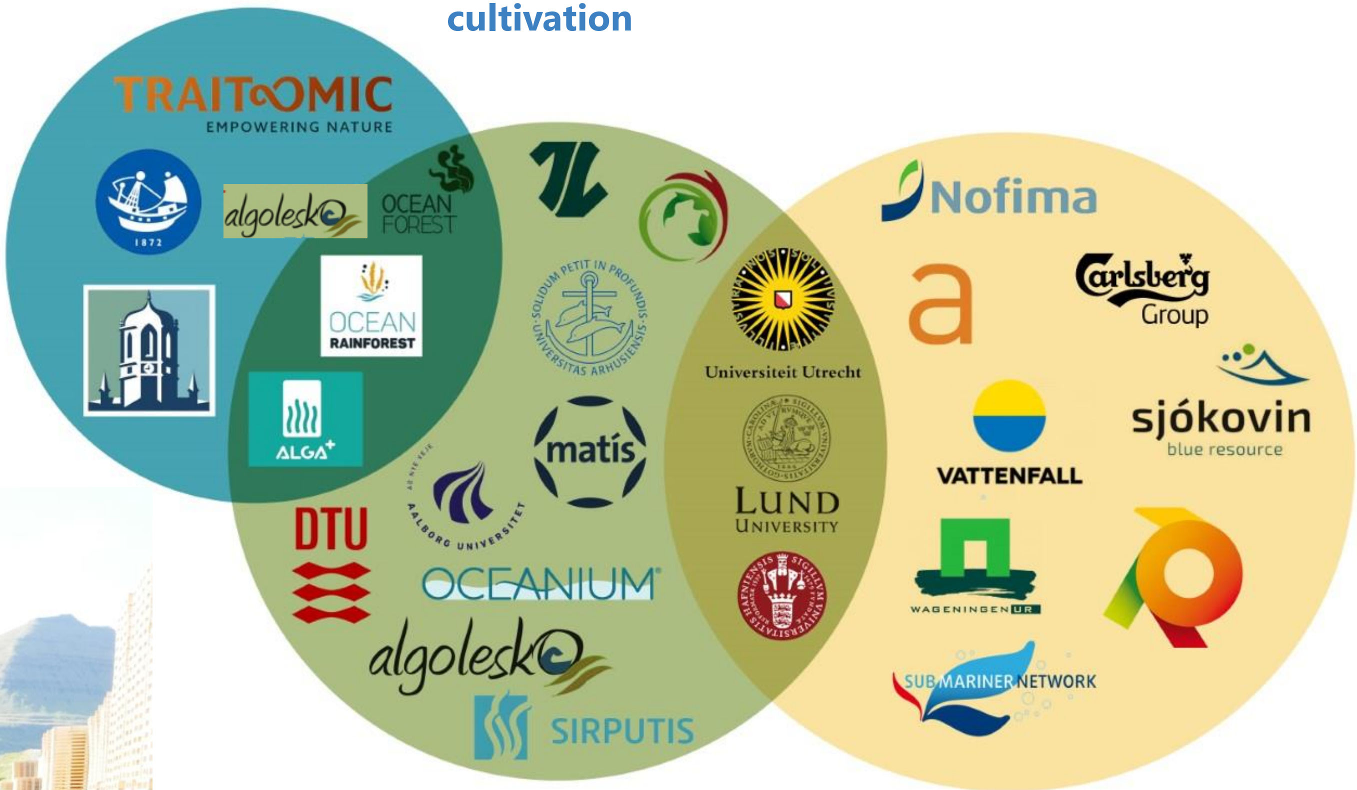
The Consortium

Breeding & cultivation



Processing into seaweed-based product applications

Market -, environmental-, socio- & techno-economic assessments & DCE

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SeaMark Snapshot

25 PARTNERS

11 COUNTRIES

4 YEARS

8 MIO € GRANT

OCEAN & LAND-BASED CULTIVATION

12 PRODUCTS

OCEANIUM

FERMENTATION EXPERTS

ALGAIA

OCEAN RAINFOREST

RUITENBERG

LEADING **SEAWEED** RESEARCHERS

DEVELOPMENT AND ASSESSMENT OF ENTIRE VALUE CHAIN

IMPROVED PROCESSES, PRODUCTS AND PROTOCOLS AND

PROVEN SUSTAINABILITY

NEXT STEP RECOMMENDATIONS

REGULATORY AND INVESTOR NEEDS IDENTIFIED

CARRYING CAPACITY AND **SCALING STRATEGY**

Objective of today

We will share our knowledge & provide recommendations

We hope you will talk together, share your point of view & ask questions

Together, we build a shared understanding that can help to move the seaweed ambition (industry?) forward.

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Agenda

CONFERENCE OPENING

12:30 **Welcome to the Final SeaMark Meeting**
Ólavur Gregersen, CEO, Project Coordinator, Ocean Rainforest

12:35 **Opening speech and insight into the European ambition**
Dr Evdokia Achilleos, Head of Sector, Biodiversity, Circular Economy & Environment, European REA

SESSION 1: TECHNOLOGY READINESS AND COST REDUCTION IN SEAWEED CULTIVATION

12:40 **Enhancing Ulva production in land-based IMTA systems**
Dr Margarida Martins, Innovation Coordinator, ALGAplus

12:55 **Open-ocean seaweed cultivation: advancing mechanised seeding and industrial readiness in Euro offshore environments**
Floor Marsman, Senior Researcher, Ocean Rainforest

13:10 **Improving yields of the kelp Saccharina latissima through breeding**
Dr Jeppe Thulin Oesterberg, Scientist, Traitomic, Carlsberg Group

13:25 **Reducing the cost of cultivated seaweed: Results from techno-economic assessments**
Dr Magni Laksáfoss, Senior Economist, Sjókovin - Blue Resource

13:40 **Q&A session: Technology Readiness and cost reduction**
Open discussion; Speakers will be on stage

14:00 **Coffee and Tea Break**

SESSION 2: BETTER PROCESSING, PRODUCT DEVELOPMENT AND MARKET PENETRATION

14:30 **Biorefinery at scale: Turning cultivated biomass into high-value products**
Dr Charles Bavington, Biochemist and Entrepreneur, Oceanium

14:45 **Fermentative and pre/pro-biotic properties of *Saccharina latissima***
Prof Reinhard Wimmer, Department of Chemistry & Bioscience, Aalborg University

15:00 **Co-extraction and potential application for greener fucoidan & alginate production from cultivated species**
Dr Jeremy Brebion, Process and R&D Manager, Algaia

15:15 **Go-To-Market strategies: Identifying pathways for seaweed-based products**
Dr Morten Heide, Senior Scientist, Nofima

15:30 **From pilot to market: Pathways towards upscaling production**
Dr Unn Laksá, CEO, Sjókovin - Blue Resource

15:45 **Q&A session: How to bring seaweed-based products to the market**
Open discussion; Speakers will be on stage

16:05 **Afternoon break**

SESSION 3: SUSTAINABILITY, IMPACT & BUSINESS MODELS TO SUPPORT STRATEGIC SCALING OF A RESTORATIVE SEAWEED INDUSTRY IN EUROPE

16:35 **Life cycle assessment of SeaMark flagship products compared to land-based alternatives**
Dr Sander van den Burg, Senior researcher, Wageningen University & Research

16:50 **Ecosystem services and monetisation pathways for sustainable industry support**
Josien Hendricksen, Marine & Aquaculture Researcher, Wageningen University & Research

17:05 **Scaling restorative marine industries: ecosystem services as transition instruments in European seaweed cultivation**
Juliana Arias Hansen, Lead Researcher, Sjókovin - Blue Resource

17:20 **Strategic Scaling of the European Seaweed Sector: Recommendations for policy and investment**
Ólavur Gregersen, SeaMark Project Coordinator, CEO, Ocean Rainforest

17:35 **Q&A session: How to attract investment and inform policymakers**
Open discussion; Speakers will be on stage

18:00 **End of conference**

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Enhancing *Ulva* production in land-based IMTA systems

MARGARIDA MARTINS
ALGAPLUS, SIRPUTIS, GALWAY UNIVERSITY
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What we do at ALGAplus?

Organic certified fish & **Seaweed Farming**

Integrated Multi-Trophic Aquaculture (IMTA)

Pre-processing & **Commercialisation**

Integrated value chain for global markets.

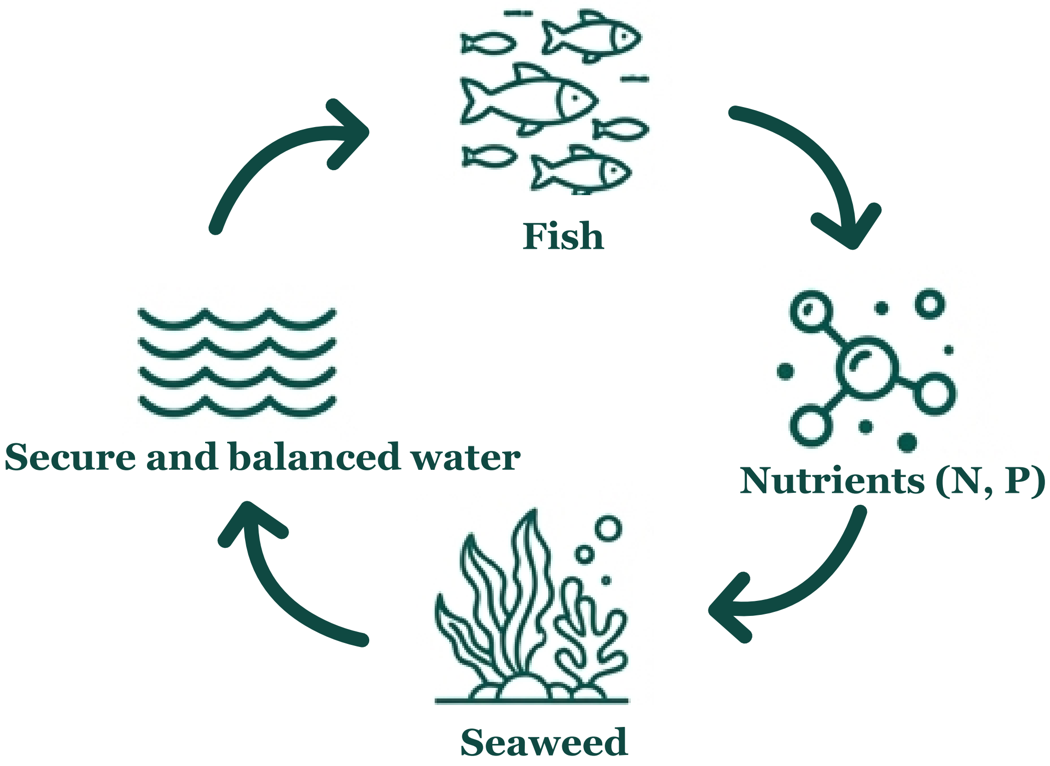
Sustainability, Innovation & **Knowledge-based**

Driven by applied R&D and ecological commitment.

Biomass & **products for Nutrition/Well-being**

Natural solutions for human food, functional food and feed, and cosmetics

Integrated Multitrophic Aquaculture (IMTA)



✓ Uses the **waste from one species as nutrients for another**, creating a **closed-loop** system that minimizes waste and reduces environmental impacts.

Nutrient circularity · Zero waste · Ecosystem services · Biomass production

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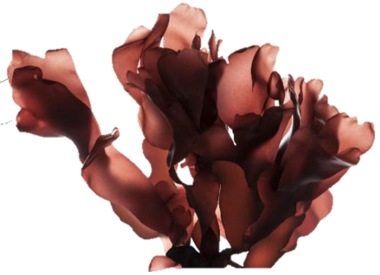
Our seaweed production: species available locally

Ulva sp.
Sea-lettuce

Codium tomentosum
Velvet fingers

Gracilaria sp.
Ogonori



Palmaria palmata
Dulse

Porphyra spp.
Atlantic Nori

Fucus vesiculosus
Bladderwrack

PT-BIO-03
EU Agriculture

Fresh, dry (whole, flakes, powder), frozen || Mono-species or customized blends

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Scale-up of production

From 2016 to 2020 only 700 m²

Expanded cultivation area to 6,650 m² in 2022.

Mainly designed for *Ulva* production

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New cultivation infrastructure in place! What's next?

- Increase cultivation capacity and quality, ensuring year-round production
  - Update cultivation protocols
  - Strains selection (together with NUIG in WP1) !
- Reduction of manual labour through process mechanization
  - Design of a new harvesting machine fully adapted to the system (together with Sirputis in WP2) !
- Develop new products and ingredients
  - New grinding system !
  - Ulvan extraction (in partership with ALGAIA in WP5)

Strain selection

Bioprospection

88 strains collected across three campaigns in Aveiro region.

Screening

Filtered for broad temperature and salinity resilience.
Selected 4 top strains: R32, R51, R55, and R99.

Cultivation trials

Indoor and outdoor (up to raceways) cultivation trials. Comparison with top performing biobank strains and industrial batch.

Strain selection

Strain	Growth	Resilience	Morphology	Verdict
GENIALG strains	High (summer)	Low ✗	Intact	Seasonal use only
Industrial batch (U1AB22)	**Moderate**	**Extremely high** ✓	**Intact**	**Core winter/ Baseline crop**
SeaMark R99	Highest initial	Low ✗	Fragmented	Discarded (epiphyte)
SeaMark R55	Moderate	Low ✗	Fragmented	Discarded (lost in winter
SeaMark R32	**High** ✓	**High** ✓	**Intact & Firm** ✓	**Optimal new raceway strain**

Ultimate scalable strain: balances growth with stress tolerance!

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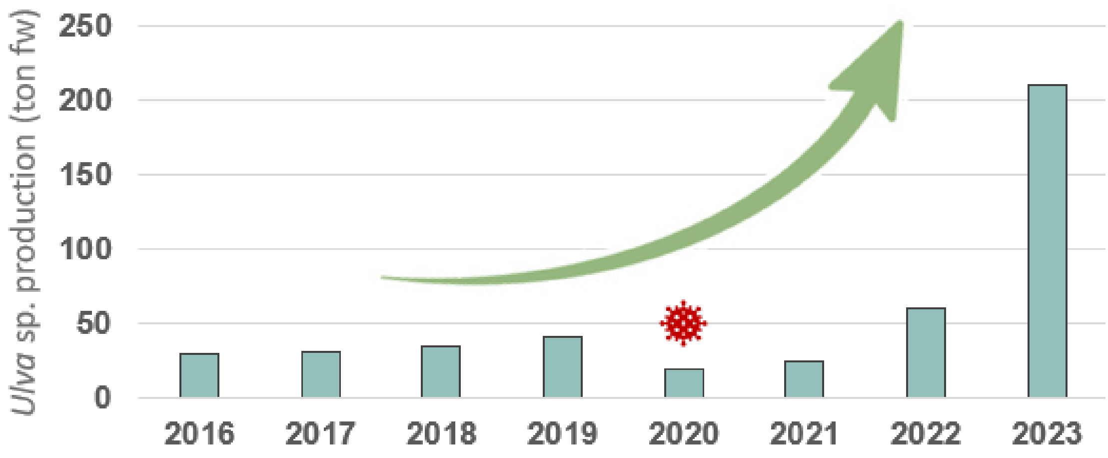
Scale-up of production



Why was that?
Optimization of cultivation protocols
Strain selection
New cultivation system

With the current infrastructure and operating conditions, production capacity could reach up to **700 tons fw/year**, depending on market demand!

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Harvesting bottleneck

Moving from 30 (in 2021) to 200 tons is **impossible using manual harvesting** techniques.

Requires, at least, 3 operators simultaneously.
Highly physical, intense labor limits daily harvest volume.
Inefficient yield extraction (kg/hour) caps the ROI of the biological improvements.

ALGP and Sirputis (SIR) collaborated to design an automated solution adaptable to both natural and artificial ponds.

SIRPUTIS

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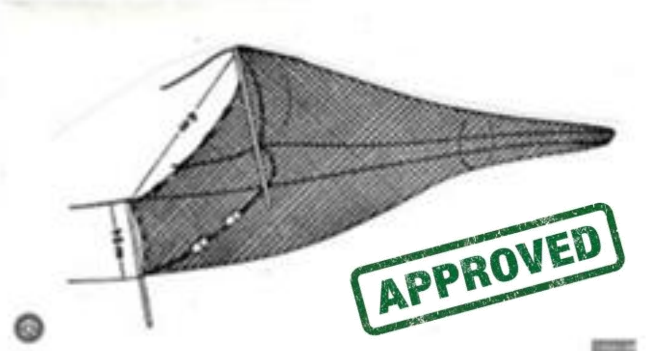
Harvesting machine – Design

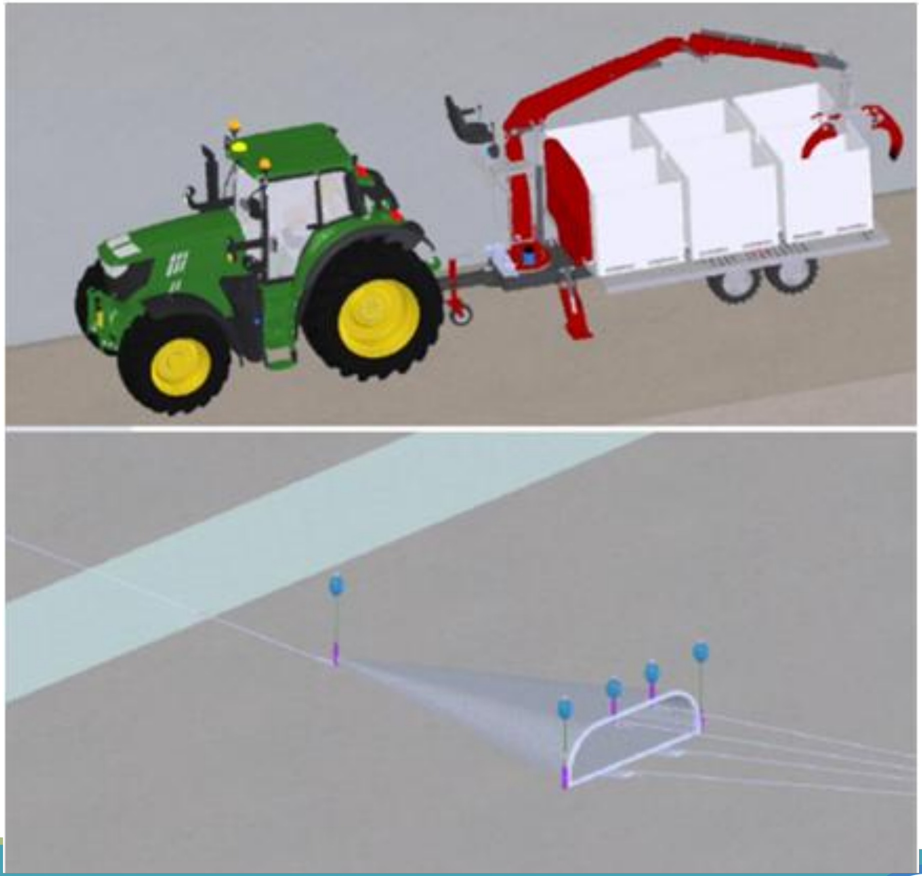
1. Remote control drone + pump harvester

2. Remote control drone + conveyor harvester

3. Remote control drone + floating net



4. Tractor-assisted net & pulley



SIRPUTIS

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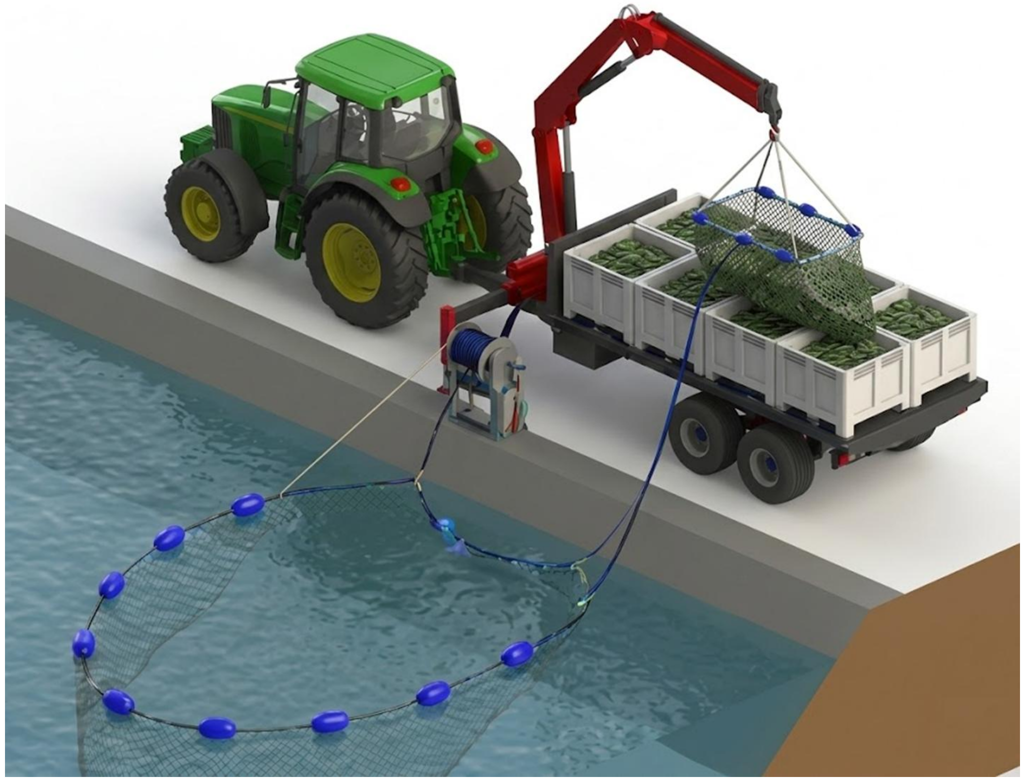
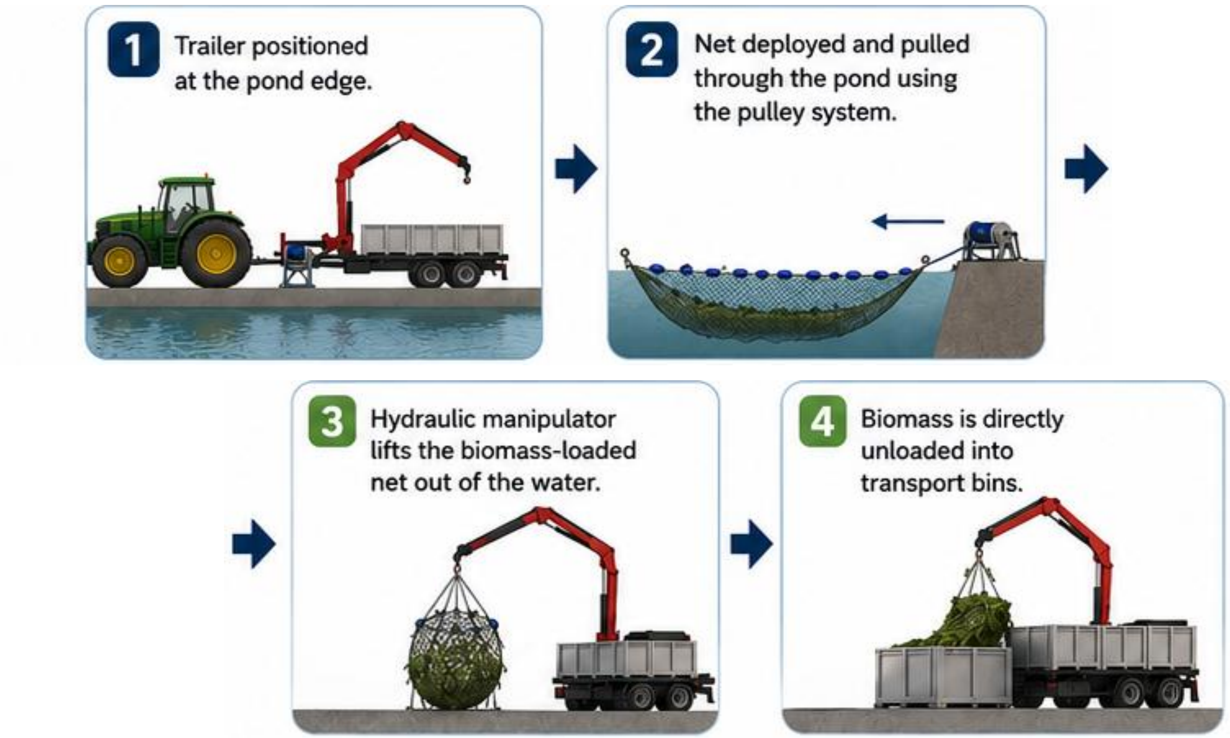
Harvesting machine – Design





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Harvesting machine – Ready to install

Expected performance

Labor Force: reduced from 3 to 2 operators

Velocity: cycle time capped at ~30 minutes/harvest

SIRPUTIS

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New grinding system

Significant changes in production capacity (5.5× increase in daily milling capacity for *Ulva*) and allowing milling in different sizes and new formats!

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Key Takeaways

- ✓ **Industrial Scale-Up:** SeaMark successfully transitioned *Ulva* production from pilot-scale to efficient, automated industrial capacity.
- ✓ **Operational Excellence:** Improved stability and efficiency by combining biology, engineering, and mechanization to eliminate bottlenecks.
- ✓ **Future Growth:** Established a robust foundation for ALGAplus's long-term competitiveness and market expansion.

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www.seamark.eu

@seamarkeu

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Open-ocean seaweed cultivation: advancing mechanised seeding and industrial readiness in European offshore environments

FLOOR MARSMAN, SENIOR RESEARCHER, OCEAN RAINFOREST
ALGPAPLUS, ALGOLESKO, OCEAN FOREST, SIRPUTIS, VATTENFALL, NOFIMA, OCEAN RAINFOREST
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Setting the scene

Europe's blue bioeconomy → offshore seaweed cultivation

SeaMark's aim:
to develop **technologies** to enable large-scale reliable supply of *S. latissima* and **reduce production costs** to make seaweed more competitive with land-based resources

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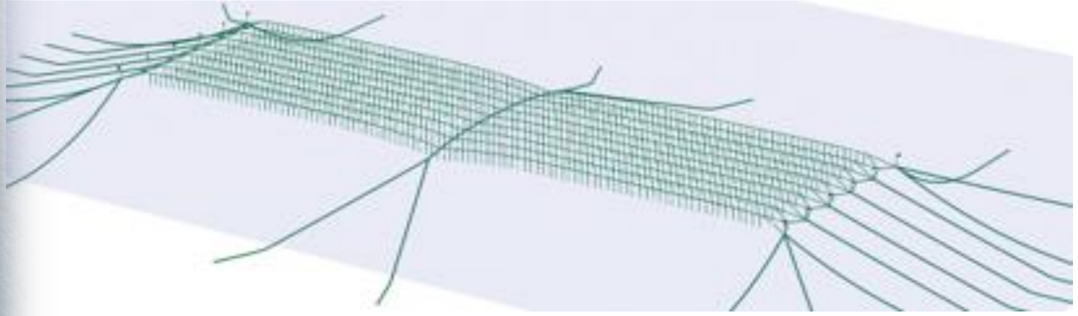
Validated offshore performance

Faroe Islands:

- Reliable cultivation systems under exposed conditions
  depths of 50–80 m, currents up to 0.74 m/s and waves up to 7 m
- Consistently high growth performance

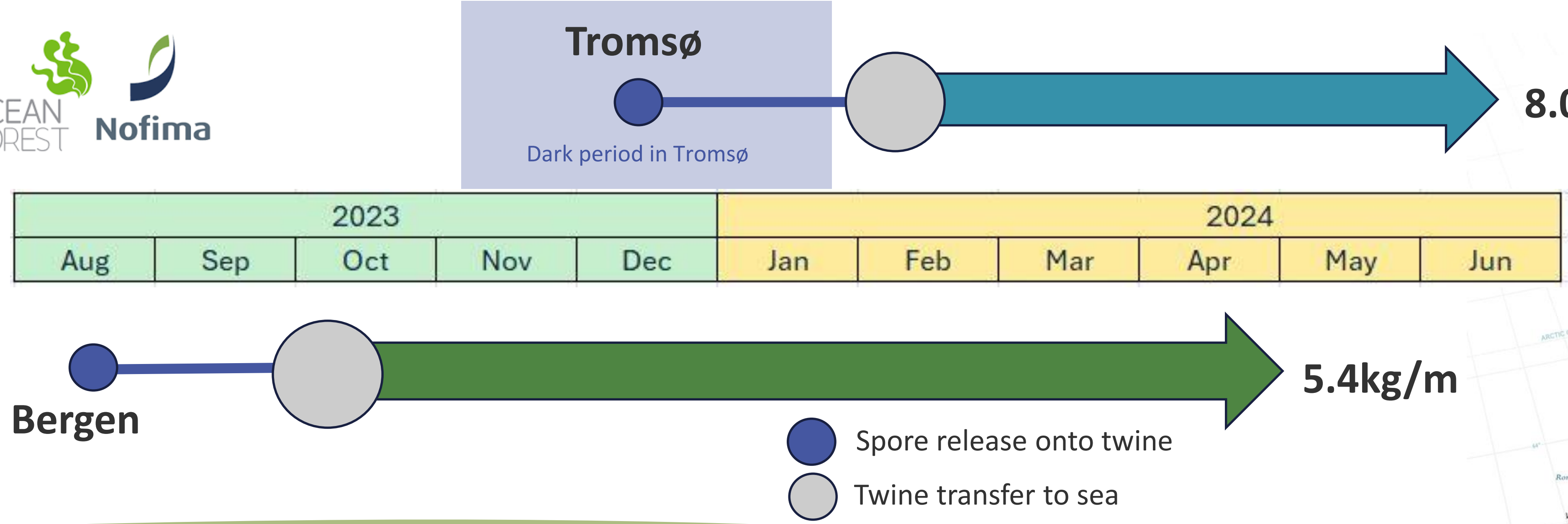
Ocean Rainforest’s Ocean Cultivation Unit (OCU)

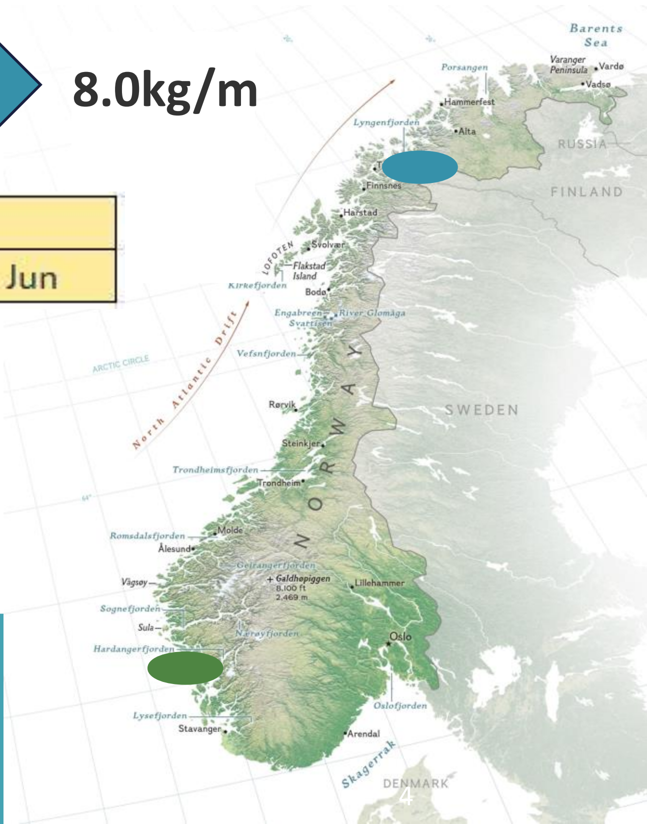


Validated offshore performance

Norway:

- Strong adaptability across sites
- Northern environments offering advantages: extended photoperiods and reduced biofouling





James, P., Evensen, T., Donovan, M. E., Sveier, H., & Kinnby, A. (2026). A comparison of potential yield and production timing for sugar kelp (Saccharina latissima) between sites in the north and south of Norway. *Journal of Applied Phycology*, 1-9.

Need for mechanisation

Scale-up of seaweed production:

ORF: 100 T/year (SeaMark start) → 30,000 T/year (SeaMark goal)

Requires:

Reduced intensive manual labour

Reduced operational costs

Increased yields

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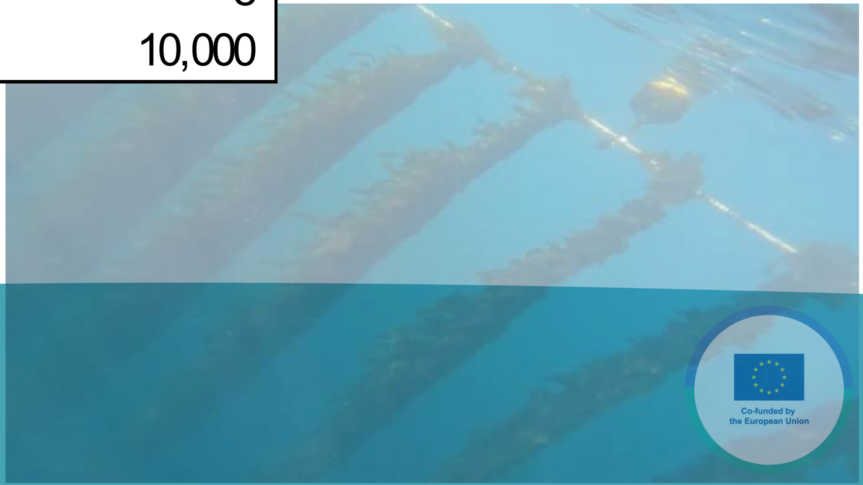
Mechanical direct seeding demonstrated in SeaMark

- Proven in 3 consecutive years
- 1 m/s, 2-person crew
- Good and consistent growth and yield

	Manual	SeaSeeder	HS SeaSeeder
Machine speed (m/s)	**-**	**0.4**	**1.0**
People needed	5	4	2
Spools per hour	-	2.5	4.5
Meters per spool	-	550	550
Meters per 8h day	5,000	9,625	17,325
Days needed to seed 1 OCU (82,500m)	**21**	**11**	**6**
Labour cost (€)	23,003	9,560	2,655
Equipment cost (€)	-	20,000	80,000
Depreciation years	-	8	8
Equipment cost / year (€)	-	2,500	10,000





	Manual	SeaSeeder	HS SeaSeeder
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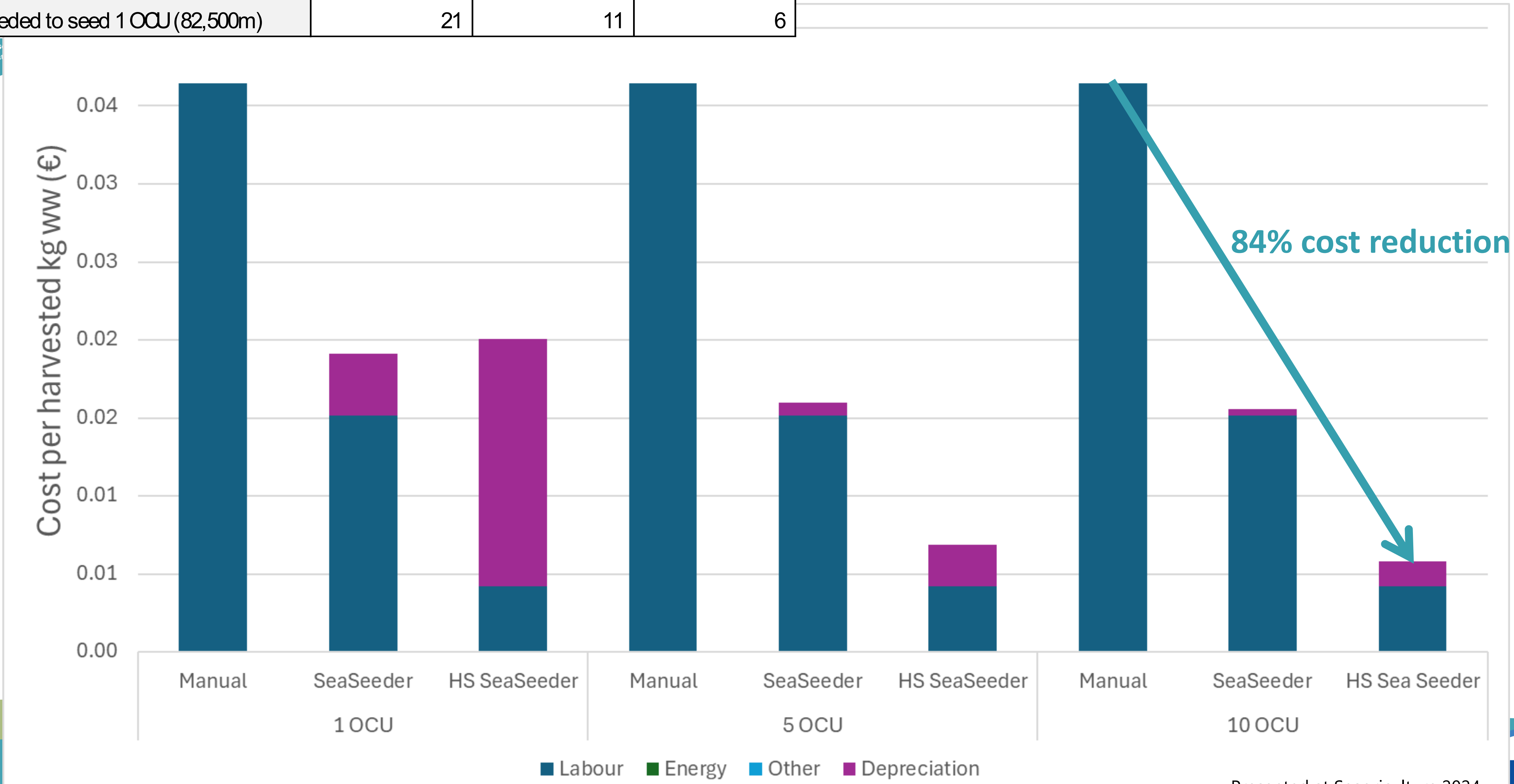

Presented at Seagriculture 2024

Mechanised harvesting

- Prototype developed, not in u
- Challenges with vertical grow cutting, heavy loads and **spee**

Re-evaluation of the cultivation system and harvest strategy →

Co-location: A strategic response to increasing spatial pressures in European waters?

Unlocking the potential of macroalgae for a thriving European blue bioeconomy

2025

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Specifications for offshore requirements for seaweed cultivation

SEAMARK DELIVERABLE 2.2

Ocean Rainforest

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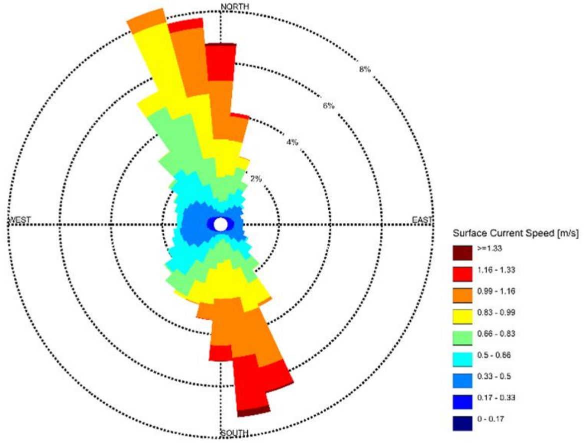
February 2026 | Deliverable 2.2 | SeaMark

- Opportunities for shared licenses, infrastructure, and reduced spatial conflict
- Potential optimal conditions mismatch
- Depending on operation integration

OCEAN RAINFOREST

VATTENFALL



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Conclusion

- Biological performance, reliable system design, and mechanisation of operations enable scaling of the seaweed industry

Action point

- Mechanisation and scalability of the harvesting process is key

Recommendation

- Current regulations are hindering market entry and expansion, limiting industry scale-up

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ALGA+

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algolesko

VATTENFALL

SIRPUTIS

Nofima

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Selective breeding breakthroughs

JEPPE T. ØSTERBERG, TRAITOMIC
PARTNERS: **ROSCOFF UNI, GALWAY UNI, ALGOLESKO, OCEAN RAINFOREST, ALGAPLUS**
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A large potential in variation and selection

Locally-sourced, wild type genotypes — S. latissima cultures at Ocean Rainforest, Faroe Islands

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Why strain improvement matters

As farming matures, the biological starting material becomes another controllable layer.

- Higher yield and farm output
- Stable composition
- Optimized morphology
- Better hatchery performance
- Robustness and stress tolerance
- Better product fit

Broad toolbox

Natural variation • phenotypic selection • crossing • common garden • marker assisted selection • genetics • induced variation • reverse genetics assisted selection

Context: Jueterbock et al. 2025 | Trait targets: Goecke et al. 2020 | Yield: Li et al. 2016 | Heat tolerance: Liu et al. 2014; Hwang et al. 2018

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Selective breeding tracks in SeaMark

The primary focus is increase of yield in Three parallel breeding tracks across species and methods

Ulva strain selection and genomic breeding

Ulva sp. strain selection and deployment of genomic selection for fast and cost-effective seaweed breeding

Natural variation • phenotypic selection • common garden • genetics • induced variation

S. latissima high-yield strain identification

Identification of highly productive, locally sourced S. latissima strains to increase productivity

Natural variation • phenotypic selection • crossing • marker assisted selection • genetics

Develop complete knock-out variant libraries

Development of complete knock-out libraries to enable rapid extraction of variants that has potential to increase aquaculture productivity

Genetics • induced variation • reverse genetics assisted selection

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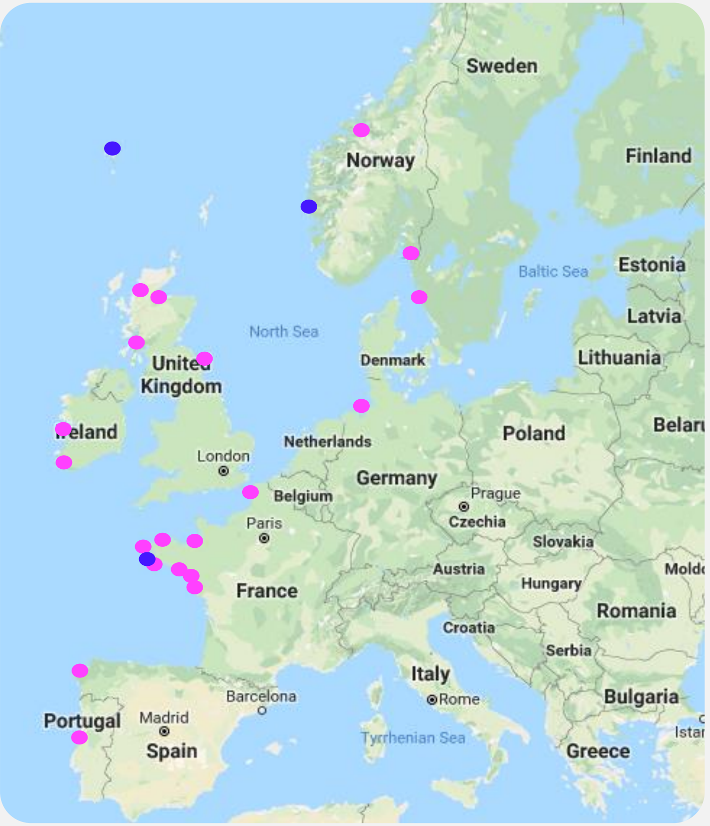
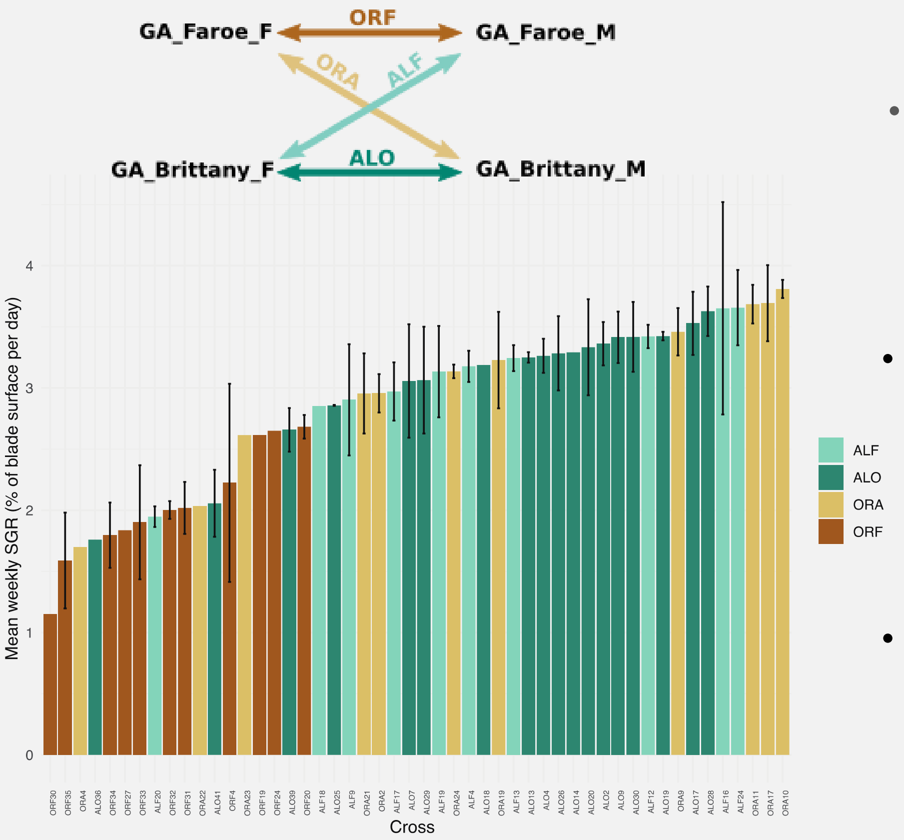
Utilizing natural variation: *S. latissima*

- **583 clonal gametophyte strains** sampled from 23 sites across Europe

GENIALG

- **All strains genotyped** using ddRAD-seq





- **168 crosses** to generate F1 hybrid sporophytes
- Phenotyping for growth and polysaccharide content
- 3 highest performing strains delivered to producers and undergoing field trials

Phenotypic evaluation of F1 hybrid sporophytes. **Zofia Nehr, Francis Le Madec**

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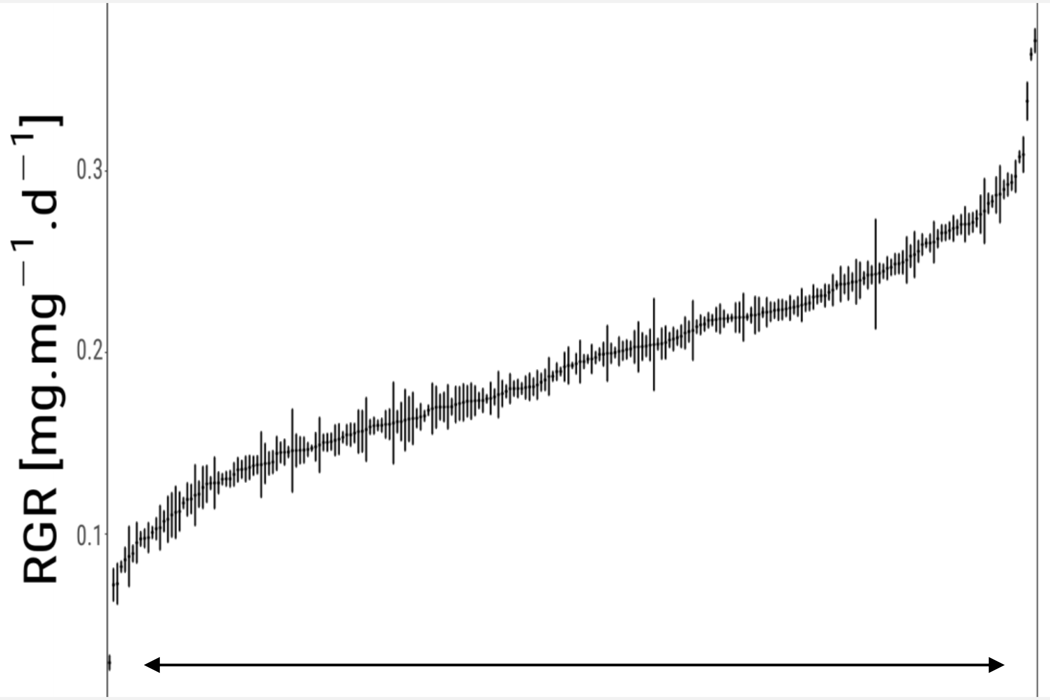
Utilizing natural variation: *Ulva sp.*

- **250 individual strains** from Algaplus facility
- and surrounding area **phenotyped for growth and protein content**

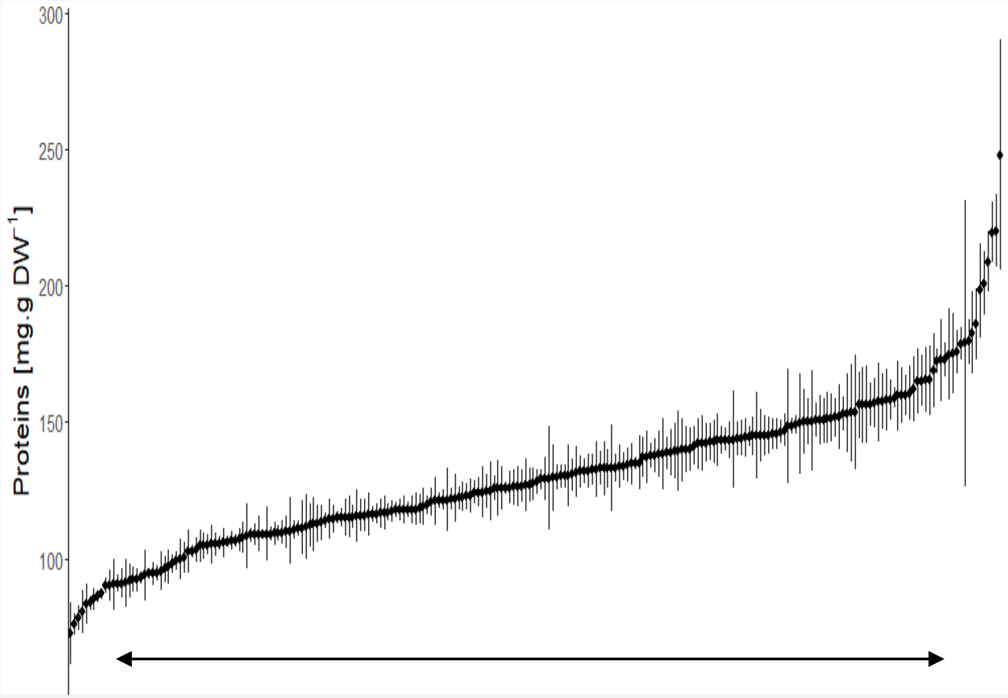
- **4-5 times variation** in growth and protein content

Relative growth rate



250 different individuals

Protein content



250 different individuals

Phenotypic evaluation of *ulva sp.* Growth rate (left) and protein content (right).

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Increasing variation: mutagenesis of *Ulva sp.*

OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

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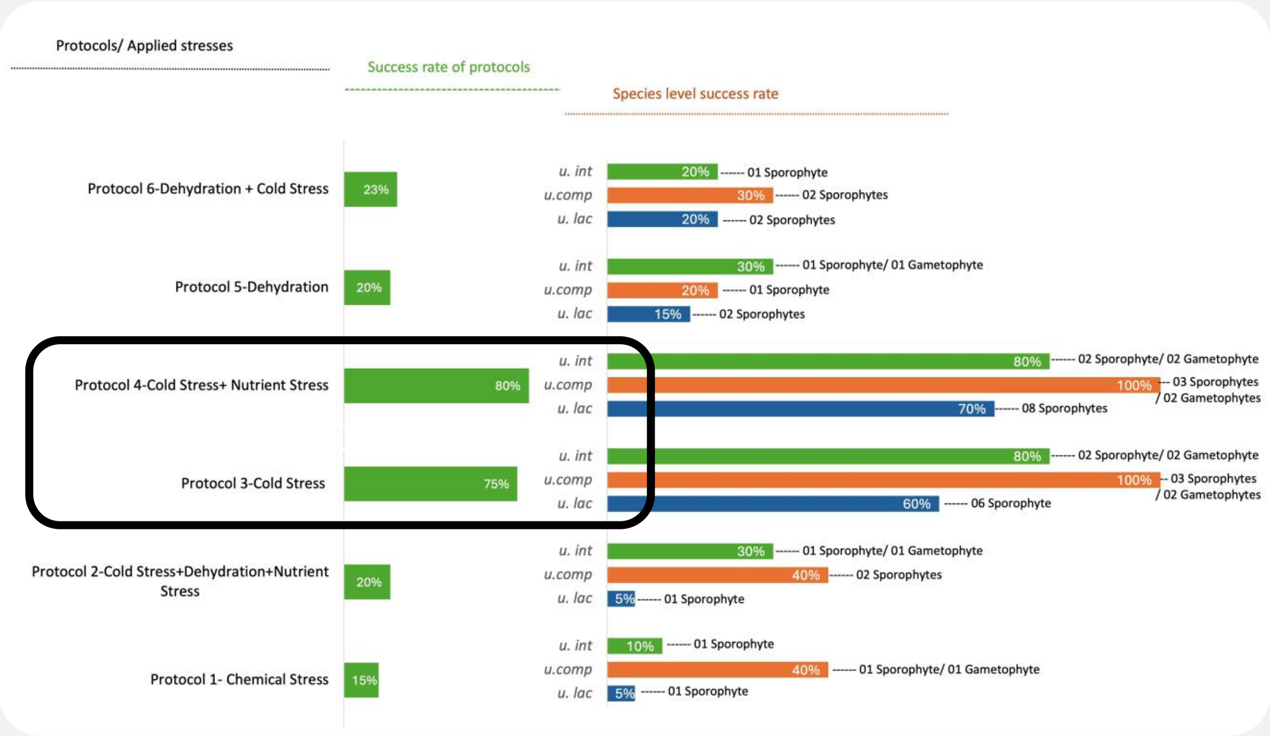
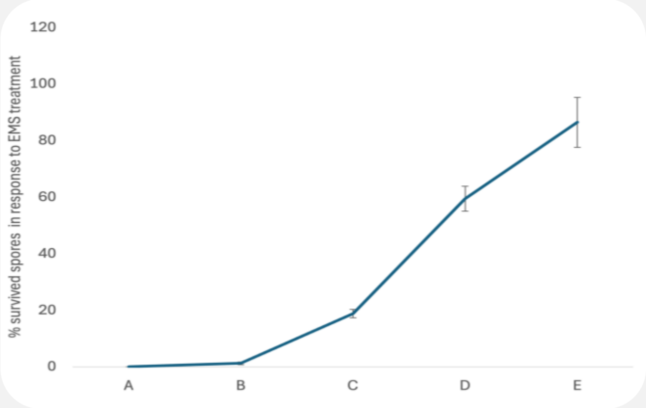
Sporulation protocol success rate in Ulva sp.

- Mutagenesis of single cell lifecycle stage (gametes) requires controlled sporulation
- Sporulation protocols established
- **3 Ulva species tested – 80% success rate**



Bibi et al., Algal Research, in revision

EMS Dose response curve on gametes



Garden experiment: Large induced variations

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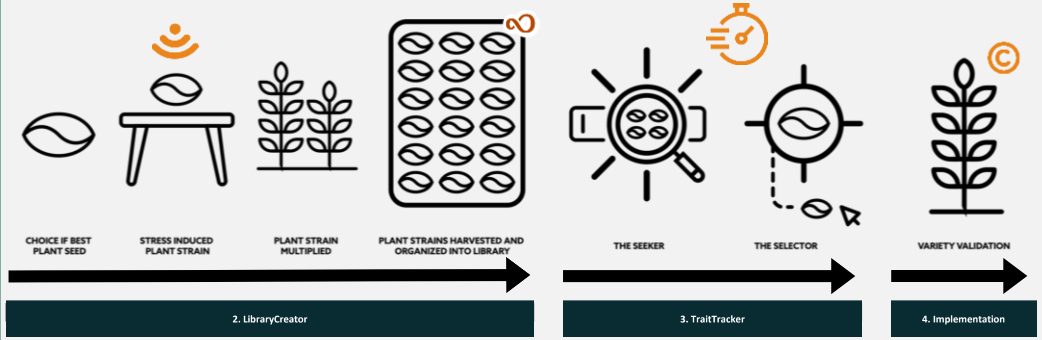
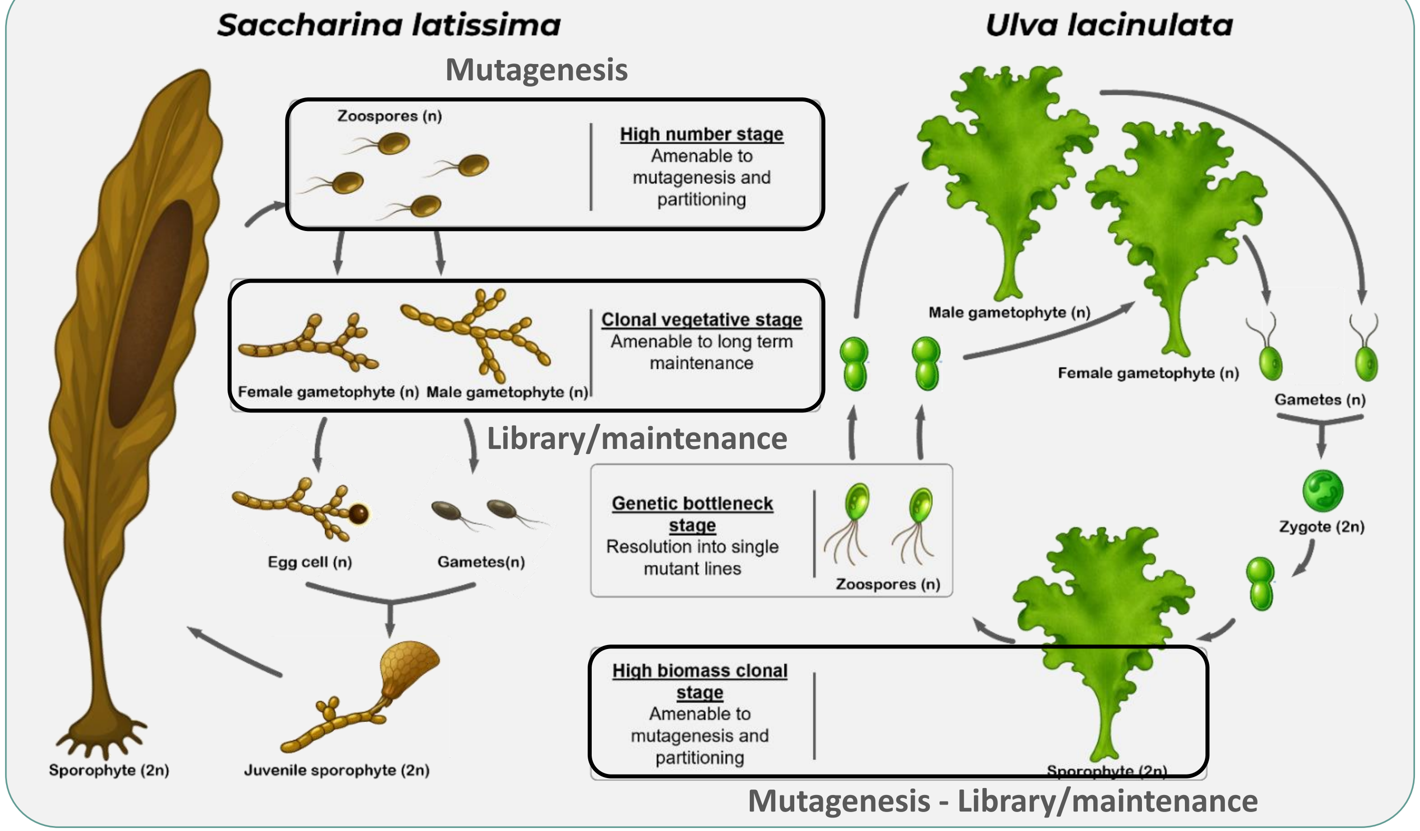
Functional genomics and full knockout libraries

FIND-IT technology: Trait development based on induced variation

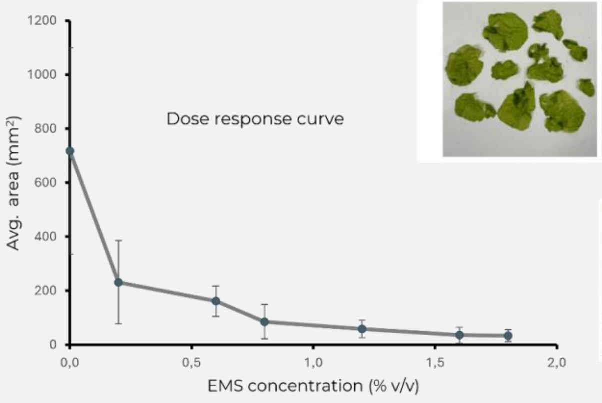


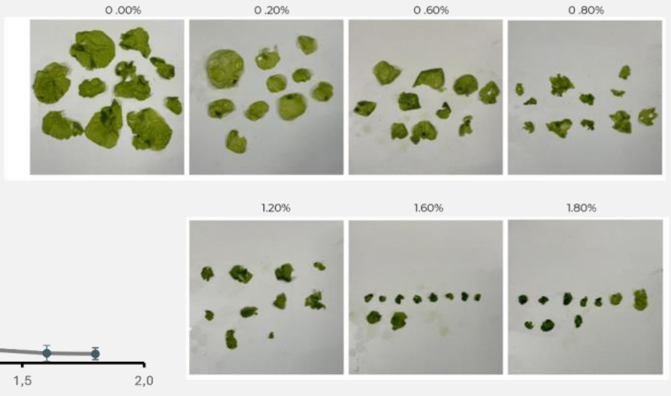
< 8 WEEKS From start to plant traits in existing libraries
< 12 MONTHS From start to plant traits in new libraries

- Established for plant and microbial trait development
- Enables rapid and specific identification of genetic variants
- For macroalgae, mutagenesis target, genetic bottlenecks and library maintenance stage must be determined.

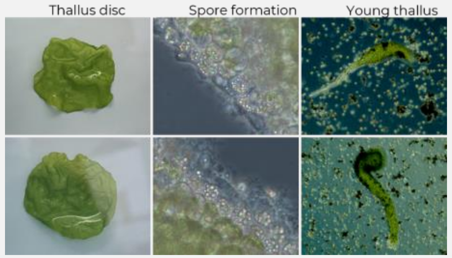


FIND-IT libraries in *U. lacinulata* and *S. latissima*



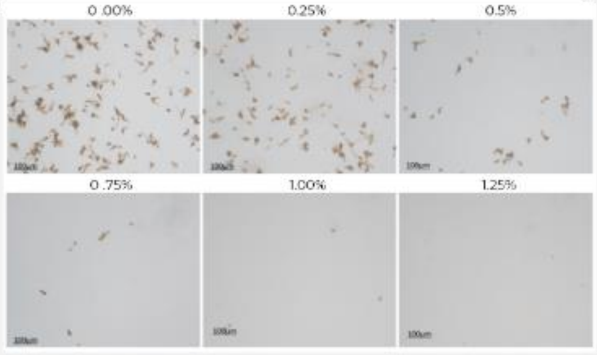


EMS mutagenized thalli 6 weeks days after treatment

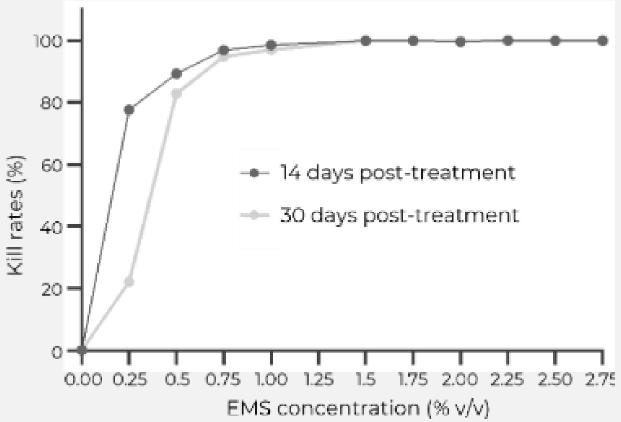


- Mutation protocol established
- Sporulation accomplished
- Library of **1000** initial thallus discs maintained
- Sequencing incomplete

S. latissima

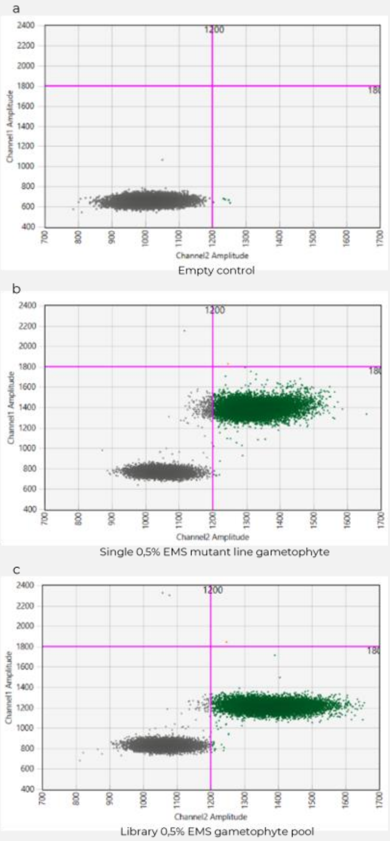


EMS mutagenized zoospores 30 days after treatment/spore release



- Mutation protocol established
- Mutation density of **1,53/Mbp** confirmed by sequencing
- Library of ~ 286.000 mutant lines established
- Estimated gene LOF coverage **99,99985%**

FIND-IT screening protocol establised in *S. latissima*



ddPCR assay validation data for S. latissima

- **FIND-IT Make use of digital droplet PCR screening to detect rare events in pooled DNA**
- **DNA extraction from *S. latissima* mutant lines and mutant pools were extracted**
- **Screening protocols were shown to detect specific probe signal for both**
- **Screening confirmed a mutation indicated by sequencing, confirming the assay ability to detect mutations in library material.**
- **As the FIND-IT pipeline is now established for S. latissima, libraries of new or other local strains can be ready for screening in <8 months**

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TRAITOMIC EMPOWERING NATURE

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Key findings

Ulva strain selection and genomic breeding

- High yielding *Ulva* strains were identified by phenotypic assessment
- Sporulation and mutagenesis protocols were established for several ulva strains
- Induced variation driven common garden experiment yielded large variation in size underlining the potential for the method for future breeding

S. latissima high-yield strain identification

- A large number of strains were collected and crossed. F1 hybrids were phenotyped for growth rate and polysaccharide content and genotyped by ddRAD sequencing.
- Highest performing strains were delivered to producers and are undergoing field trials

Develop complete knock-out variant libraries

- Mutagenesis protocols were established for both *S. latissima* zoospores and *Ulva lacinulata* thalli
- A large full gene LOF coverage library was established for *S. latissima* and is ready for FIND-IT screening.

Future Directions

Ulva sp.

- Mutagenesis-based variation enables phenotypic screening for additional traits:
  - Temperature tolerance
  - Stress tolerance
  - Tailored biochemical composition
- Genotyping of identified variants will enable causal gene identification and subsequent targeted breeding
- Sequencing confirmation of the mutant library and FIND-IT protocols will enable rapid extraction of trait variants for breeding implementation

S. latissima

- Large strain collection and F1 hybrids can be phenotyped for additional traits to identify high-quality source material
- Continued selection on subsequent generations combined with genetic markers can generate elite material and identify underlying genetics
- Screening the existing FIND-IT mutant library for key genetic loci can accelerate breeding
- With an established FIND-IT pipeline, new S. latissima libraries can be generated in less than a year, enabling rapid trait development in local strains

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Jeppe Thulin Østerberg

Traitomic

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Reducing the cost of cultivated seaweed: Results from techno-economic assessments

DR MAGNI LAKSÁFOSS
SENIOR ECONOMIST
SJÓKOVIN

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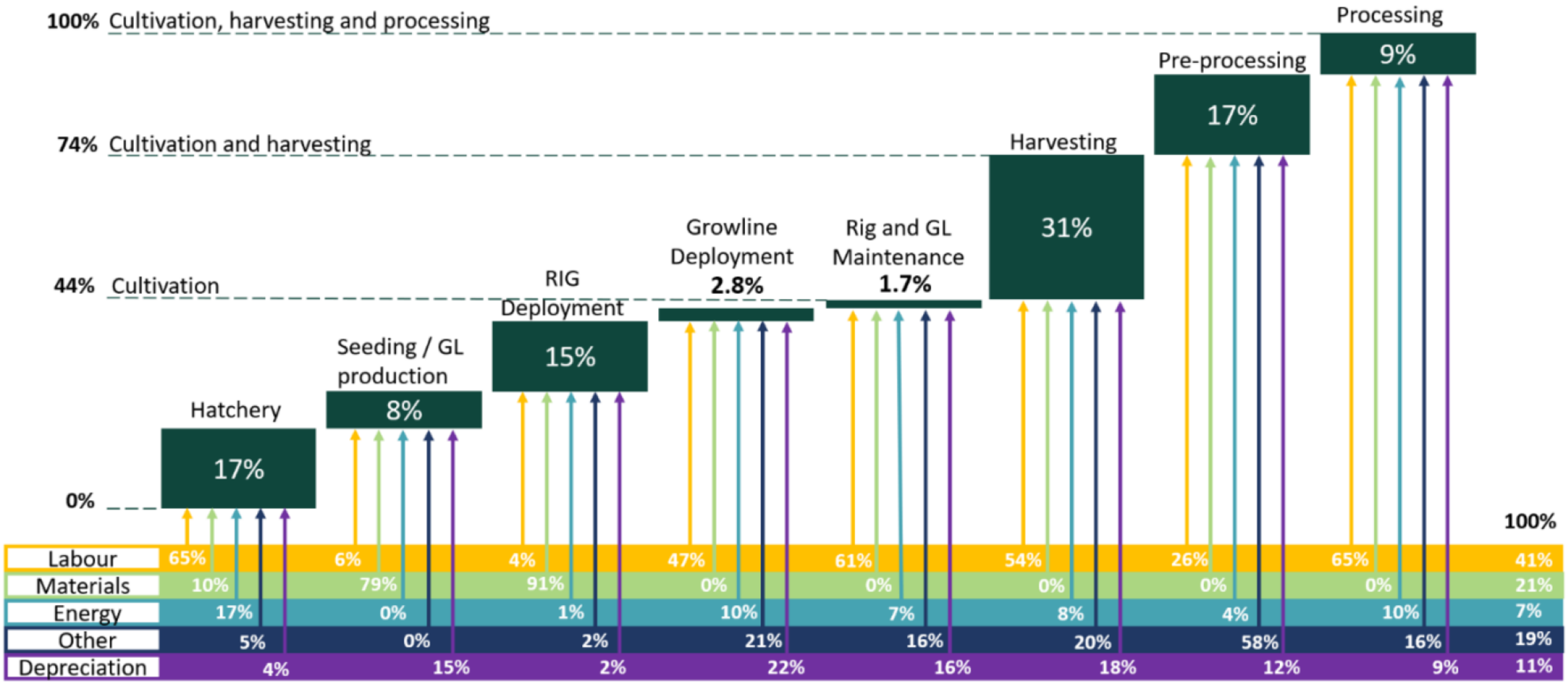
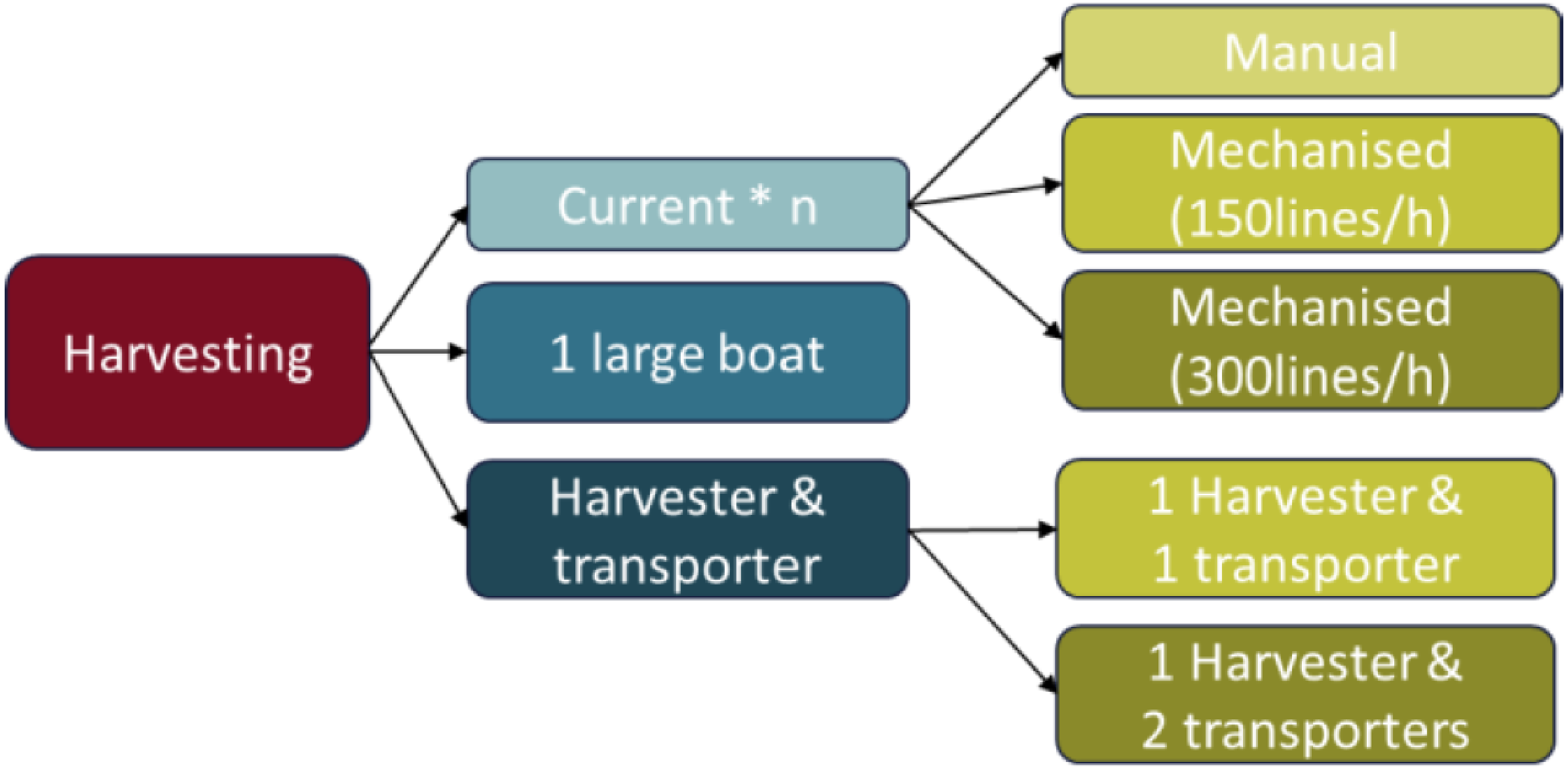
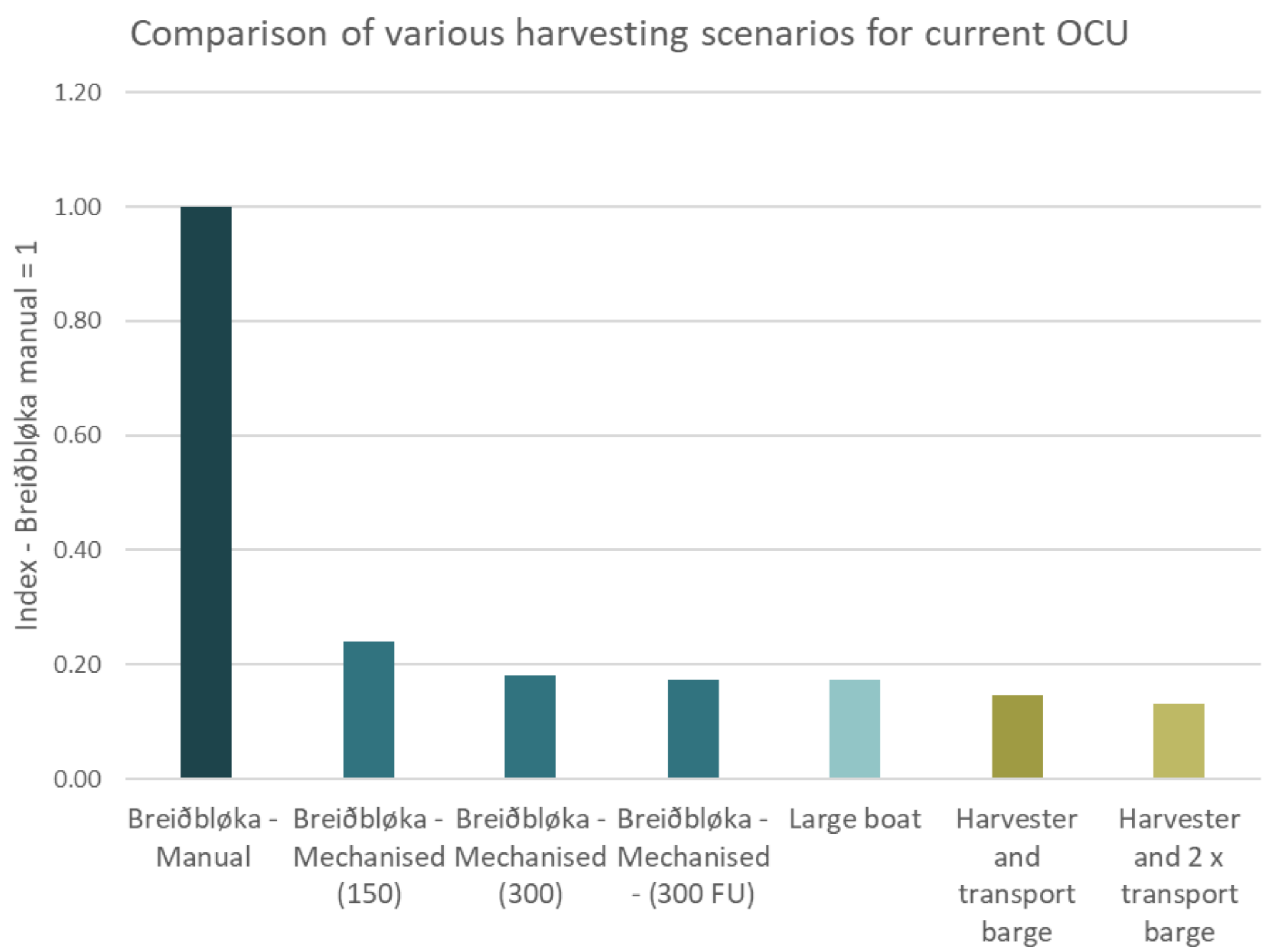
sjókovin
blue resource

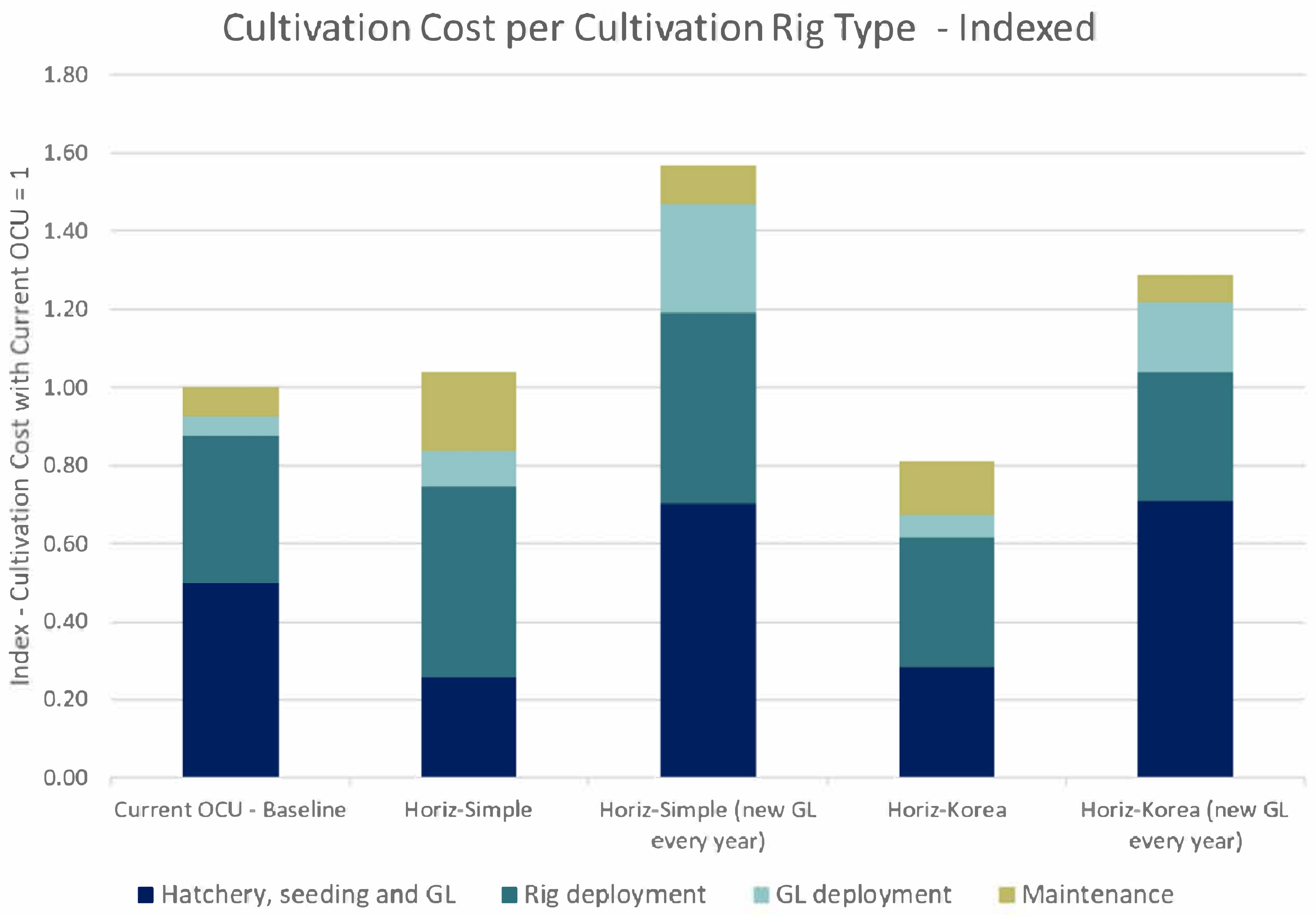
Current value chain for fermented macroalgae

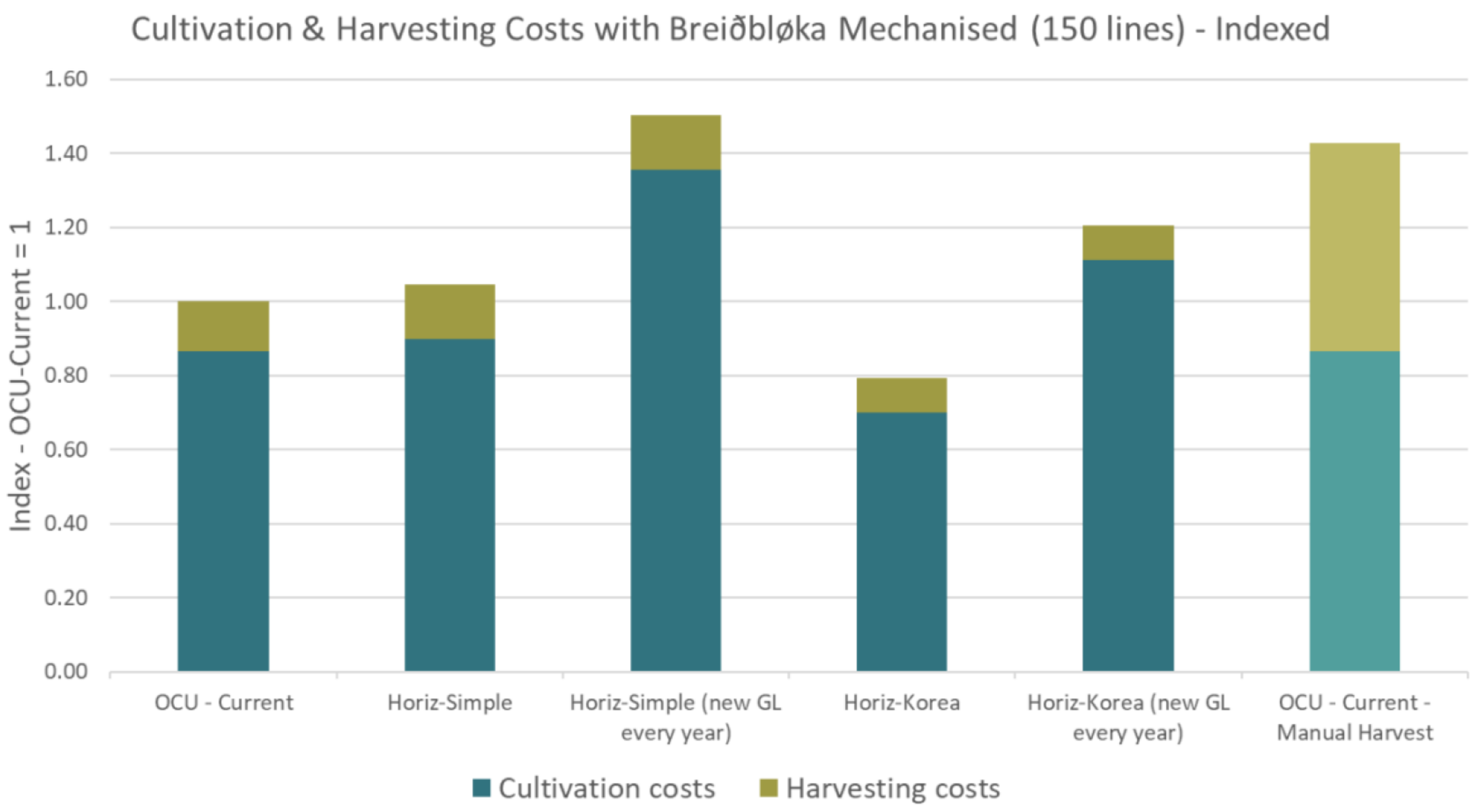
Cost expressed as a % of total cost of producing fermented macroalgae



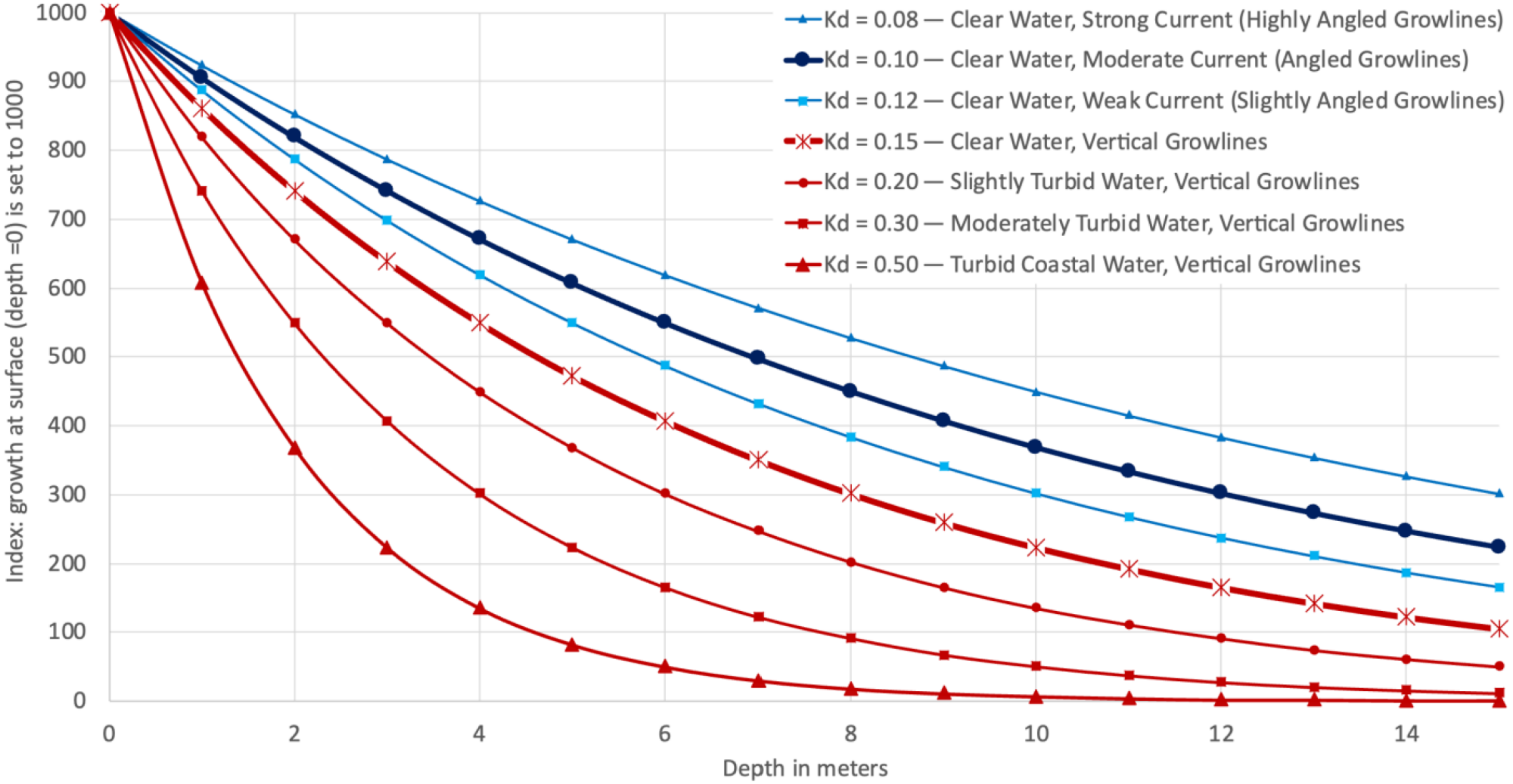

Harvesting
Current * n
1 large boat
Harvester & transporter
Manual
Mechanised (150lines/h)
Mechanised (300lines/h)
1 Harvester & 1 transporter
1 Harvester & 2 transporters

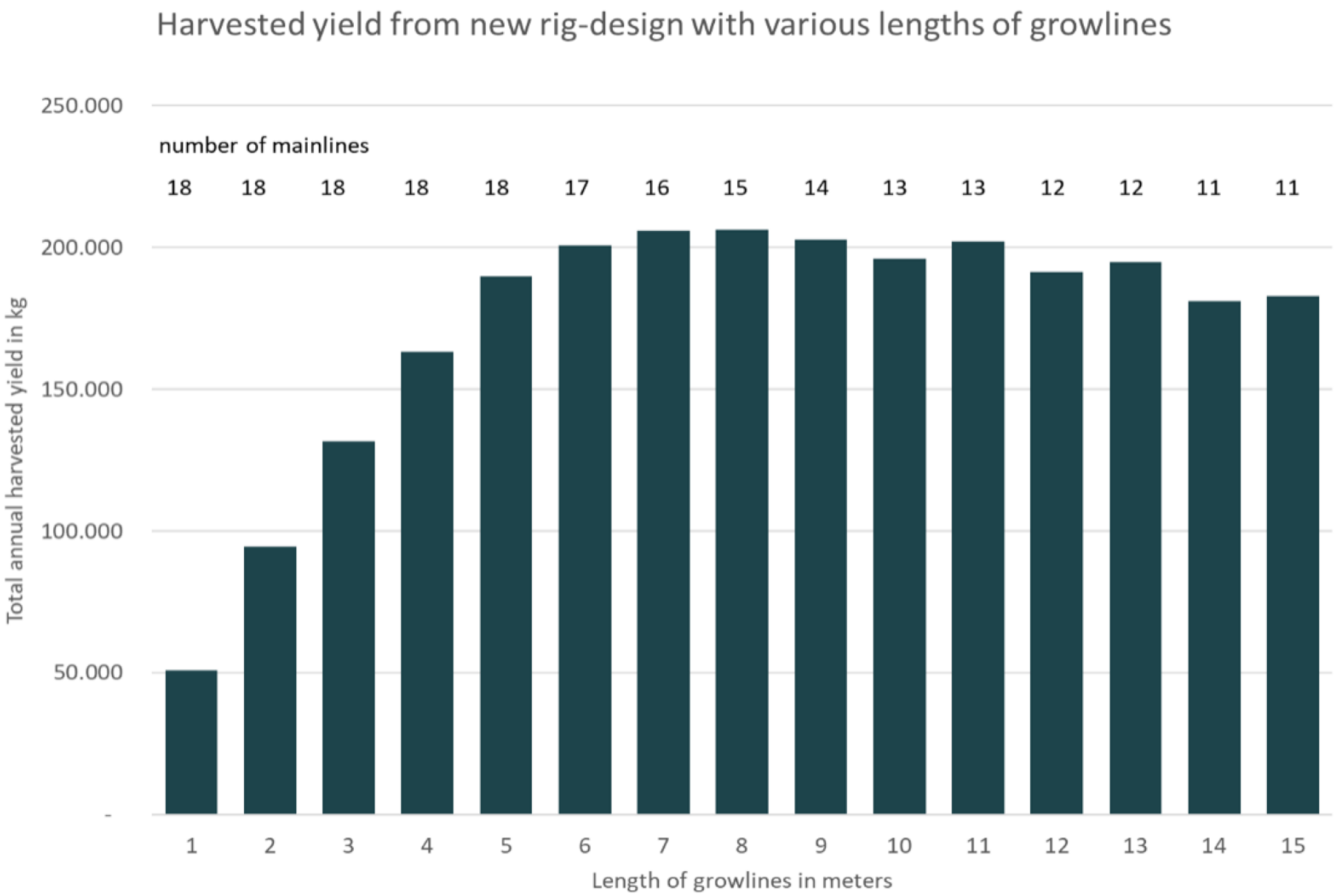

Comparison of various harvesting scenarios for current OCU
Index - Breiðbløka manual = 1
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Breiðbløka - Manual
Breiðbløka - Mechanised (150)
Breiðbløka - Mechanised (300)
Breiðbløka - Mechanised - (300 FU)
Large boat
Harvester and transport barge
Harvester and 2 x transport barge


Cultivation Cost per Cultivation Rig Type - Indexed
Index - Cultivation Cost with Current OCU = 1
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Current OCU - Baseline
Horiz-Simple
Horiz-Simple (new GL every year)
Horiz-Korea
Horiz-Korea (new GL every year)
Hatchery, seeding and GL
Rig deployment
GL deployment
Maintenance


Cultivation & Harvesting Costs with Breiðbløka Mechanised (150 lines) - Indexed
Index - OCU-Current = 1
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
OCU - Current
Horiz-Simple
Horiz-Simple (new GL every year)
Horiz-Korea
Horiz-Korea (new GL every year)
OCU - Current - Manual Harvest
Cultivation costs
Harvesting costs

Yield profiles with various turbidity





Harvested yield from new rig-design with various lengths of growlines
250.000
200.000
150.000
100.000
50.000
-
number of mainlines
18 18 18 18 18 17 16 15 14 13 13 12 12 11 11
Total annual harvested yield in kg
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Length of growlines in meters

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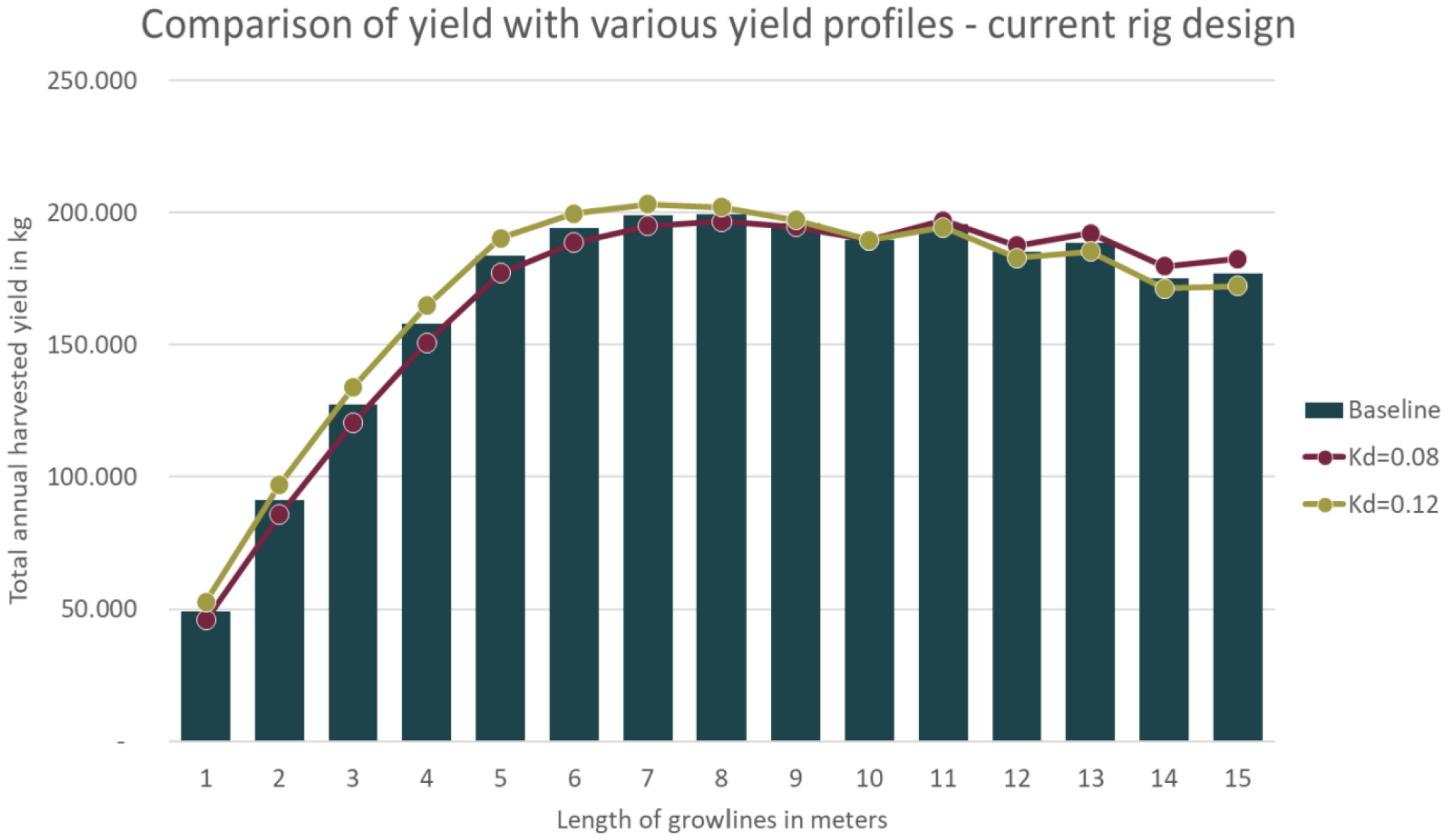

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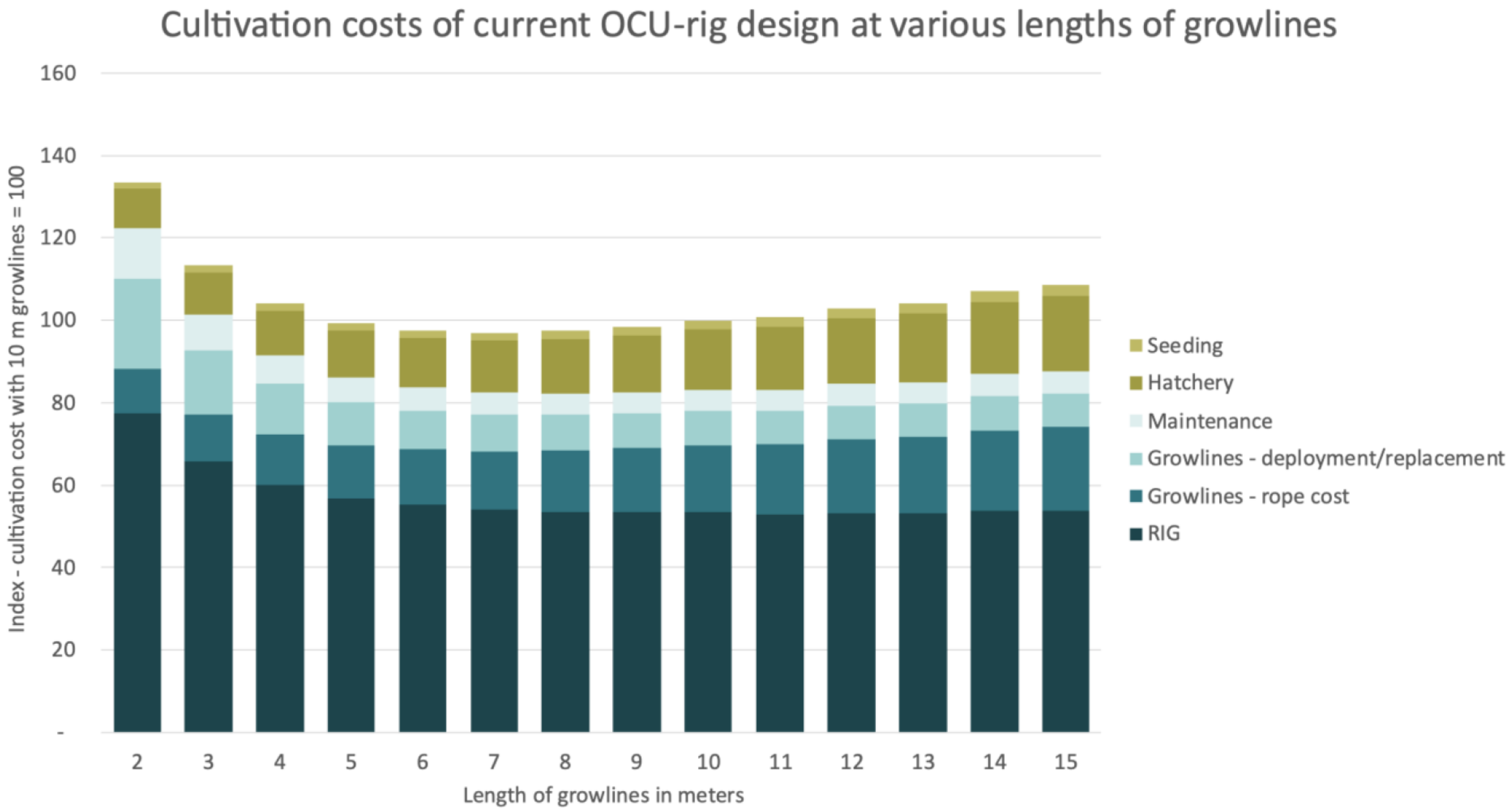
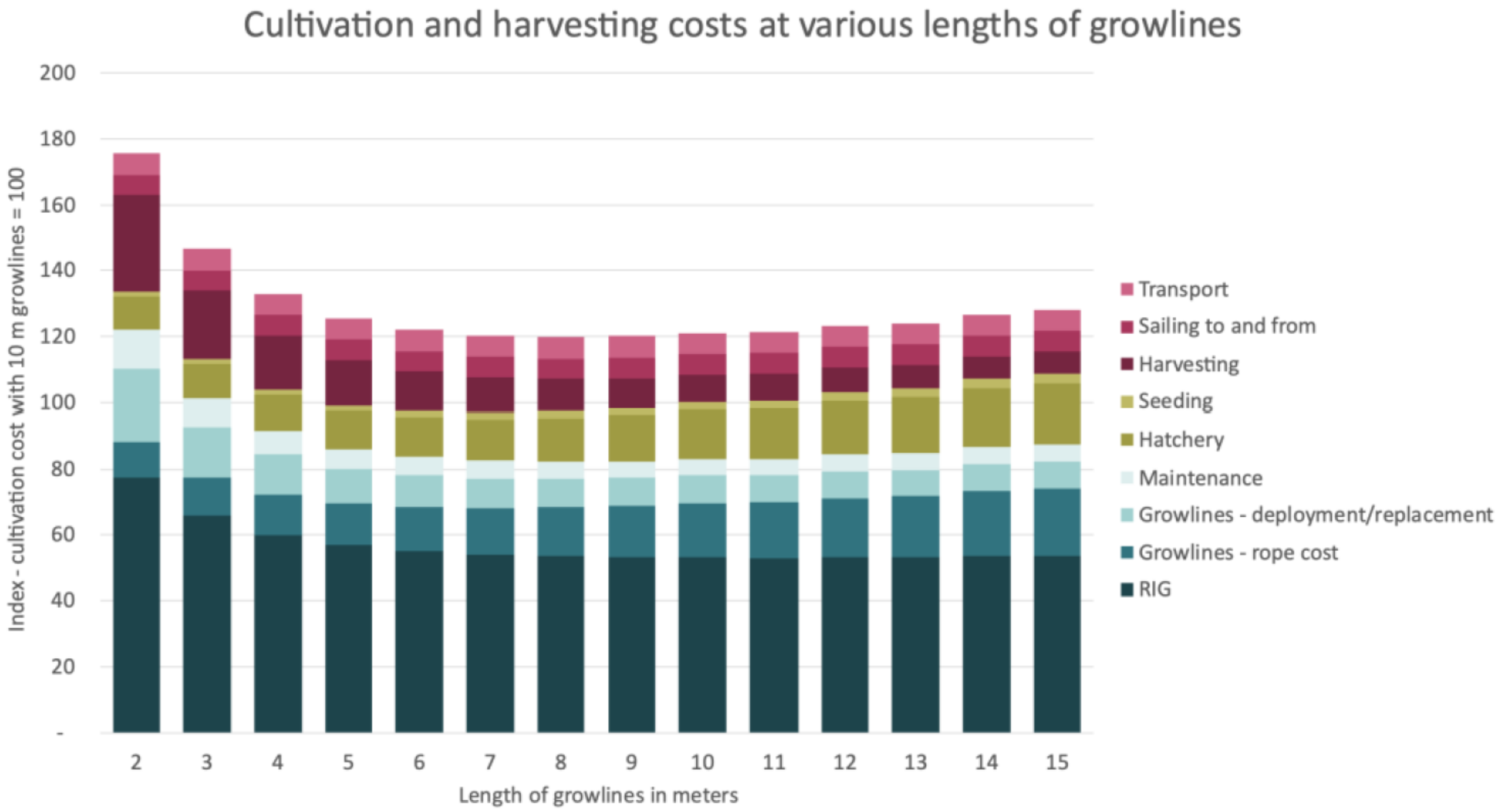
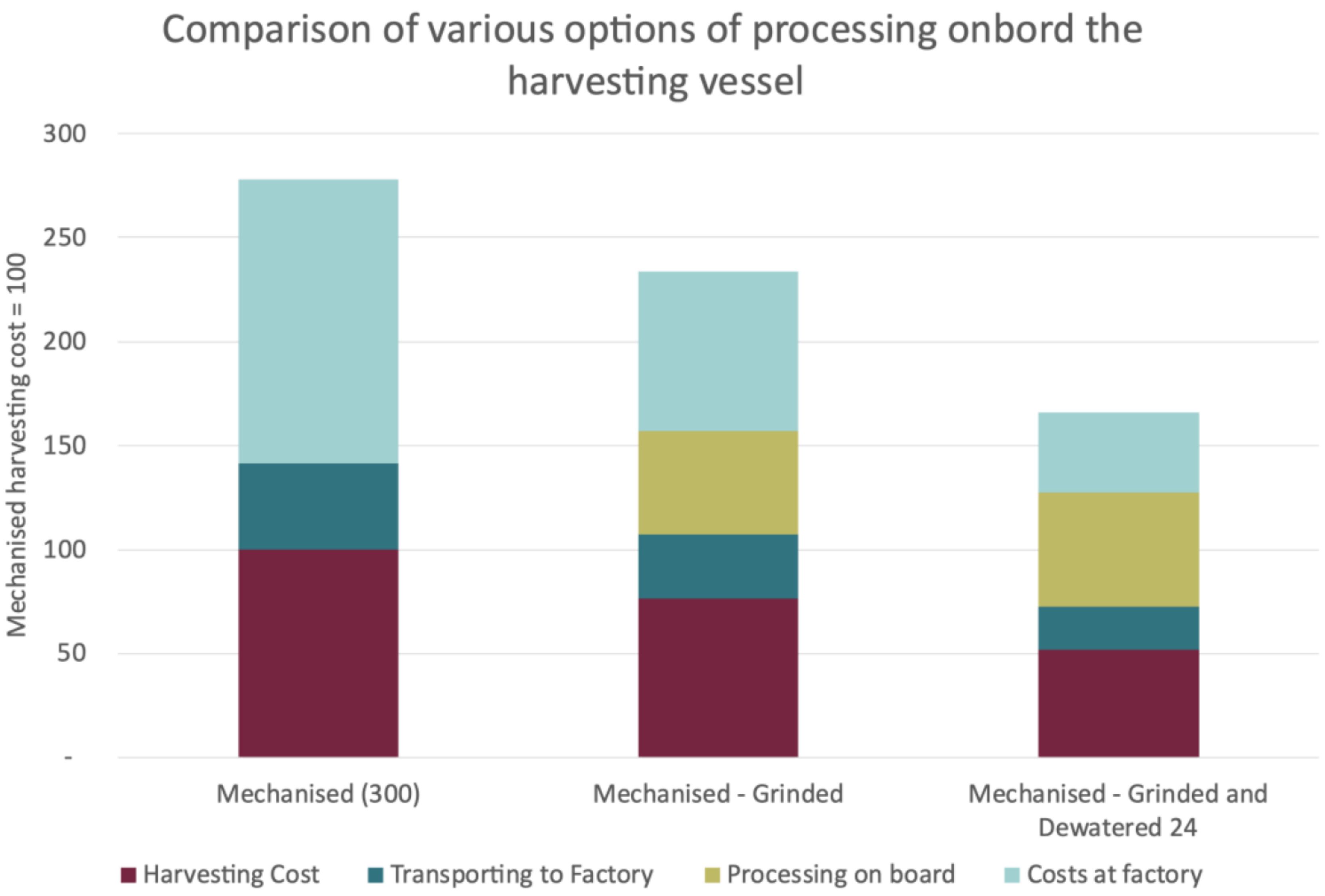

Cultivation costs of current OCU-rig design at various lengths of growlines
160
140
120
100
80
60
40
20
-
Index - cultivation cost with 10 m growlines = 100
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Length of growlines in meters
Seeding
Hatchery
Maintenance
Growlines - deployment/replacement
Growlines - rope cost
RIG



Cultivation and harvesting costs at various lengths of growlines
Index - cultivation cost with 10 m growlines = 100
200
180
160
140
120
100
80
60
40
20
-
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Length of growlines in meters
Transport
Sailing to and from
Harvesting
Seeding
Hatchery
Maintenance
Growlines - deployment/replacement
Growlines - rope cost
RIG



Comparison of various options of processing onbord the harvesting vessel
Mechanised harvesting cost = 100
300
250
200
150
100
50
-
Mechanised (300)
Mechanised - Grinded
Mechanised - Grinded and Dewatered 24
Harvesting Cost
Transporting to Factory
Processing on board
Costs at factory

Thank you

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From Pilot to Market: Pathways towards Upscaling Production

DR. UNN LAKSÁ, CEO SJÓKOVIN – BLUE RESOURCE
JULIANA ARIAS HANSEN, KATRINE ERIKSEN, SANDER VAN DEN BURG
THE FINAL SEAMARK MEETING, MAY 20TH, 2026, LIMASSOL, CYPRUS

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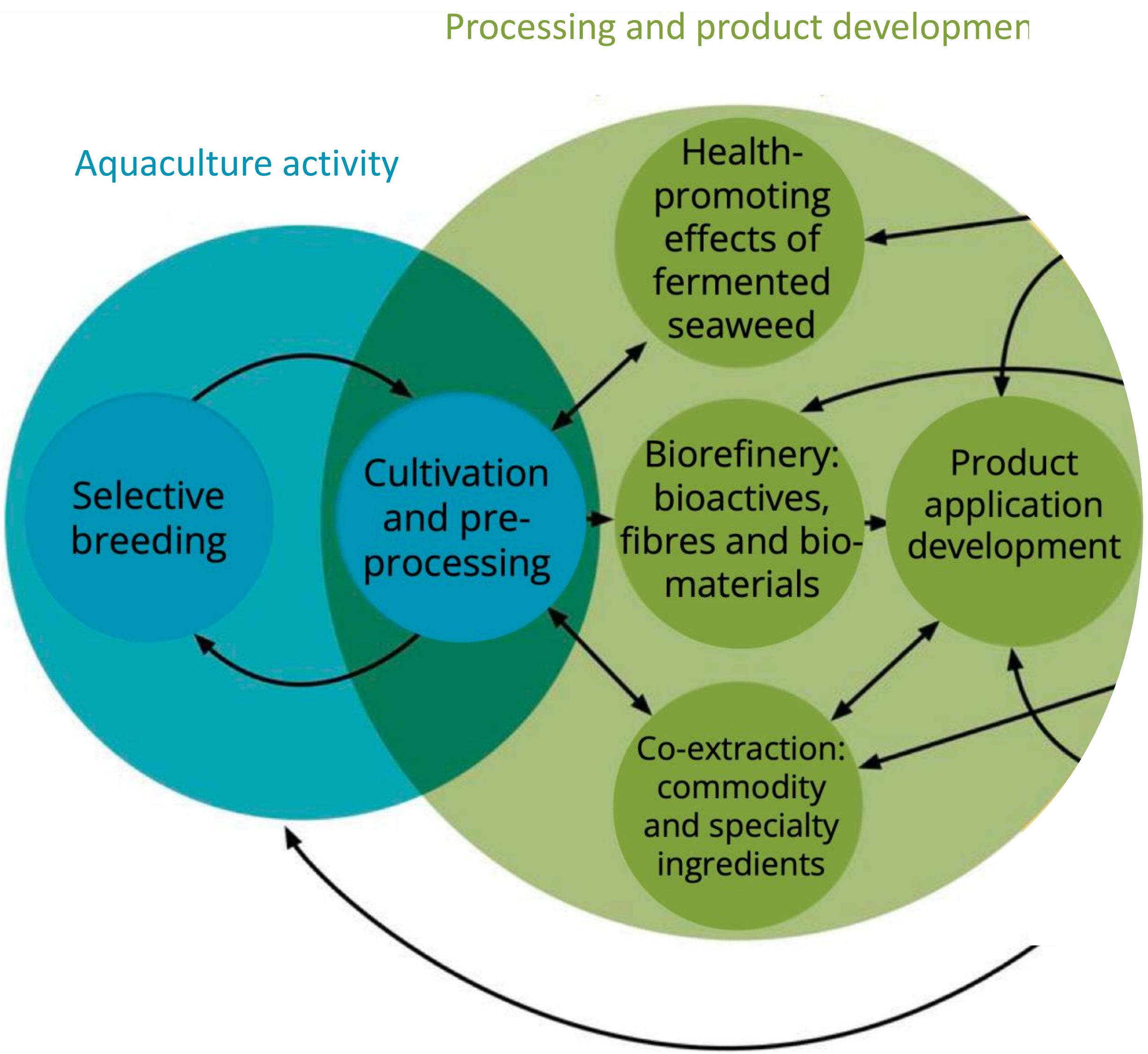
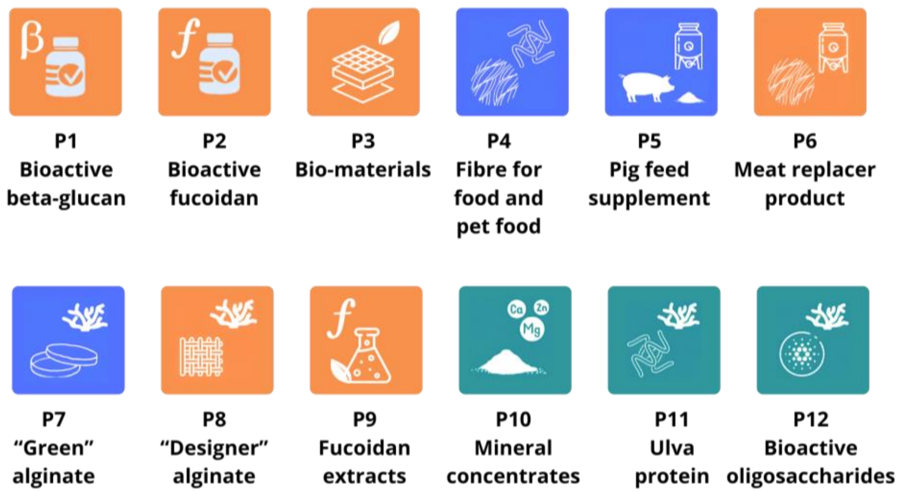


12 SeaMark Products



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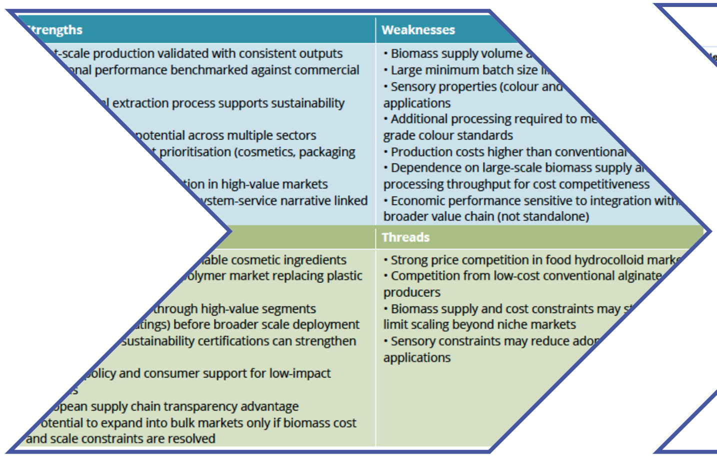
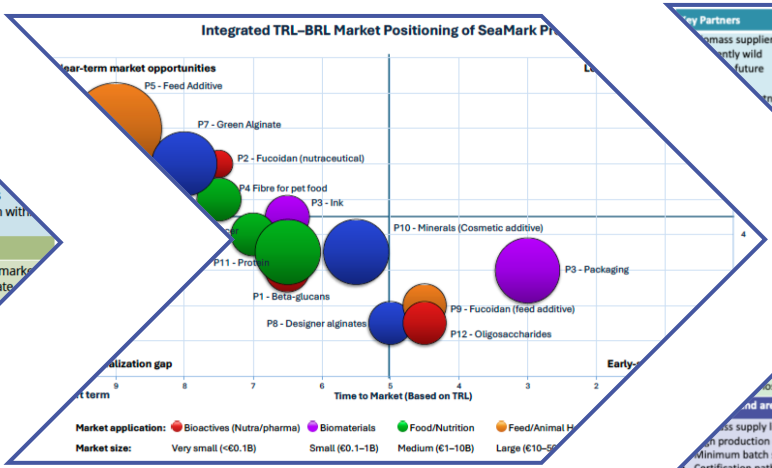
Integrating SeaMark portfolio: TRL–BRL and Business Exploitation Plans

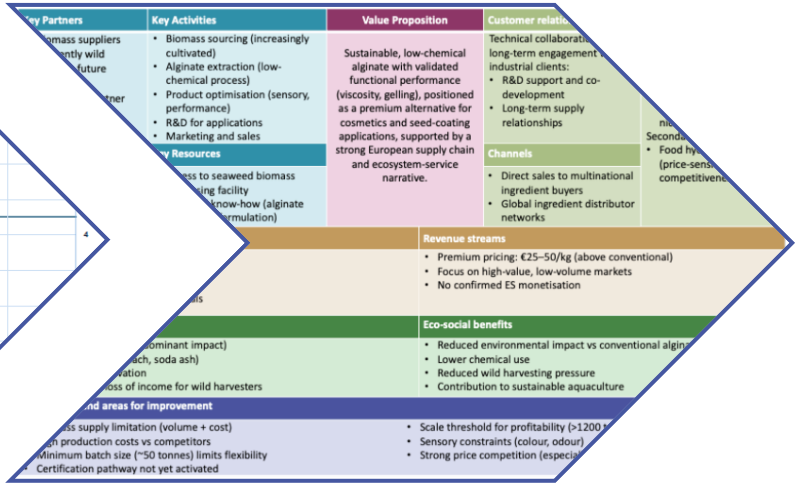
- The previous assessments were integrated - *at the product level* - through:



SWOT Analysis



TRL/BRL integration



Business Canvas Models

S

Strong sustainability narrative

- cultivated seaweed brings positive ecosystem services and low negative environmental impacts compared to many alternatives

Potential co-extraction synergies

- multi-product processing can increase biomass utilisation and improve overall resource efficiency.

Functional differentiation

- unique material/functional properties (alginate variants, bioactives, fibre/protein functionalities

Demonstrated pilot successes and existing IP and know how

- Production process demonstrated at pilot scale

Early market validation

- initial customer testing, distribution channels or repurchase behaviour

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W

Biomass supply constraints

- limited volumes, high unit cost and seasonal compositional variability.

Co-extraction economics

- lower-value fractions often have weak standalone techno-economic cases

Regulatory complexity

- novel-food, health-claim and sectoral fragmentation create long, expensive approval paths for many products

Sensory & quality issues

- colour, odour and compositional variability can restrict use in sensitive applications

Limited commercial scale

- Lack of replicated large-scale validation and stable cost structures

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Premium niches, certification & claims

- cosmetics, seed-coating biopolymers, pet food and specialty feed where sustainability and traceability can command premiums, certification can unlock market access and premium

Ecosystem-service monetisation

- blue-carbon, nutrient-credit or other MRV-backed payments to de-risk finance and lower net costs

Co-location & vertical integration

- near-farm processing and long-term supply contracts reduce transport and handling costs

Process optimisation & technological innovation

- heat recovery, drying optimisation, onboard dewatering and enzyme scale-up can materially cut costs

Targeted clinical/field validation

- robust trials (farm ROI, clinical studies) can validate claims and accelerate adoption

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T

Low-cost competition

- established terrestrial ingredients, conventional alginate and commodity feedstocks produced at scale and low price

Price sensitivity in target markets

- many host markets tolerate only limited premiums unless clear, immediate ROI is proven

Regulatory delays/uncertainty

- slowing market entry and increasing development cost and risk.

Supply-chain failures

- Issues with production or permitting problems can disrupt production and increase unit costs

Investment risk / CAPEX barriers

- Upscaling production requires large up-front capital and competitive financing; lack of offtake agreements undermines investment.

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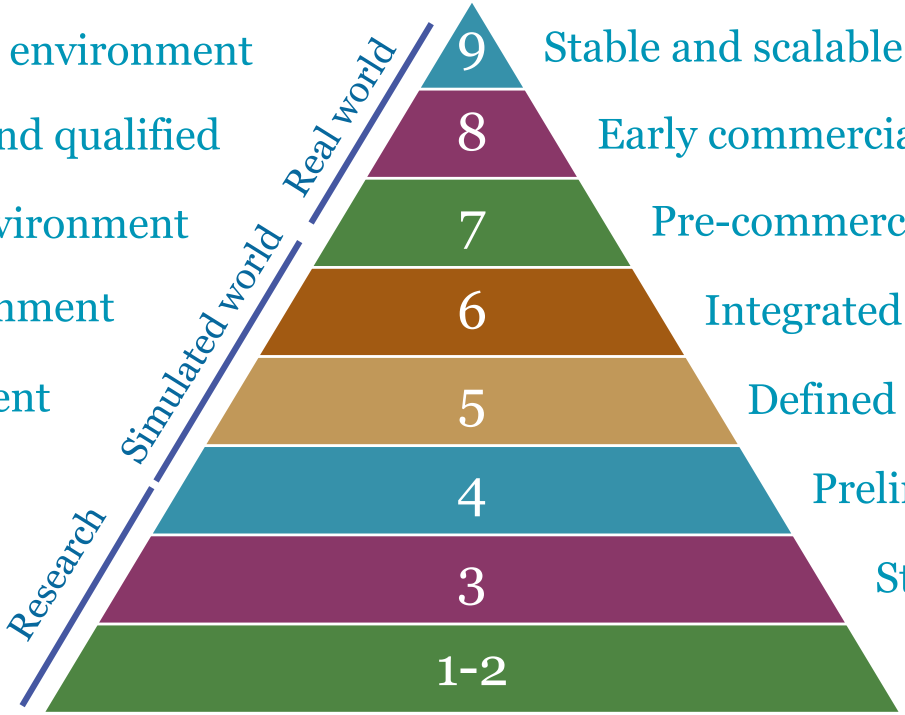
“Does the technology work?”

“Can we make a profitable business out of it?”

Technological readiness level

- Actual System proven in operational environment
- System complete and qualified
- System prototype demonstrated in operational environment
- Technology demonstrated in relevant environment
- Technology validated in relevant environment
- Technology validated in a lab
- Experimental proof of concept
- Technology concept formulated



Business readiness level

- Stable and scalable commercial system
- Early commercial deployment
- Pre-commercial operational readiness
- Integrated value-chain feasibility
- Defined business model and supply concept
- Preliminary business case development
- Structured commercial concept
- Initial Commercial Hypothesis

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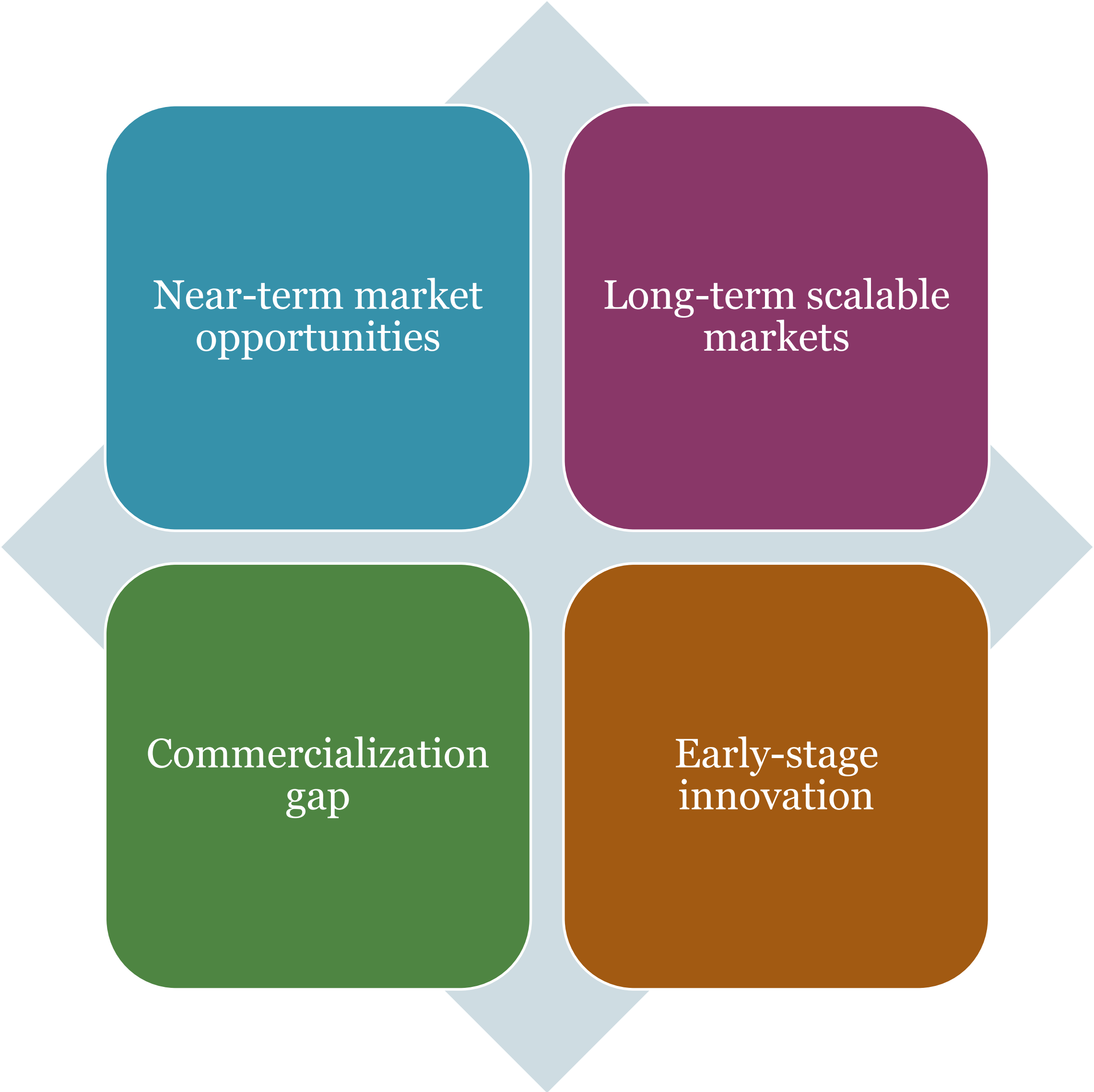
integrating TRL and BRL

- TRL and BRL assessment allows us to place the SeaMark products into four separate quadrants
- Identification of alignment or misaligment between technological and commercial maturity



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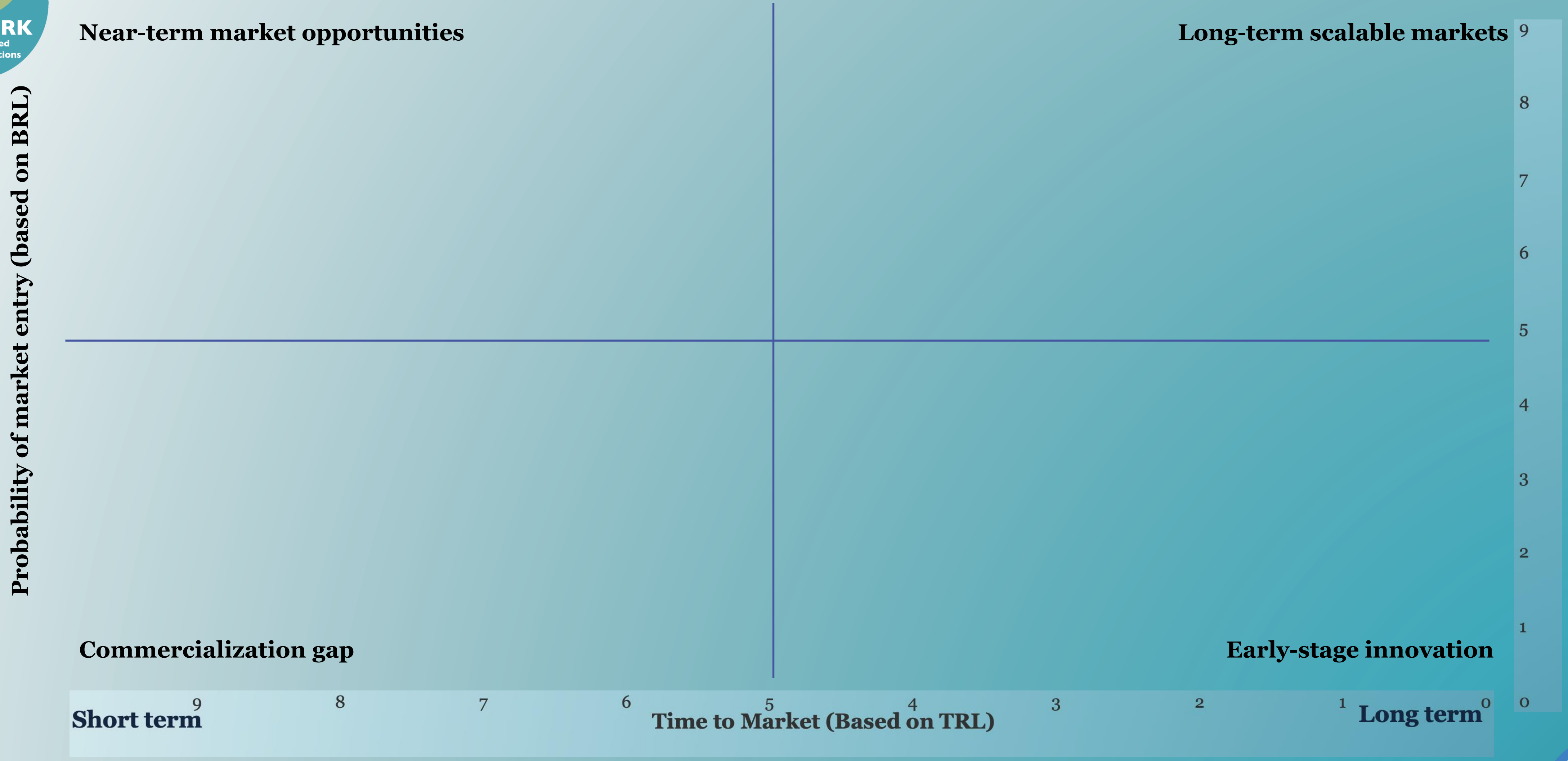
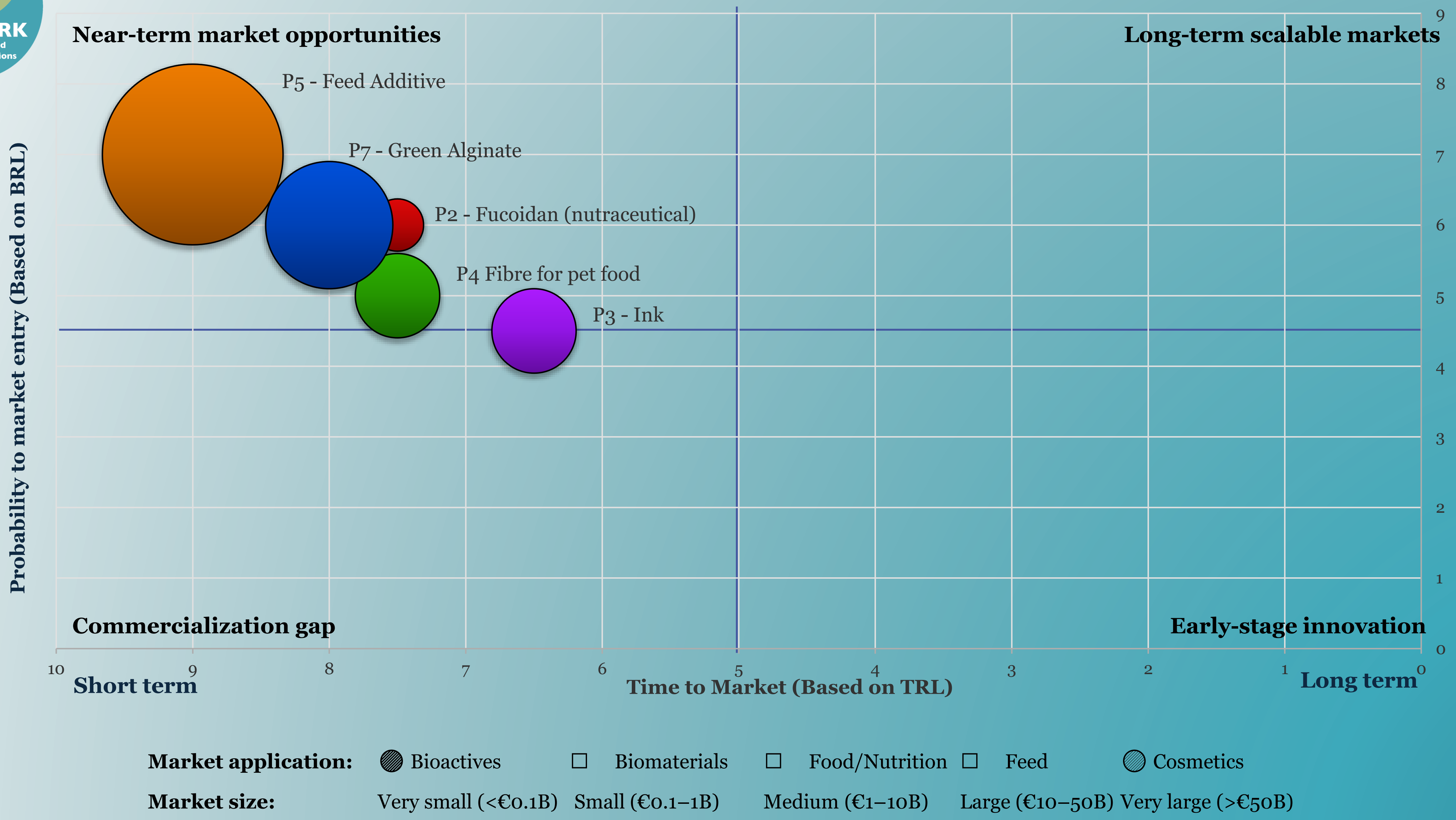


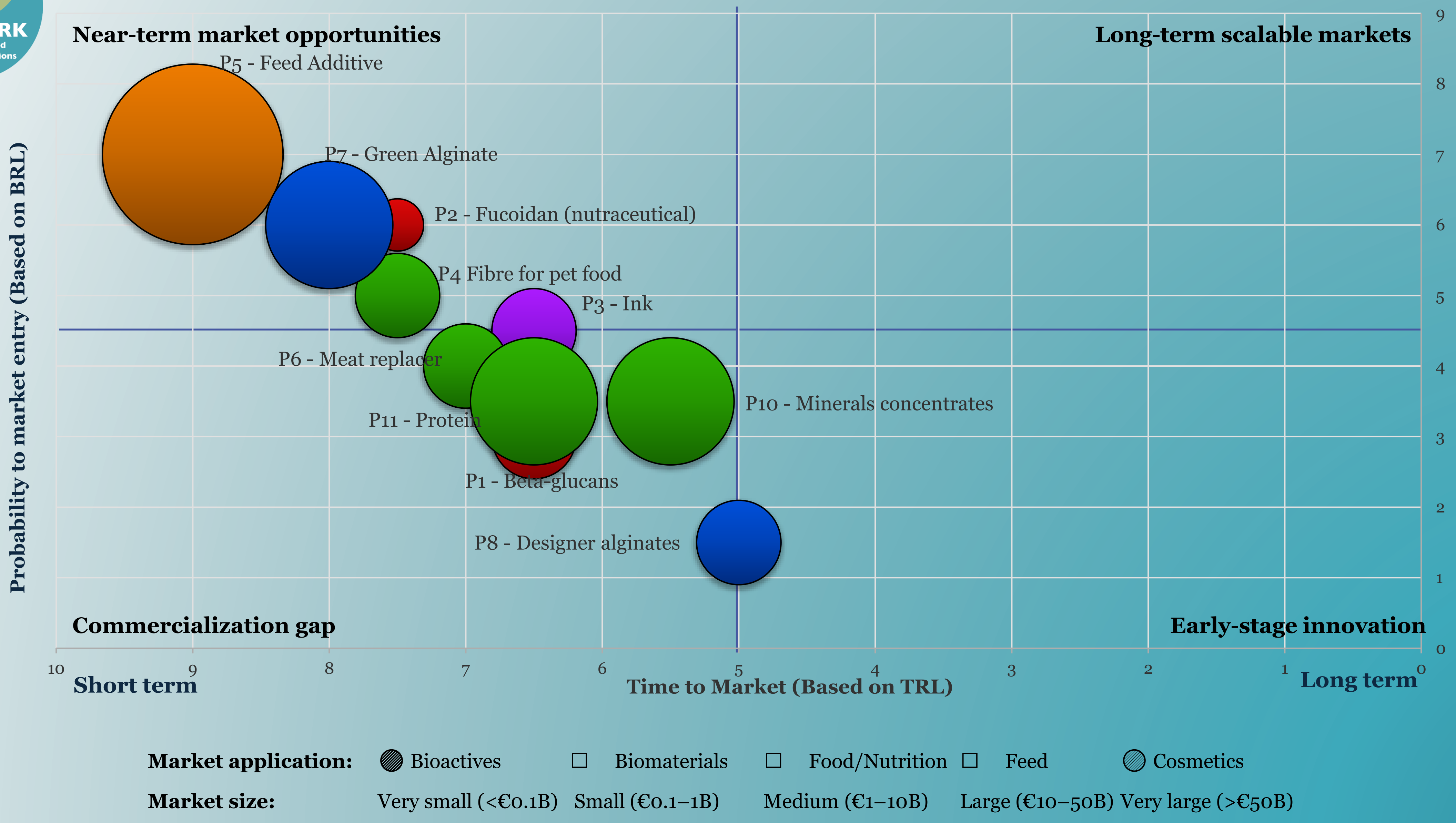
Market application: Bioactives ☐ Biomaterials ☐ Food/Nutrition ☐ Feed Cosmetics

Market size: Very small (<€0.1B) Small (€0.1–1B) Medium (€1–10B) Large (€10–50B) Very large (>€50B)

Integrated TRL–BRL Market Positioning of SeaMark Products



Integrated TRL–BRL Market Positioning of SeaMark Products



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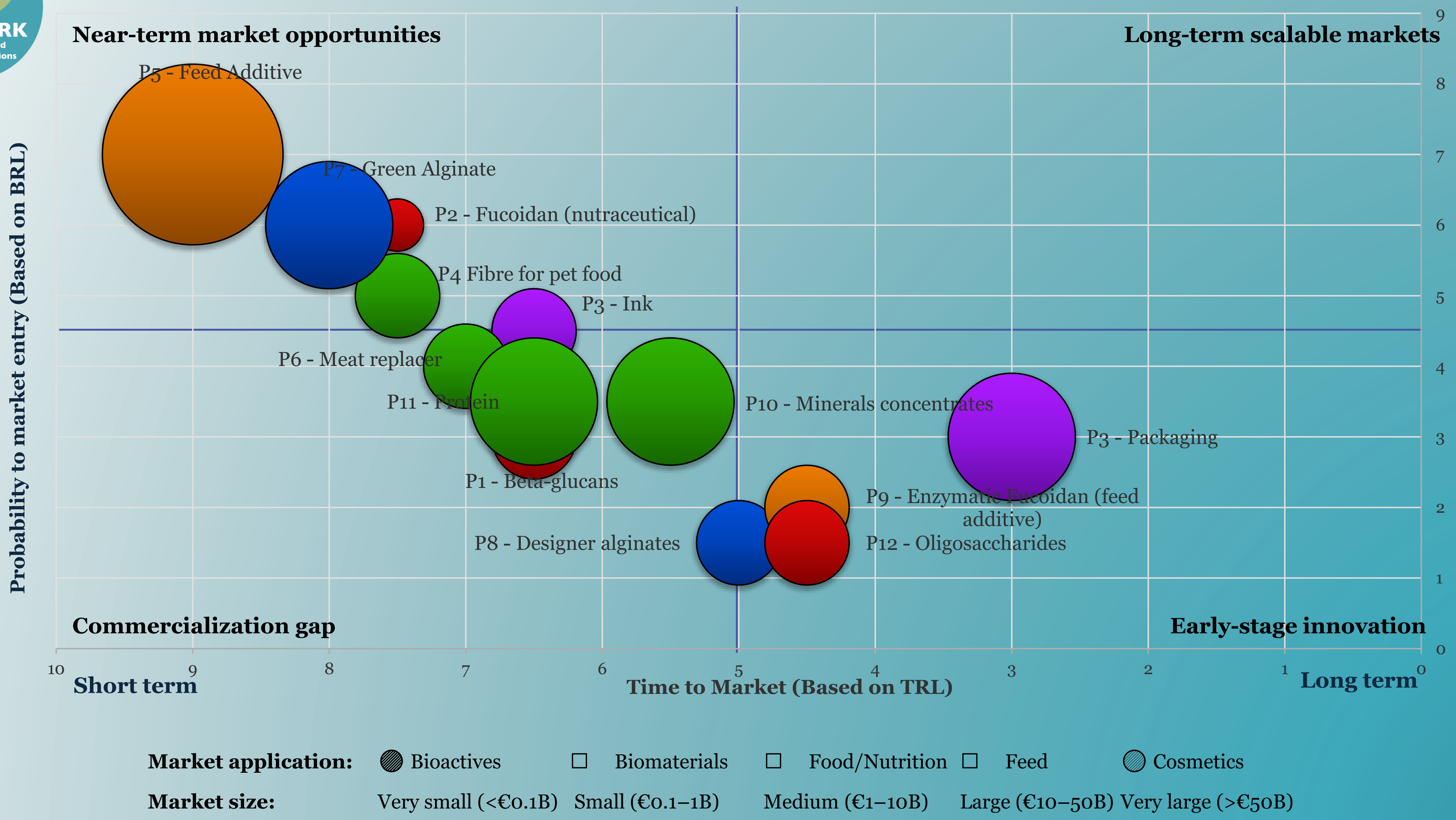
Integrated TRL–BRL Market Positioning of SeaMark Products



Challenges

- Biomass cost dominates economics
- Energy use is a major cost driver
- Transport/logistics strongly affect viability
- High-value products can improve margins but increase complexity and costs
- Sustainability and ecosystem value is underleveraged on the market and not embedded in financing

Strategic implications

- Strengthen cultivation systems and secure biomass reliability
- Support step by step commercialisation pathways
- Accelerate customer validation and offtake partnerships
- Improve regulatory and certification alignment
- Develop finance mechanisms that recognise ecosystem value
- Support industrial transition and improve sector governance

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SeaMark has demonstrated that Europe's seaweed sector is advancing toward commercial reality...

but realising its potential will not come from a single breakthrough.

Successful scale-up requires coordinated alignment between technology, biomass supply, market formation, regulation and financing

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seamarkeu

Dr Unn Laksá
CEO
unn@sjokovin.fo

sjókovin
blue resource

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Strategic implications

- Strengthen cultivation systems and secure bio… …ility
- Support step by step commerciali… …ways
- Accelerate customer v… …nd offtake partnerships
- Improve reg… …d certification alignment
- Develop … …e mechanisms that recognise ecosystem value
- Coordinate pilot to industrial transition and sector governance

The next phase is no longer proving the concept — it is enabling the conditions for commercial deployment

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Biomass scale

Commercial viability depends on stable, scalable biomass supply

Upstream cultivation constraints propagate across the value chain

Focused market entry

Lower-complexity applications achieve faster uptake

Integrated biorefinery systems remain longer-term configurations

Finance and regulation

Sustainability is an underutilised driver that should be leveraged

Ecosystem services must be embedded

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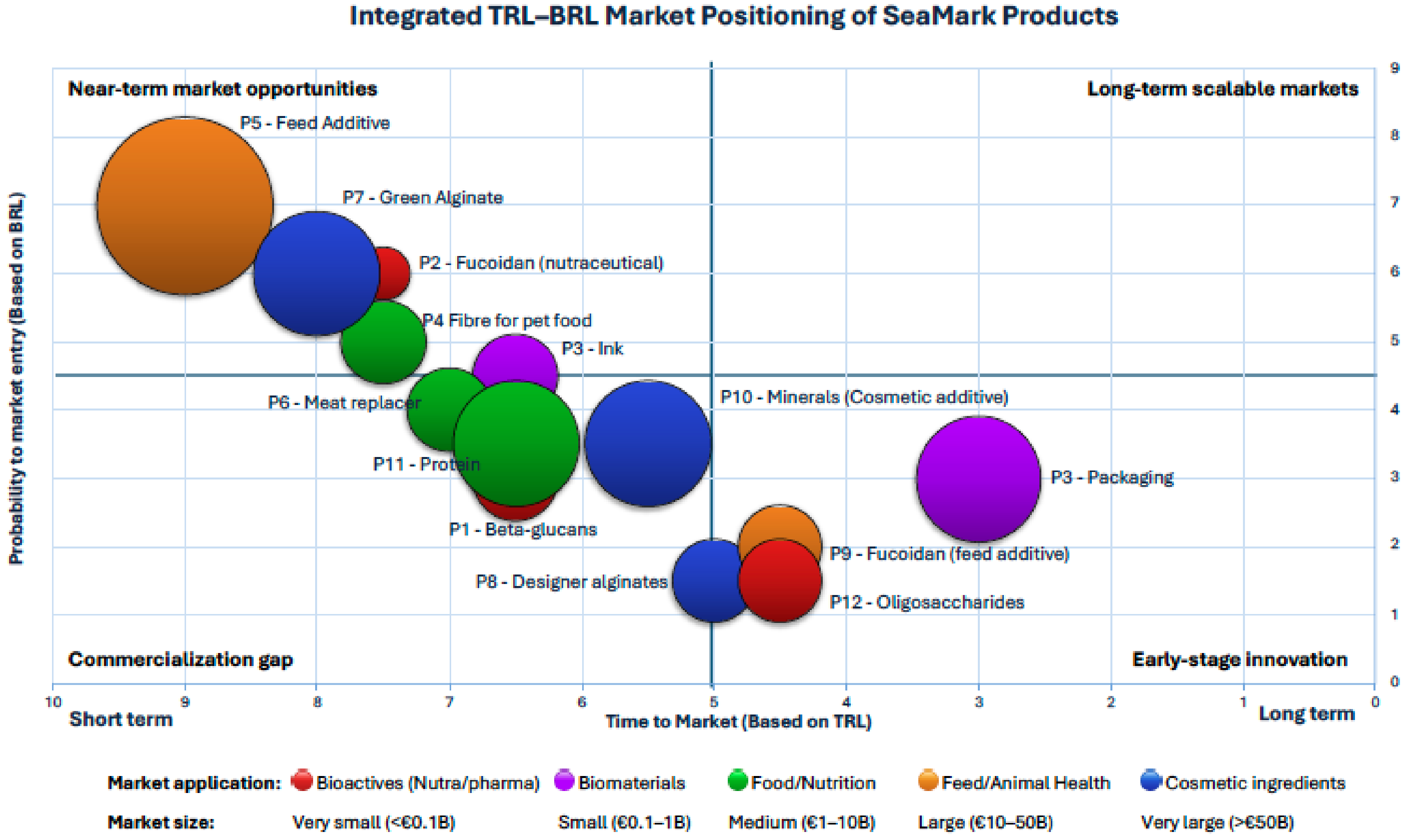
Key findings



- Some products are nearer-market (P5, P4, P7, P2)
- Others remain innovation-stage
- Market size ≠ accessible market
- Higher technological maturity does not guarantee deployment
- Commercial readiness depends on system alignment

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Biorefinery at scale: turning cultivated biomass into high-value products

DR CHARLIE BAVINGTON, GLYCOMAR (EX-OCEANIUM — WP3 LEAD)
SEAMARK FINAL CONFERENCE, LIMASSOL — 20 MAY 2026
WP3: BIOREFINERY PROCESSING FOR BIOACTIVES, FIBRE & BIOMATERIAL

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Oceanium Biorefinery objectives within SeaMark (WP3)

- **Mission** — Scale seaweed biorefinery to 10 tonnes wet weight per day, processing cultivated *Saccharina latissima*.
- **Contribution to SeaMark Products (KER1)** — 12 SeaMark products -- 'a suite of products for high and low value market segments across food, feed, nutraceuticals, cosmetics and medical devices'
- **Oceanium products**
  - **P1 bioactive beta-glucan;**
  - **P2 bioactive fucoidan;**
  - **P3 bio-packaging material**
  - **P4 fibre & protein food ingredient.**

TRL ambition — P1 5→7; P2 6→7; P3 5→7; P4 6→8 — overall biorefinery TRL 6→8.

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High value biorefinery products

P1
Bioactive beta-glucan

Ocean Actives *Beta*-glucan plus: gut & immune health
Target market: Nutraceutical — TRL 5→7

P2
Bioactive fucoidan

Ocean Actives C+ / H+: gut health and skincare
Target market: Nutraceutical & cosmeceutical — TRL 6→7

P3
Bio-materials

Ocean Ink: Bio-packaging material
Target market: Packaging / textiles — TRL 5→7

P4
Fibre for food and pet food

Ocean Health Nutra / Oceanium Pet: Fibre ingredient
Target market: Food — TRL 6→8

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Technical success

- **Biorefinery scaled** — highly reproducible processing of 70 T ww *S. latissima* at 10 T ww/day
- **P1 & P2 –** clinical efficacy
- **Product quality & safety (all four products)** — All products met specification; full food-safety compliance (P1, P2, P4); cosmetic compliance (P2)
- **No overriding technical barrier to biorefining cultivated *S. latissima* at scale.**
- **Residual constraints** — Biorefinery not built in-house (investment-driven, not technical); P1 beta-glucan production - low yield not commercially viable.

Material	kg dw	Purity (%)
Seaweed	5000	N/A
P1 – beta-glucan	11	70
P2 - fucoidan	221	90
P3 Biopackaging material	Materials: 500	N/A
P4 Fibre	Food: 2000	N/A

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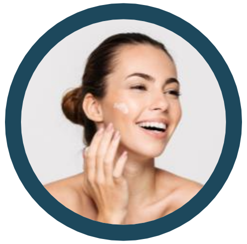
Commercialisation outcomes

- **Technical-market fit achieved** — Customers trialled Ocean Actives C+ and H+ (P2), Ocean Ink (P3), and Oceanium Pet (P4); products performed— D. P1 entered PreCode clinical trial.
- **First commercial sales** - Direct sales and small distributor orders achieved across the four product lines
- **Customer-pulled process changes (P2 Ocean Actives C+)** — COSMOS compliance; reduced colour and aroma.
- **Regulatory progress** — P2 fucoidan and P1 beta-glucan product dossiers (GRAS > EFSA); P2 fucoidan health claims developed; P4 GRAS amendment completed.
- **Price and time remained barriers** — Cosmetic and nutraceutical channels price-sensitive at current cost-of-goods; adoption cycles 18–36 months — the structural "second valley of death".

OCEAN ACTIVES® C+



OCEAN ACTIVES® H+

OCEAN INK®
AN OCEANIUM® BRAND

OCEANIUM PET

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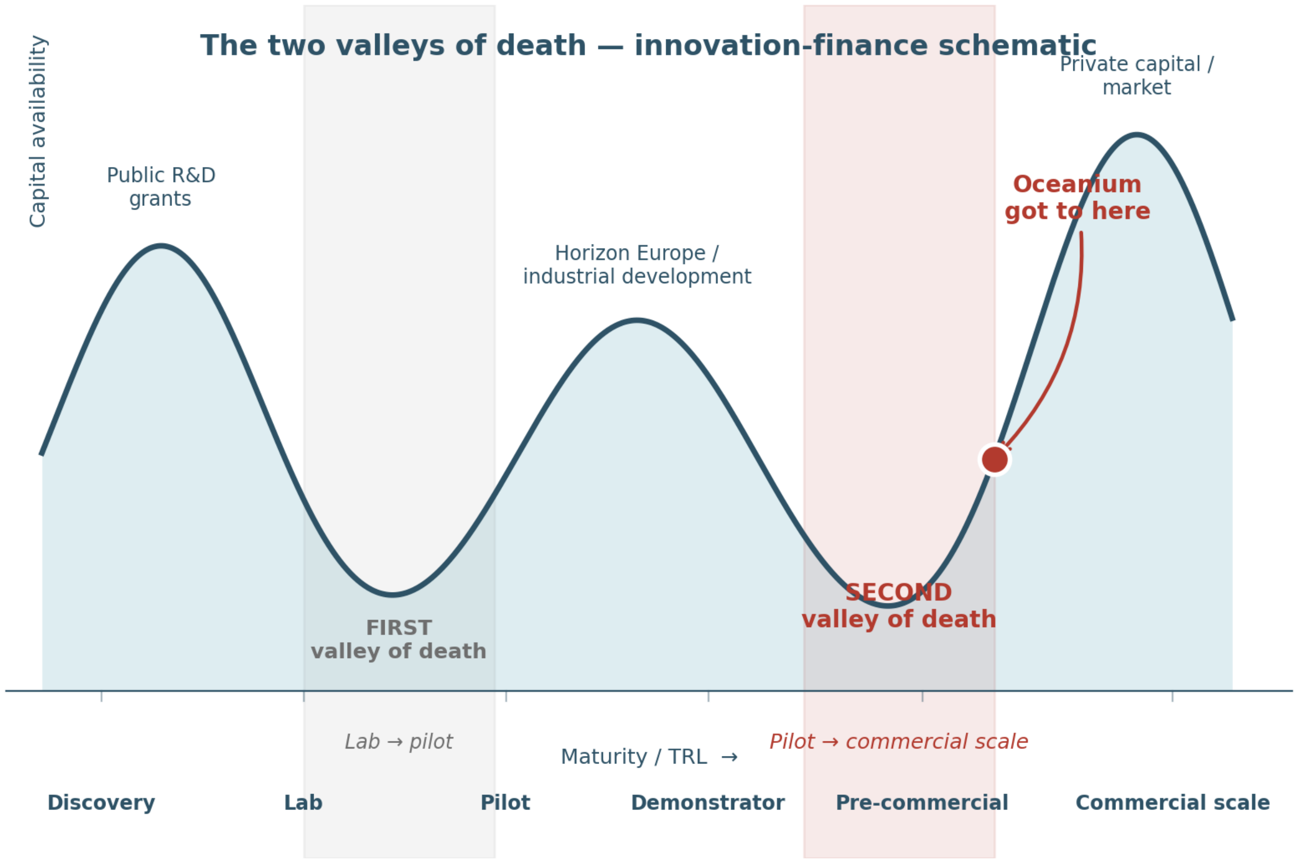
The second valley of death

- **Price** — Customer price points are below current cost of goods.
- **Time** — Adoption cycles of 18–36 months in food and nutra; 12–24 months in cosmetics.
- **Volume** — Distributor and ingredient-house orders require continuous supply at a scale that triggers further capex.
- **Capital** — Investment in a full commercial-scale biorefinery is not bankable until cost and adoption proof points are demonstrated.
- **Implication** — Technology is not the bottleneck — structural gap between proven pilot and the conditions that release private capital.



Schematic adapted from standard EU innovation-finance literature (KETs / Horizon Europe).

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Learning from SeaMark

- **Build cost discipline in from day one** — Cost of goods, not technical novelty, defines exploitation. Design processes for unit cost at target volume from the outset.
- **Sequence by adoption speed, not by margin** — Long-cycle markets alone cannot underwrite a young biorefinery; a fast-adopting lead product anchors revenue while slower products mature.
- **Seasonality is a commercial issue, not just a technical one** — A pipeline economic for only 3–4 months of the year cannot be financed.
- **Species choice is important** — *S. latissima* not optimal for all products. Biorefinery needs to be multi-species.

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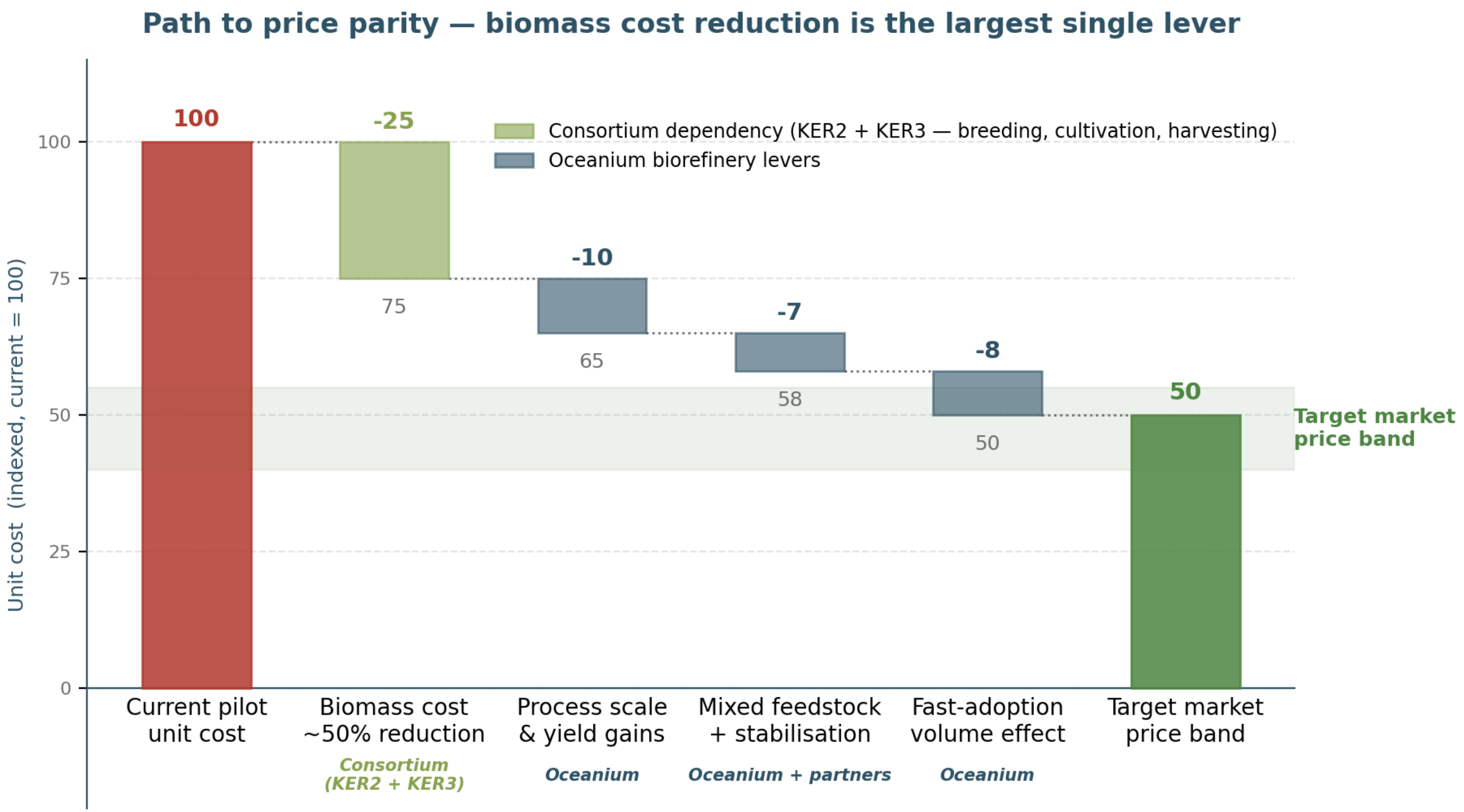
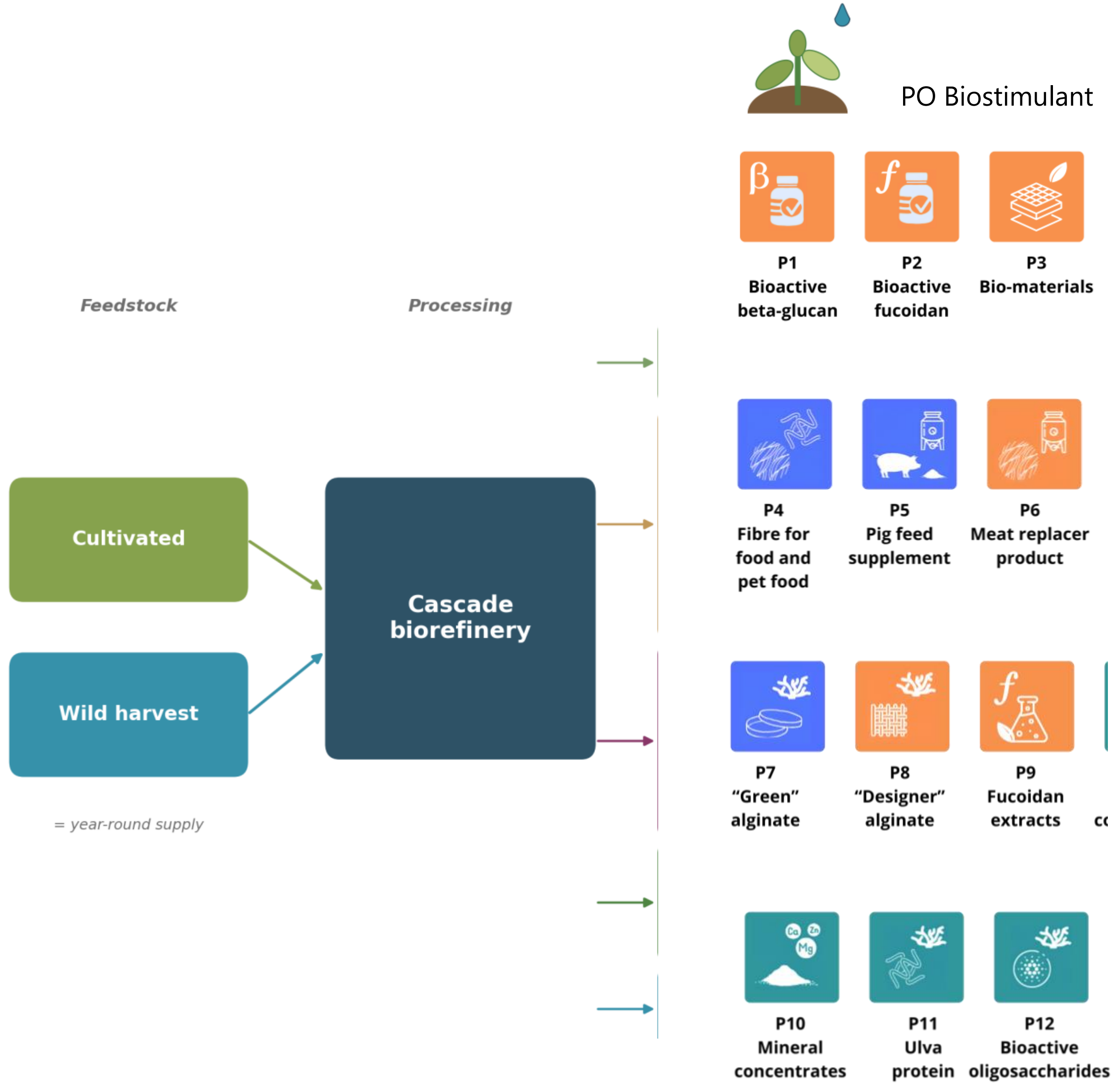
Where the seaweed biorefinery opportunity now lies

- **Cost reduction to meet market price**
- **Fast-adoption product lines** — Prioritise products with short sales cycles
- **Wild harvest integrated with cultivation** — Sustainably wild-harvested biomass
- **Stabilisation of biomass and intermediates** — Decouple processing from harvest season.
- **Investment-readiness** — Commercial-scale capex becomes bankable once cost and adoption proof points are demonstrated



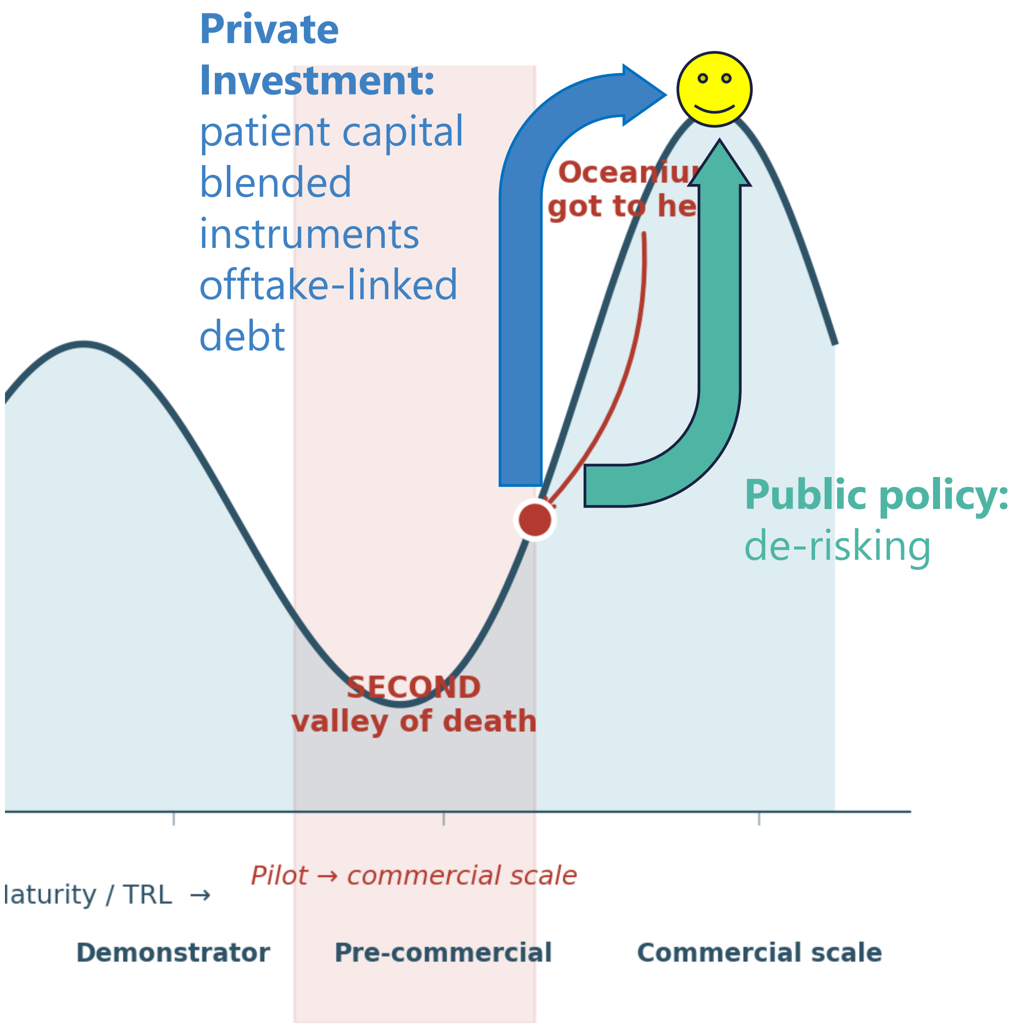
Future biorefinery model

- **Mixed feedstock** — Cultivated Saccharina/Alaria PLUS sustainably wild-harvested biomass — towards year-round operation.
- **Stabilisation at the front end** — Decoupling processing from harvest season; consistent intermediate quality.
- **Cascading extraction across multiple products –** essential to include faster adoption products while others mature
- **Modular capex tied to confirmed offtake** — Capacity expansion follows verified demand, not speculative scale-up.
- **Mission retained** — Health and ocean-health outcomes — 'Kelp the World'. A faster path to market does not change the why.



Investment & policy asks

- **To investors** — Patient capital sized for 2–3 year adoption cycles; blended instruments that share second-valley risk; offtake-linked debt structures.
- **To policymakers** — De-risking instruments aligned to KER commercialisation timelines; public subsidy to support adoption cycles; continued support for the integrated cultivation-to-product evidence base.
- **Closing message** — Seaweed biorefinery science works. The market is responsive. The remaining gap is structural — and structural gaps are exactly what targeted investment and policy can close.



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WP5: Co-extraction towards commodity & speciality ingredients
ALG, DTU, RUI, CARL

20TH OF MAY 2026

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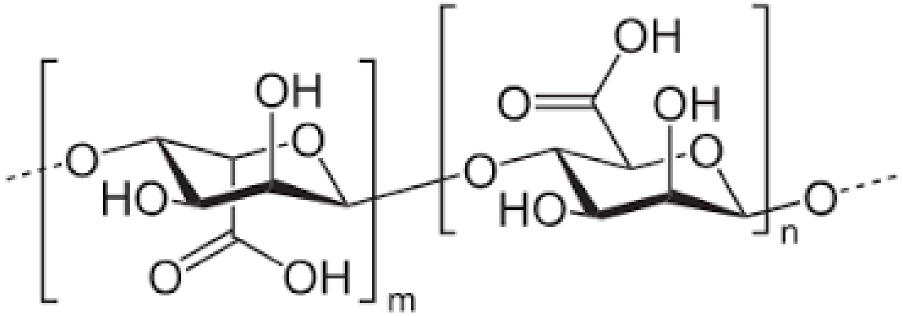
How to valorise cultivated *S. latissima* biomass?

Can the biomass be stable or stabilised before processing ?

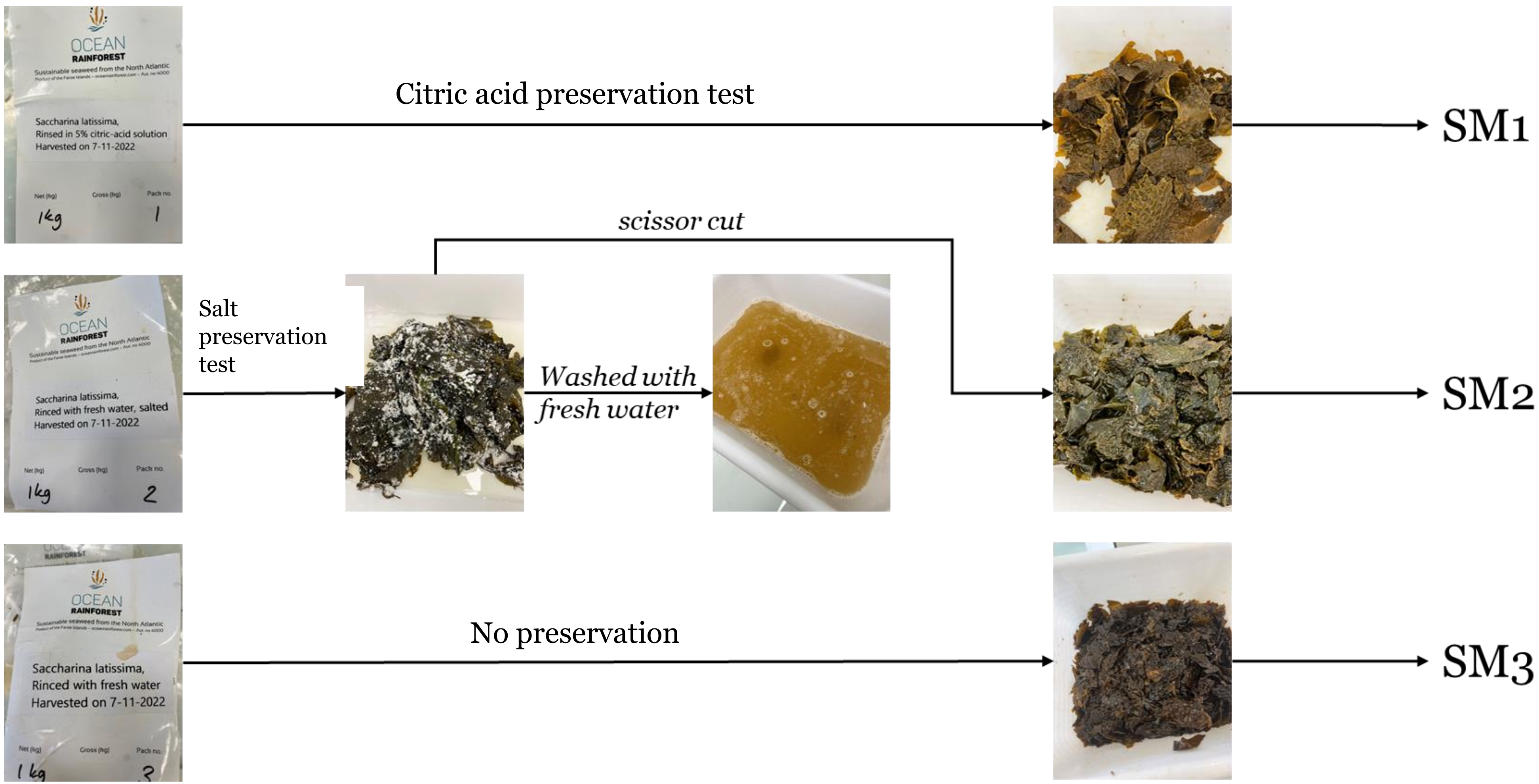
Can the fucoidan be co-extracted ?



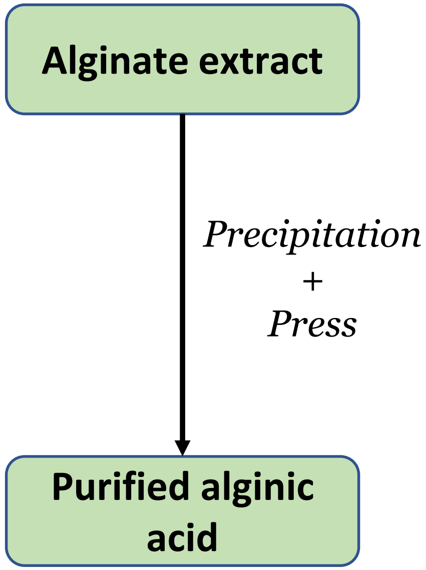
How to valorise extracted products ?

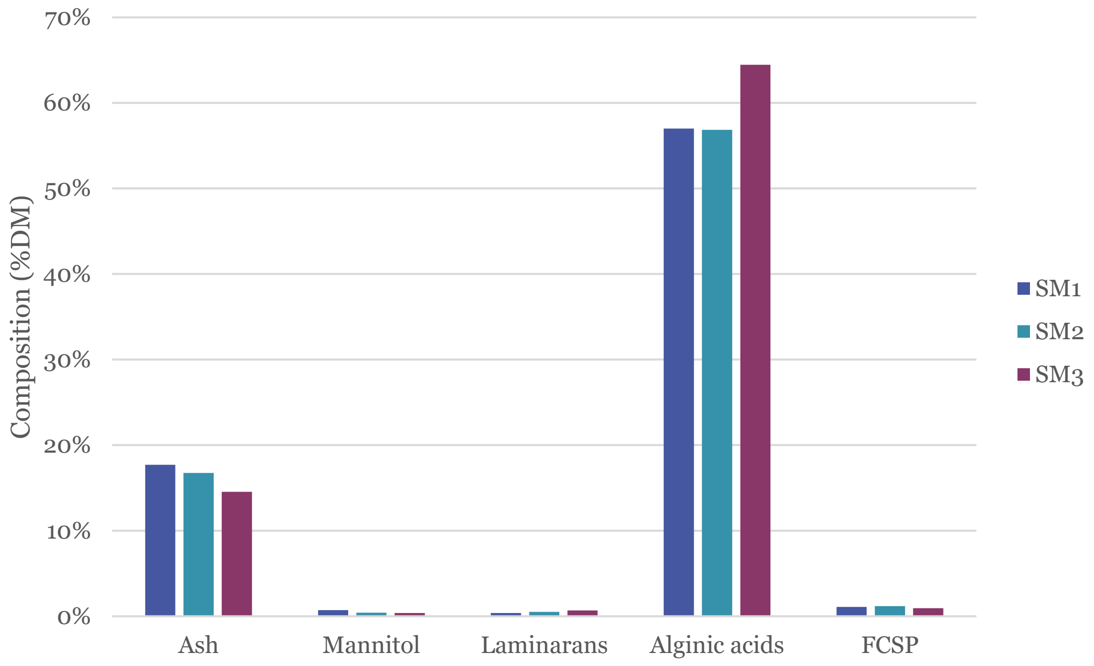
Can the alginates be extracted with a significant reduction of chemical input ?

Seaweed treatment for preservation



Alginic acid purification





- Alginic acids content up to 60% of dry matter
- Salt and acid treatment had the same effect on alginic purity (7% less than non treated biomass)
- Additional step required to finalise the purification (one more is done at industrial scale)

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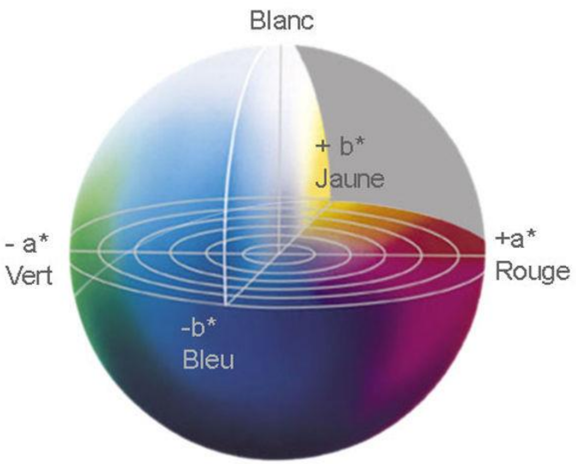
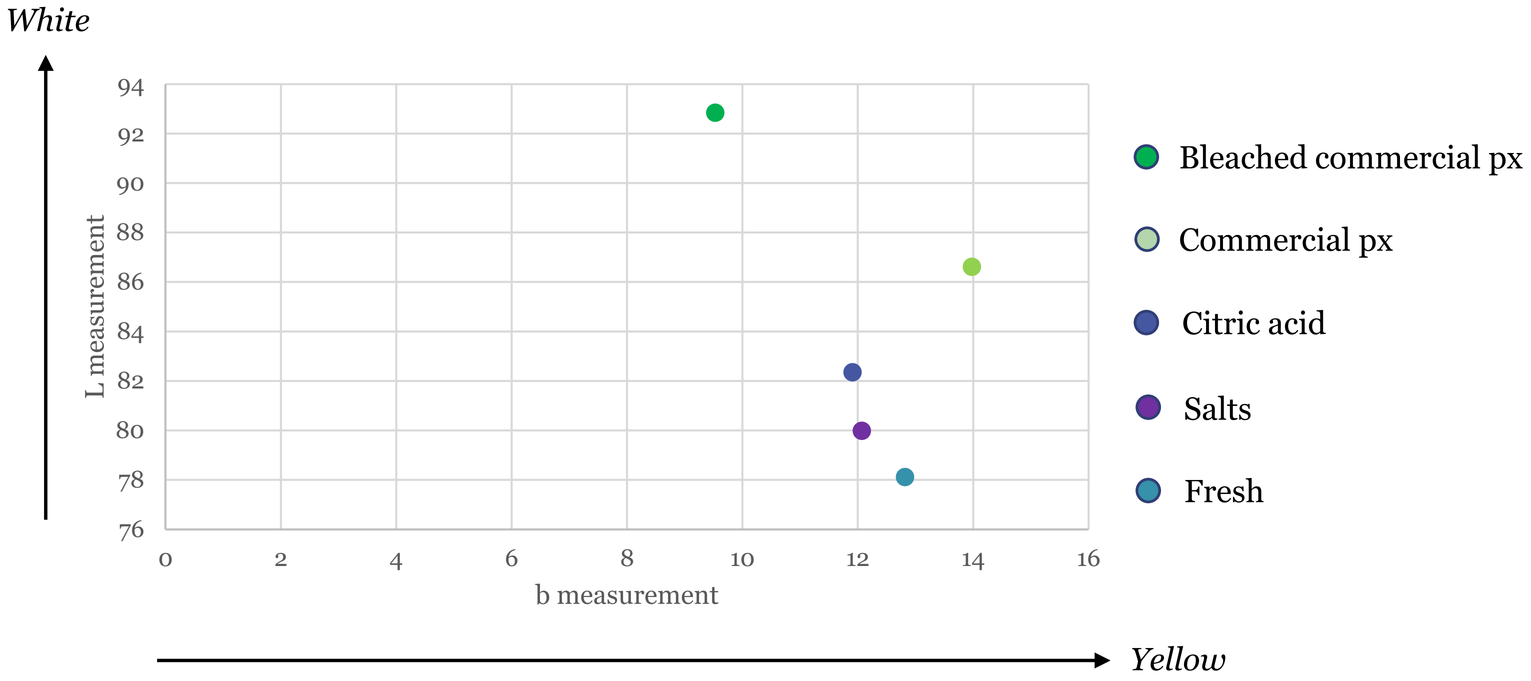
Colour of the alginic acid obtained

	SM1	SM2	SM3	Commercial	Bleached
L	79,98	82,35	78,11	86,61	92,84
a	0,5	1,86	2,67	0,15	-0,33
b	12,07	11,91	12,82	13,98	9,53



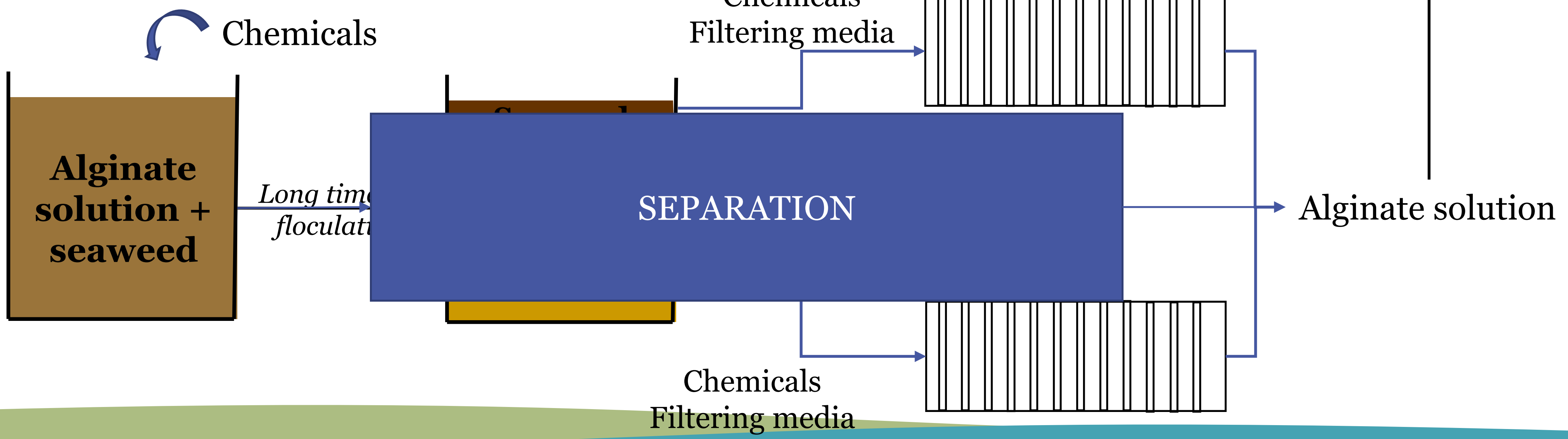


- b value (yellow) within the range of commercial products
- L values (white) slightly lower than commercial references
- Additional washing step might increase L values

Focus on alginate process

Seaweed → Acid treatment → Alcaline extraction → Liquid/solid separation → Alginate purification

<u>Separation process</u>



Results on separation

- Chemicals were 100% remove for the separation step

- No effect on final product was noticed comparing to current separation process

- Less 0.5% (w/w) of particles were identified in the liquid fraction
  - Security filter (50µm) remains mandatory to remove the residual particles

Scale up installation to the factory

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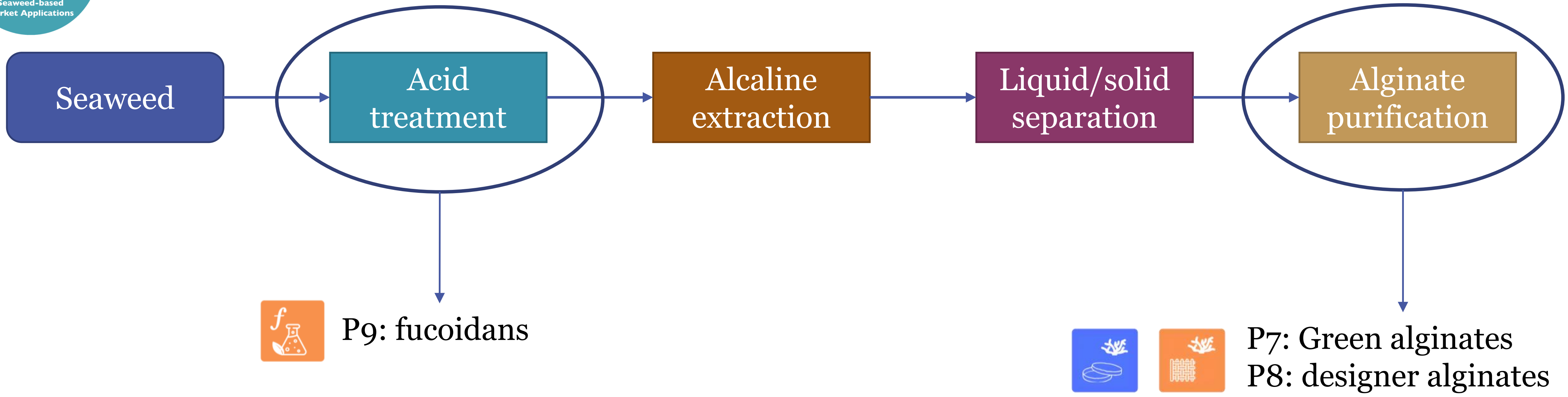
Products from *S. latissima*



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Results obtained on Alginate fraction

Seaweed received in IBC
Preserved in citric acid solution

Grinding

Separation

45 kg of seaweed
35 kg used or extraction

Alginates extraction

Separation

460 L of extract

Precipitation and press

1,29 kg of Alginic acid

Ultrafiltration

Retentate: 4,57 kg L

Green alginates for paper coating application

Algaia Liquid Alginate Assessment - Project Seamark

Sample received 3/26

- Batch number SMK7
- Prod January 2026, exp Jan 2027
- Viscosité à 1% (0.17% alginate) : 42cPs
- Extrait sec de l'alginate liquide : 17%
- Green alginate based on *Saccharina Latissima*
- 'réduction drastique des intrants chimiques et des gains de couts énergétiques notamment par la suppression du séchage.'

Observations

- Very viscous
- Algal odour
- Easy to solubilise in water

3 formulations tested, varying concentrations of components

Formulation A: Not OK

Formulation B: Not OK

Formulation C: OK

- Formulation have to be adapted
- Colour is not an issue
- Seaweed odour have to be reduced if possible
- Green alginate can be a candidate for this application

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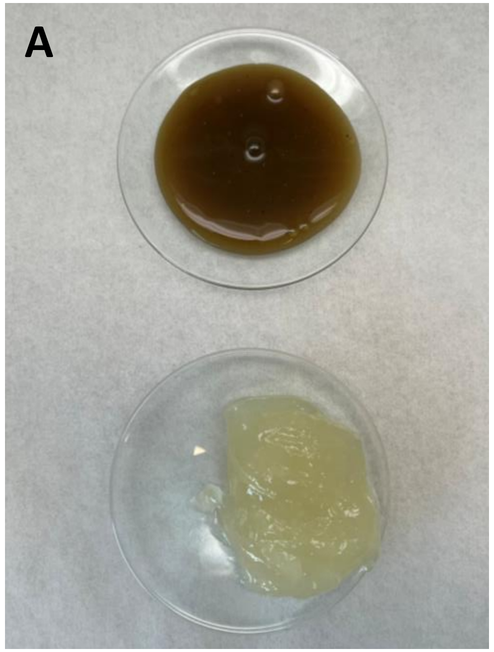
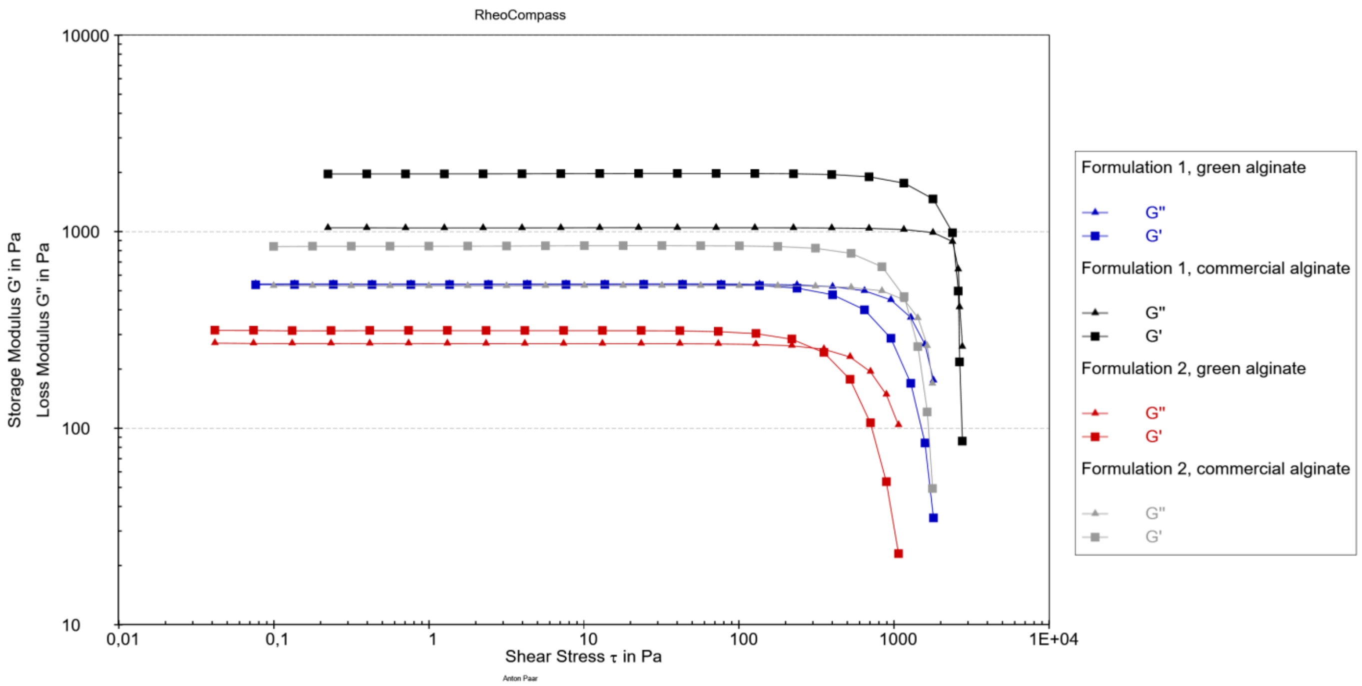
Green alginates for casing application



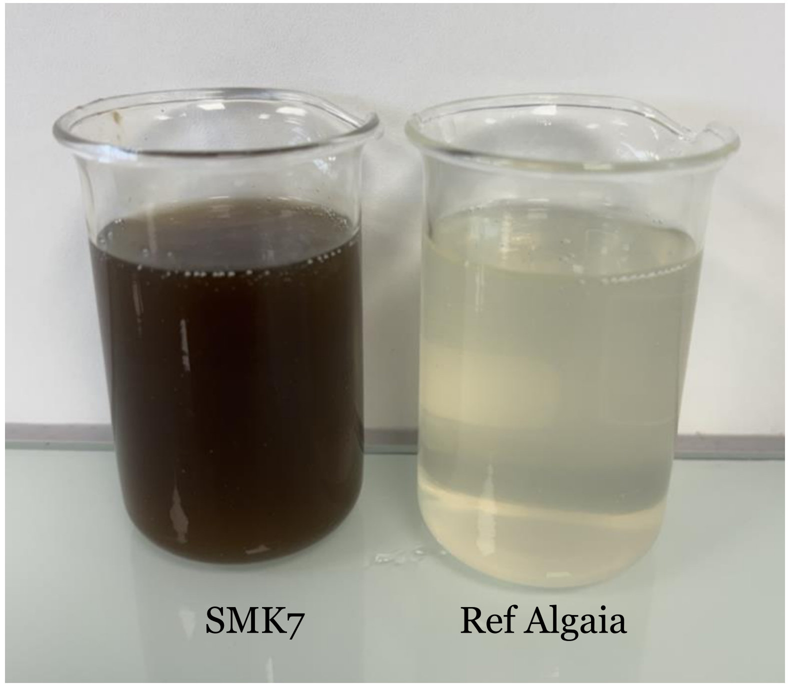
- Film formed with green remain transparent
- Films were more flexible than reference with comparable strength

- Green alginate could be a candidate for casing application
- Nevertheless, odour might be an issue in final application



Concentration must be adapted to reach reference properties

Green alginates for cosmetic application



- **Cosmos** and **natrue** can be claimed
- Color could be an issue
- Green alginate concentration is higher than reference to reach the same viscosity
- Test with liquid alginate fraction also done without affecting the results (production costs reduced)

Once formulated, colour difference is less important
Could be accepted for some application

Conclusions

- Acidic treatment allowed preserving the seaweed during shipment as well as extracting the fucoidans (even at low temperature)

- Chemicals and filter aids represented 67% (w/w) of the solid cake after separation, is now free of inputs

- Green alginates, produced without chemicals were not subjected to bleaching treatment
  - Color remained dark
  - Smell of seaweed was still present

- Utilisation of green alginates might be accepted by customers for different application
  - Reducing the dark color might be a plus for all application tested
  - Definition of application costs

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"Unlocking the potential of macroalgae for a thriving European blue bioeconomy"

Market assessment: Identifying pathways for seaweed-based products

MORTEN HEIDE, SENIOR SCIENTIST, NOFIMA
NOF, SJO, ORF, SUB, ALG, OCE, FEXP
THE **FINAL SEAMARK MEETING**, MAY 20TH, 2026, LIMASSOL, CYPRUS

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Background

- Seaweed is key to Europe's blue bioeconomy
- Strong public investment (>€500M)
- Commercialization still limited
- Need realistic Go-To-Market (GTM) strategies

Photo: Marthe Jordbrekk Blikra, Nofima

Our approach

- Iterative GTM development (3 cycles)
- From initial → tested → refined strategies
- Customer engagement central
- Industry partner-driven process

Our products

- 20 products → reduced to 6 key cases
- Selection based on feasibility and market potential
- 6 Products selected
  - Fibre for pet food
  - Bioactive fucoidan for nutraceuticals and cosmetics
  - Green alginate for cosmetics, food, and packaging

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What drives market success

- Sustainability is an important strength and differentiator
- Strong scientific validation is a key differentiator
- Certification shapes access to key markets
- Regulatory readiness affects speed to market

Photo: Robert Kneschke

How the market responds in practice

- Market interest is emerging across several applications
- Strongest traction in high-value segments
- Some applications remain challenging
- Clear differentiation recognised by customers
- Commercial uptake is still very limited

Business & investment recommendations

- Prioritise applications with the strongest traction
- Focus on validation and market adoption
- Invest to move from pilot to scale
- Build strong value-chain partnerships

Policy recommendations

- Support research and validation to substantiate product claims (e.g. health effects)
- Reduce regulatory uncertainty and time to approval
- Support certification and evidence development
- Enable collaboration across the value chain

Photo: Joe Urrutia, Nofima

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Life cycle assessment: Environmental performance vs. land-based crop alternatives

JONNA SNOEK, ELIZABETH MIGONI ALEJANDRE, RUNI JOENSEN, URD GRANDORF BAK, FRANCK HENNEQUART, JEREMY BREBION, CHARLIE BAVINGTON, RENE SCHEPENS, MARÍA ALMIND, SANDER VAN DEN BURG

THE **FINAL SEAMARK MEETING**, MAY 20TH, 2026, LIMASSOL, CYPRUS

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Setting the scene

Seaweeds are seen as promising alternative to land-based biomass resources.

Various LCA studies have assessed the environmental impact of seaweed cultivation and seaweed-based products.

This study applied LCA to evaluate the SeaMark flagship products against (land-based) alternatives.

Acknowledging the innovative character, this is done under current and future scenarios.

Seaweed-based product	Alternative compared
Seaweed fibre (P4), produced by Oceanium: a texturizing ingredient used in food for its water binding and gel forming properties. Suitable for many applications including gluten-free breads, plant-based meats, and beverages.	Inulin, extracted from chicory roots
Seaweed-based experimental pig feed ingredient (P5), produced by FEXP: protein supplier, based on rapeseed meal and fermented seaweed, primarily sold to pig farmers for its many vital benefits stemming from the fermentation process.	South American High Protein soybean meal (alternative for sows) South American Soy protein concentrate (alternative for pigs)
Green alginates (P7), produced by ALG: Alginates are mainly used in the food sector for replacing fats, salt excess and carbohydrates.	Alginates extracted with conventional (high chemical input) methods.

Starting point: Seaweed cultivation

All LCAs are based on seaweed cultivated by Ocean Rainforest

Looking at current and future scenario

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Impacts of seaweed cultivation

- From hatchery to deployment, harvesting and transport to shore
- Based on operational activities 2022-2024
- Large contributions:
  - hatchery, specifically from the electricity consumed at this stage
  - nylon for the seeded lines
  - steel for anchors and chains used in the cultivation rig
- Diesel consumed during harvest and deployment has a minimal contribution to impacts compared to those linked to the production of main materials nylon and steel

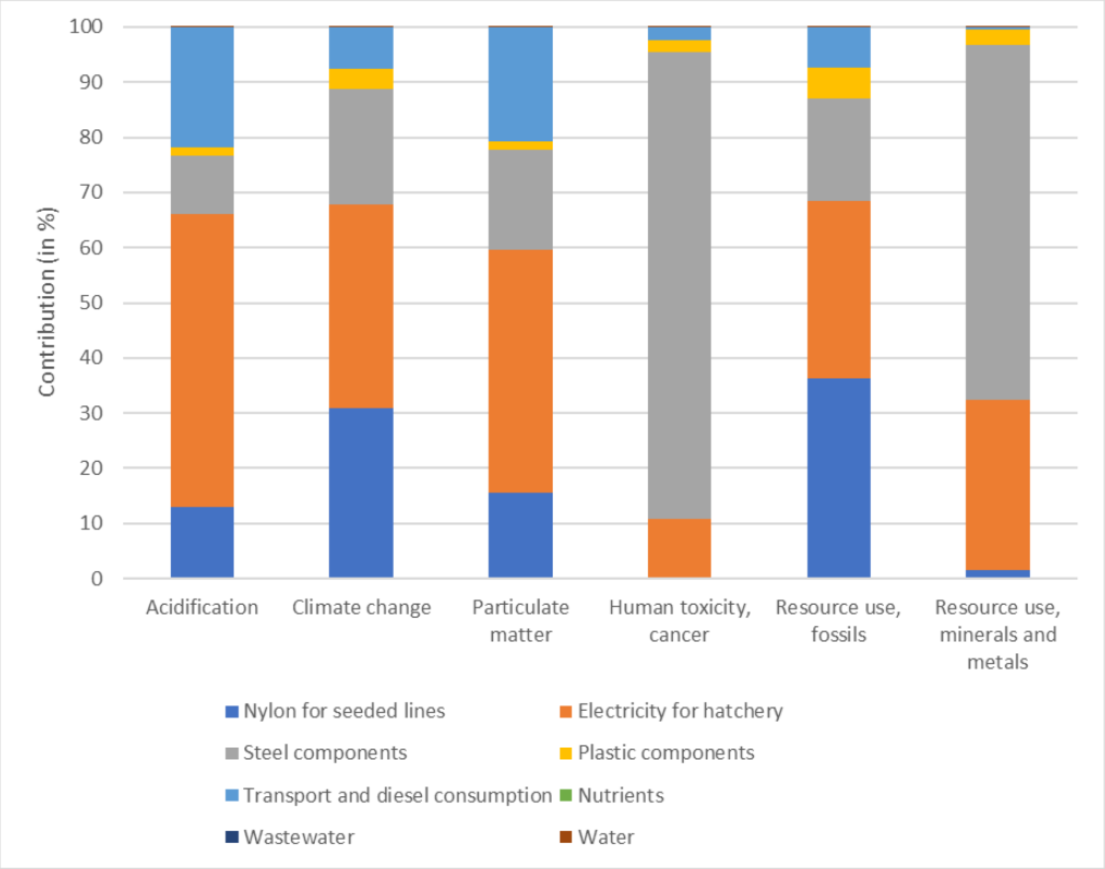


Figure 4: Contribution (in %) per group to the impact categories within the 80% threshold. Functional unit: 1kg of fresh Saccharina latissima *(ww) produced by Ocean Rainforest.*

Impacts of seaweed cultivation

- The future scenario:
  - Electricity from renewable sources
  - Increased yield
- Total environmental impact reduced by 60%
- Across all impact categories (ranging from 40%-80% reduction)

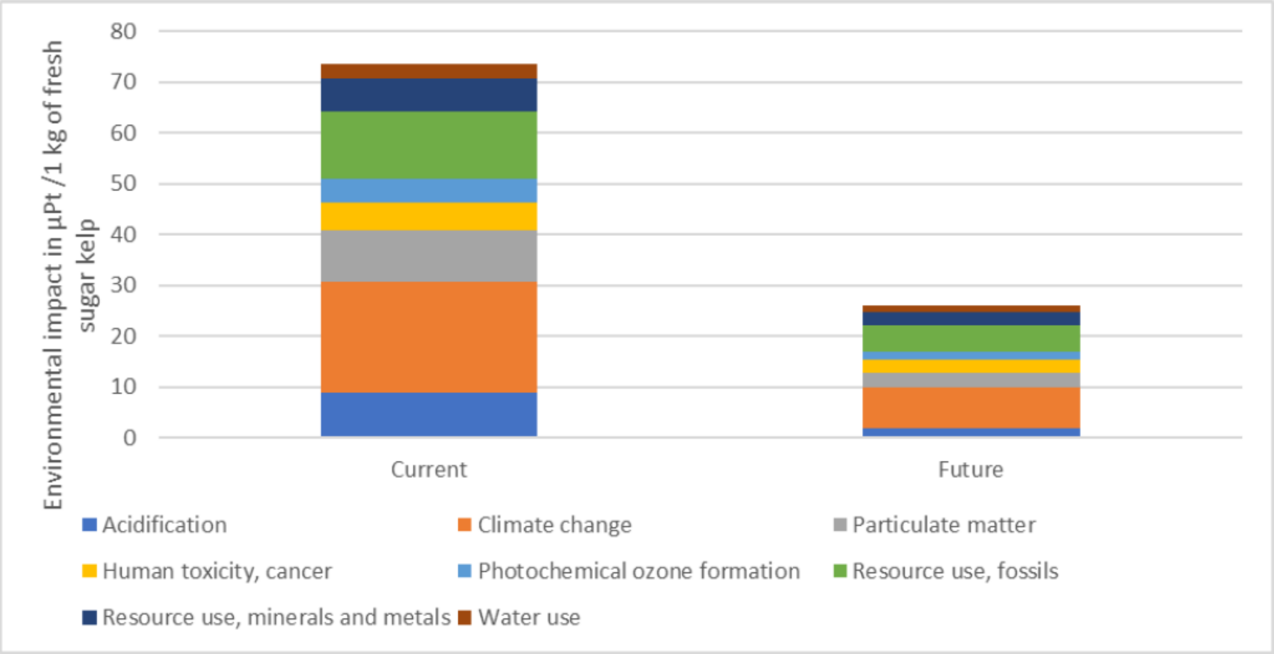
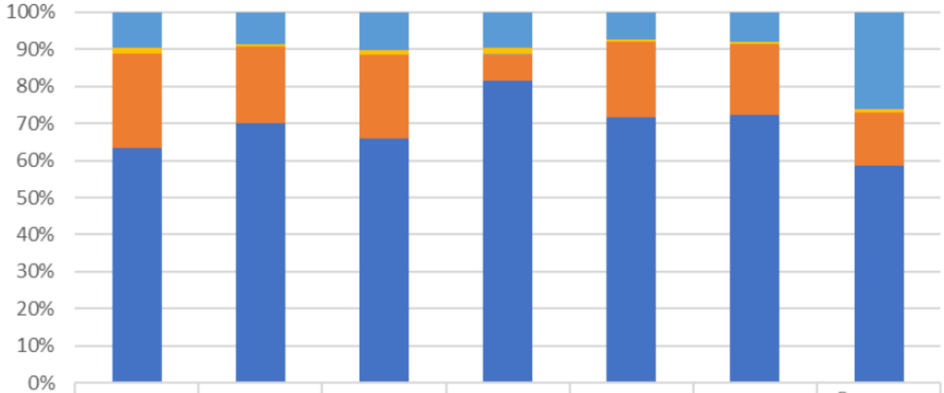


Figure 5: Environmental impacts contribution to single score (in µPt) for current and future scenario. Functional unit: 1kg (ww) of fresh Saccharina latissima produced by Ocean Rainforest.

Fibre – current situation

- Seaweed produced at ORF site and dried
- Transport to processing site in the UK + Rewetting and processing
- Cultivation stage is the main hotspot across all impact categories
- The environmental impact of the fibre production stages is minimal (10-20%) in comparison with the impact contribution of the seaweed cultivation stages (60-80%).
- The second largest contributor to impacts across all impact categories is the seaweed drying step (10-30%).



	Acidification	Climate change	Particulate matter	Human toxicity, cancer	Photochemical ozone formation	Resource use, fossils	Resource use, minerals and metals
Fibre processing	9.5	8.6	10.2	9.6	7.2	7.9	26.3
Acid wash	1.5	0.6	1.4	1.7	0.7	0.7	0.9
Pre-processing at OCE	0.1	0.0	0.0	0.0	0.1	0.0	0.0
ORF dried seaweed	25.7	20.6	22.5	7.0	20.5	19.1	14.3
ORF fresh sugar kelp	63.3	70.2	65.9	81.7	71.5	72.2	58.5

ORF fresh sugar kelp ORF dried seaweed Pre-processing at OCE Acid wash Fibre processing

Figure 10: Contribution (in %) of each life cycle stage to the environmental impact categories identified within 80% threshold. Current scenario; Mass allocation.

Fibre – future scenario

- Higher production volume at ORF
- Processing close to production site
  - Transport by boat
  - No drying, instead 90% directly processed

Single score impact of producing 1 kg of seaweed fibre decreased 80%.

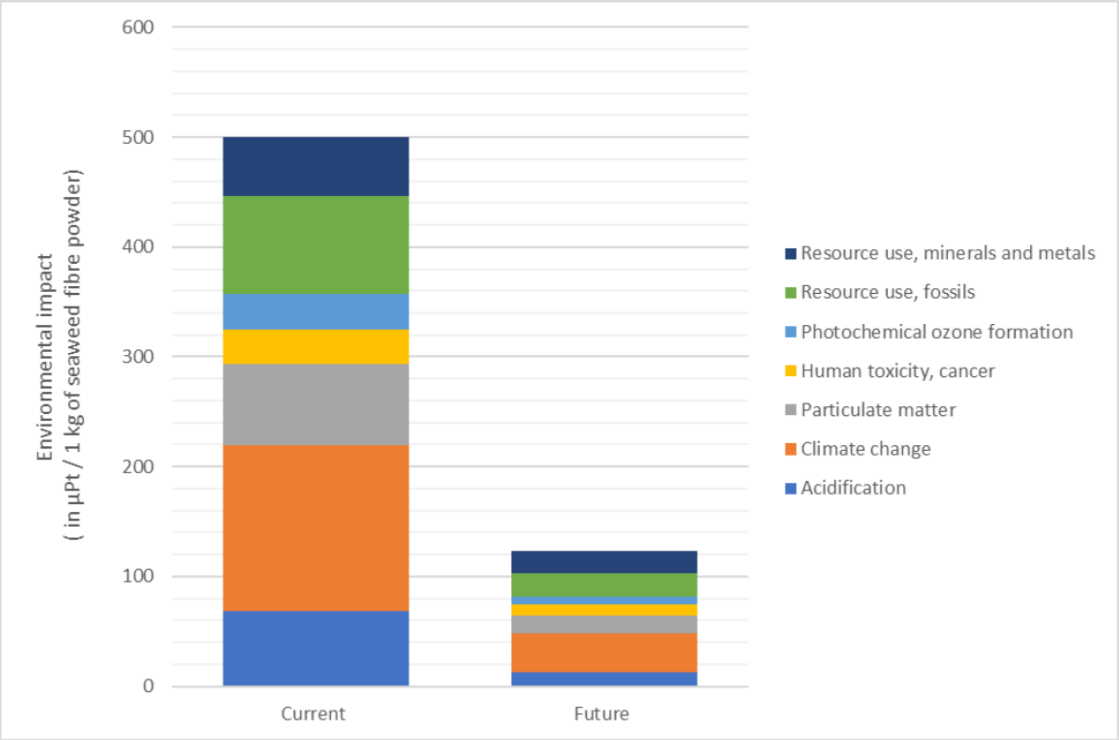


Figure 11: Environmental impacts (in µPt) to produce 1 kg of seaweed fibre, in a current and future scenario. Mass allocation.

Fibre comparison with land-based alternative

source: https://www.hollandandbarrett.nl/shop/vitamines-supplementen/supplementen/prebiotica/inuline/

- Inulin from chicory roots
- Under a current scenario, 2.4 times a larger impact than producing 1 kg of inulin powder derived from chicory roots.
- In a future scenario, the total single score impact of 1 kg of seaweed fibre is ~60% lower than the impact of 1 kg of inulin powder.

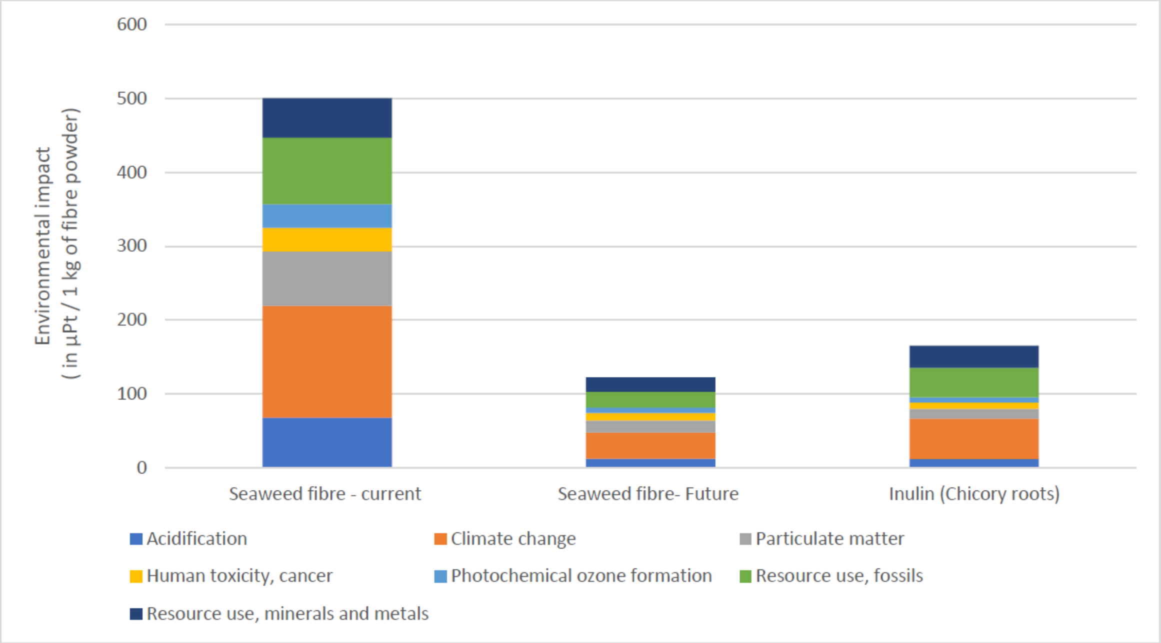


Figure 13: Environmental impacts (in µPt) to produce 1 kg of seaweed-based fibre (for current and future scenario, mass allocation), and 1 kg of inulin powder.

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Experimental pig feed ingredient- current

- The production of rapeseed meal, contributes most to the environmental impact of the experimental pig feed ingredient in the current situation (89%).
- The processing by FEXP is responsible for 6% of the total impact.
- The cultivation of S. latissima and the fermentation of S. latissima contribute less than 2% (1.2% respectively 0.2%) to the total impact.

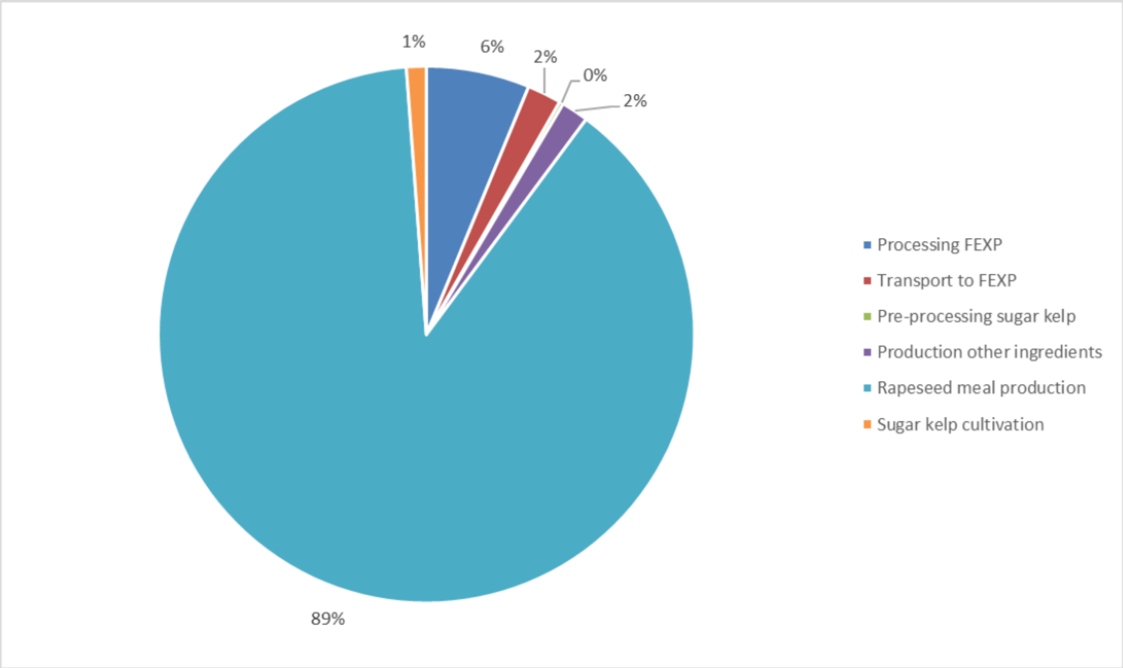

Figure 19: Contribution of the current experimental pig feed ingredient production activities to total of all 16 EF3.1 impact categories. Note: land use – biodiversity losses are not included in graph, since it could not be assessed with the EF3.1 method.

Experimental pig feed - comparison

- Per 1 kg dry powder the environmental impact of SA HP soybean meal is about 2.7 times higher than the experimental pig feed ingredient.
- Per 1 kg dry powder the environmental impact of SA soy protein concentrate is about 4.5 times higher than the experimental pig feed ingredient.

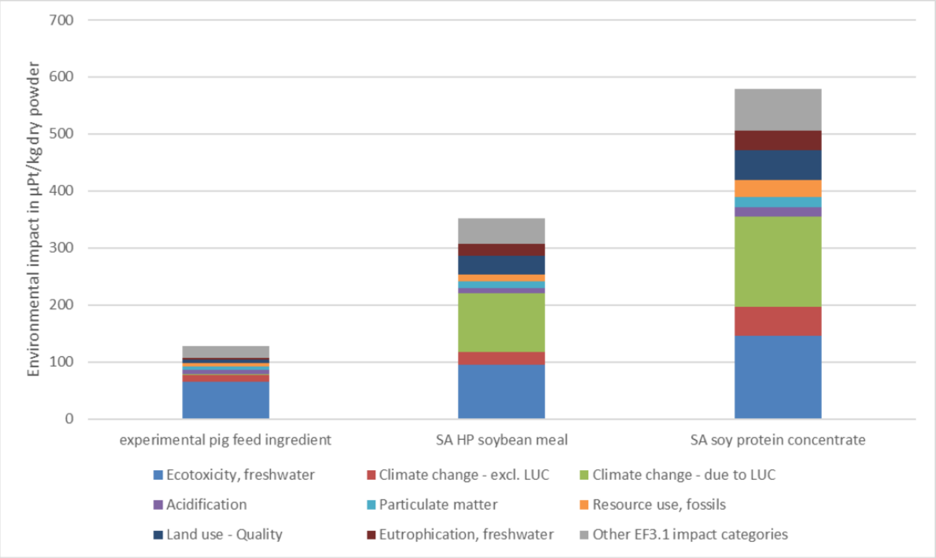

Figure 21: Environmental impact of 1 kg the experimental pig feed ingredient, 1 kg SA HP soybean meal and 1 kg SA soy protein concentrate (Functional unit = 1 kg dry powder); Note: land use – biodiversity losses are not included in graph, since it could not be assessed with the EF3.1 method.

Alginate extraction - current

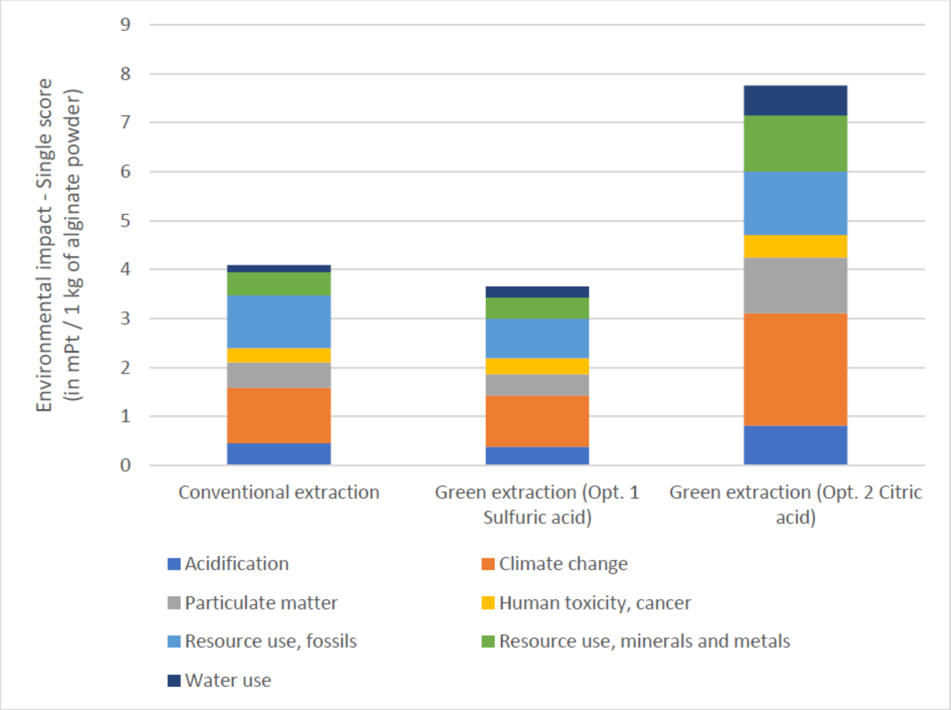

Figure 31: Environmental impacts (in µPt) to produce 1 kg of alginate powder, for all extraction scenarios. Seaweed production is assumed as current scenario.

Seaweed produced at ORF,

Transport (lorry – boat – lorry) to France

Alginates extraction

Three extraction options

- Conventional
- Green extraction with sulfuric acid
- Green extraction with citric acid

Alginate extraction - current

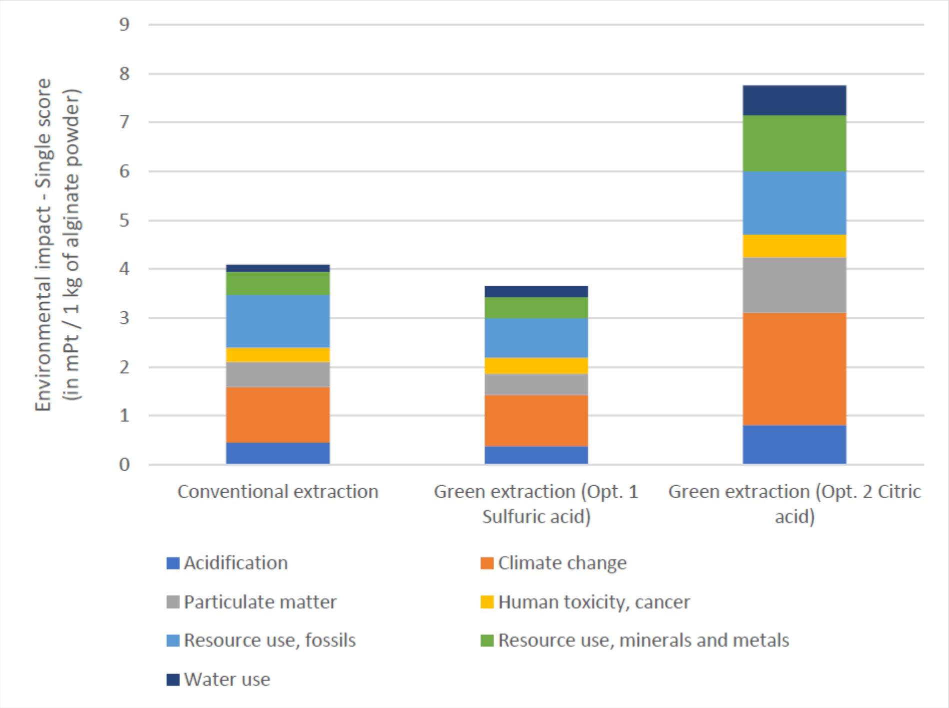

Figure 31: Environmental impacts (in µPt) to produce 1 kg of alginate powder, for all extraction scenarios. Seaweed production is assumed as current scenario.

Green alginate extraction with citric acid has the largest environmental impact, almost doubled in comparison to conventional alginate extraction and green extraction with sulfuric acid.

Climate change has the highest contribution to the single score impacts across all extraction scenarios.

In the case of green extraction opt. 2 with citric acid, 62% of the climate change impact is linked with the citric acid consumed in this scenario.

There are opportunities to reduce impact of citric acid through different production process

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Opportunities for the seaweed sector

Upscaled macro-algae (seaweed) production has the potential to alleviate pressure on the environment by providing marine-based alternatives for feed and fibre.

Green extraction process do reduce the environmental impact of alginate production.

Projected and realistic improvements in seaweed cultivation and processing further reduce the environmental impacts.

Among these, particularly pointing at the benefits of

- Increasing scale of production
- Geographical proximity of production and processing

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Five main take-aways

1. LCA provides valuable insight for the companies, illustrating how to reduce environmental impacts.

2. Case-by-case comparison shows the potential of seaweed cultivation to provide biomass with low environmental impact.

3. Systematic comparison is challenging. LCA studies takes different approaches (e.g. functional unit and system boundaries).

4. Commonly used Life Cycle Impact Assessment and Inventories are not equipped to deal with marine biodiversity.

5. Challenge to bring in the benefits of seaweed cultivation, linking LCA to the ecosystem services assessment.

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SeaMark - Seaweed-based Market Applications:
"Unlocking the potential of macroalgae for a thriving European blue bioeconomy"

Ecosystem services & monetization pathways for sustainable industry support

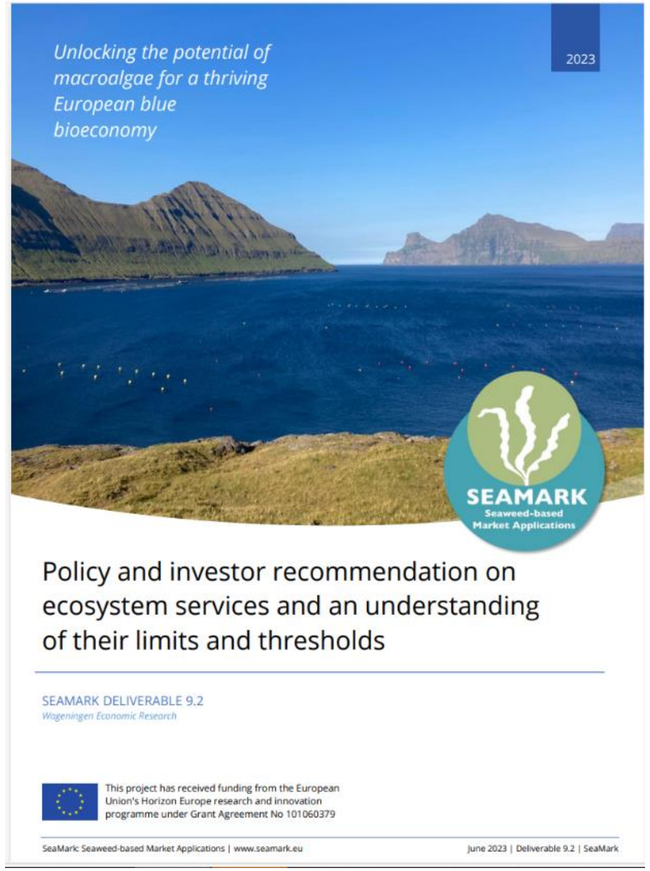
JOSIEN HENDRICKSEN (WAGENINGEN UNIVERSITY & RESEARCH)
WUR, SJO, ORF

THE **FINAL SEAMARK MEETING**, MAY 20TH, 2026, LIMASSOL, CYPRUS

Co-funded by the European Union

Setting the scene – background

- Seaweed farms deliver measurable ecosystem services (ES)
- Currently, Europe lacks structured ES payment schemes and access to blue/green finance for seaweed farming
- SeaMark (1) developed methods to quantify nutrient bioremediation, carbon sequestration and biodiversity enhancement, (2) applied them in the field, (3) valued these benefits and (4) formulated policy and investor recommendations for ES monetisation


Unlocking the potential of macroalgae for a thriving European blue bioeconomy

2023

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Policy and investor recommendation on ecosystem services and an understanding of their limits and thresholds

SEAMARK DELIVERABLE 9.2
Wageningen Economic Research

This project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101060379

SeaMark: Seaweed-based Market Applications | www.seamark.eu   June 2023 | Deliverable 9.2 | SeaMark

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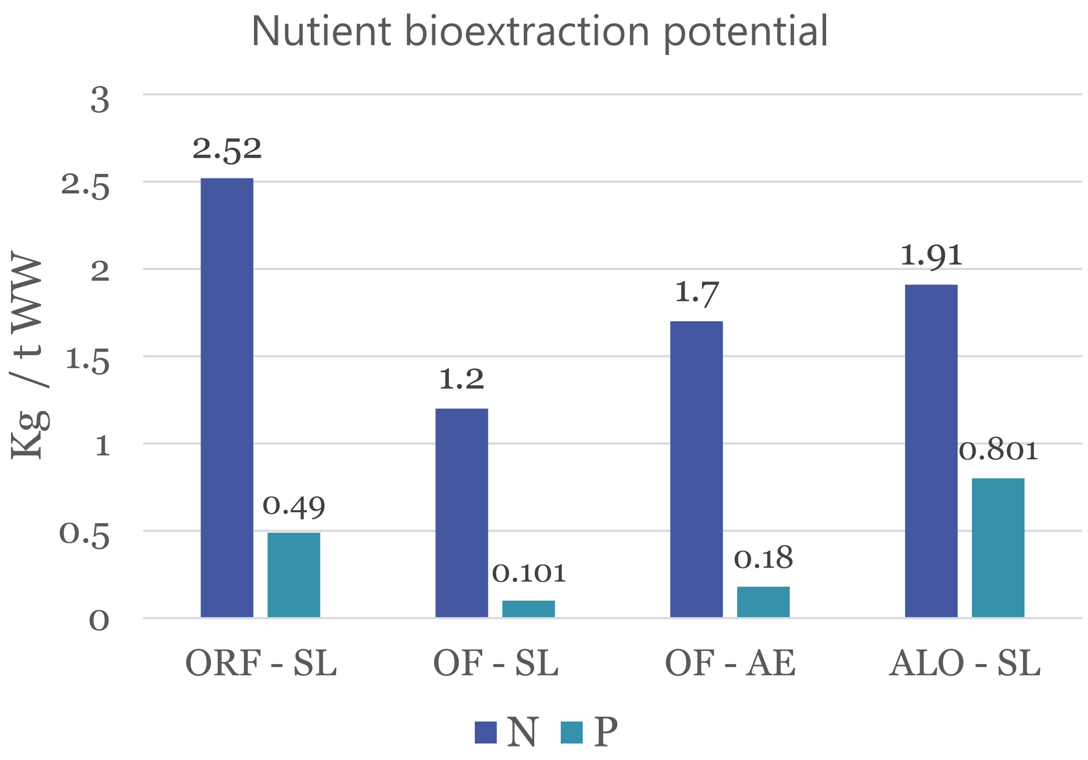
Ecosystem service assessment: quantification and monetization

- *Saccharina latissima* (all sites) & *Alaria esculenta* (OF)
- **3 cultivation sites & 3 ES quantified :**
  - Faroe Islands — - Nutrient bioremediation (all)
  - Norway — - Carbon sequestration (all)
  - France — - Benefits to biodiversity (ORF)
- **Data collection methods:**
  - Site specific nutrient (N & P) and carbon content
  - ORF: seaweed blade loss data + sampling for biodiversity development over time
  - Literature review
  - Replacement cost methodology

Results of **Nutrient bioremediation**



Monetization values of *S. latissima*:

- €65 t^{-1} WW for Faroe Islands (ORF)
- €62 t^{-1} WW for France (ALO)
- €27 t^{-1} WW for Norway (OF)

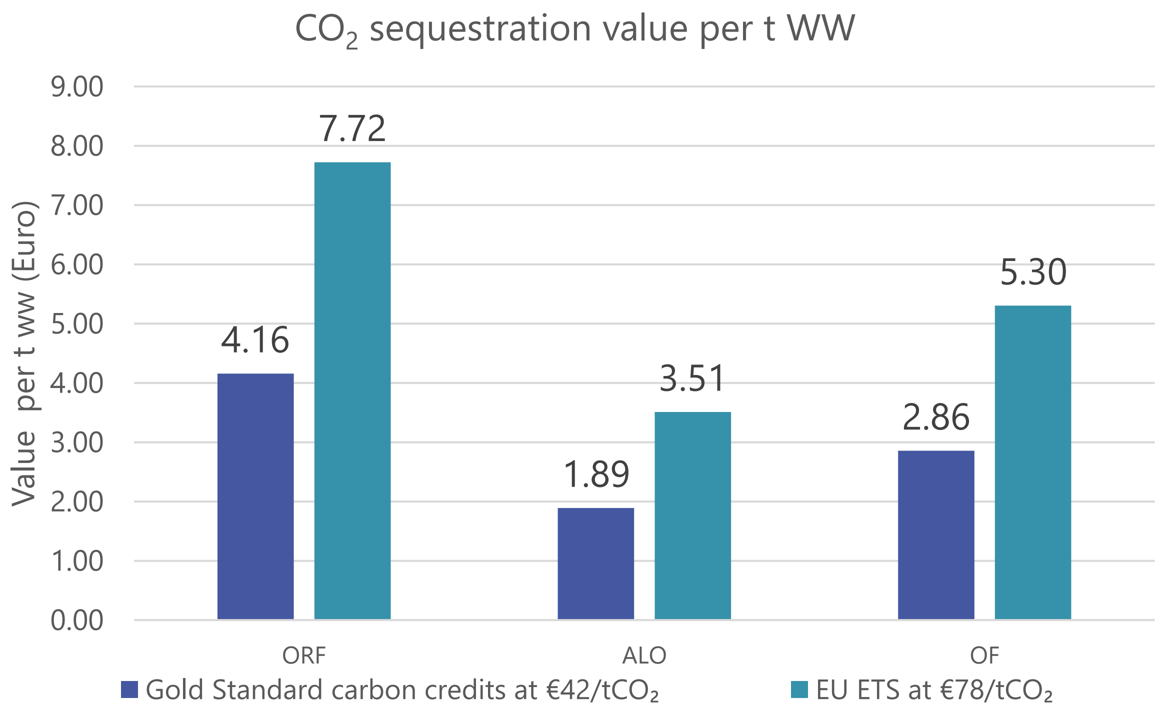
Results of **Carbon sequestration**

Estimated carbon uptake:

- 99 kg CO_2eq t^{-1} WW in the Faroe Islands
- 45 kg CO_2eq t^{-1} WW in France
- 66 kg CO_2eq t^{-1} WW in Norway

⇒ Assuming carbon is sequestered in sediment
⇒ Destination of the biomass matters!
  ⇒ Seaweed based products can reduce/avoid emission

Monetization values: €1.89 to €7.72 per t WW



Results of **Biodiversity enhancement**

Multiple years with same grow lines seem beneficial for biodiversity (e.g. successional species like bivalves)

Monetization:

- Additional socio-economic data necessary for economic valuation of these ecological benefits
- There is no standadized value or valuation method, but potential is there!

Key findings of ES assessment

Nutrient bioremediation

- **1.2 - 2.5 kg N t^{-1} WW**
- **€27 - 65 t^{-1} WW**
- Easy to quantify
- Scientifically mature method
- N & P content varies over site/season, reflected by difference in value

Carbon sequestration

- **45 - 99 kg CO_2eq t^{-1} WW**
- **€1.89 - 7.72 t^{-1} WW**
- Uncertainties remain
- Carbon content & cultivation practice matter (storms in winter)

Biodiversity enhancement

- Continuous habitats had higher biodiversity
- More research needed to understand the economic value of biodiversity in seaweed farms

Payment mechanisms: The gap

Seaweed farming delivers real, quantifiable Ecosystem Services.

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But no payment is realized from them.

The gap: Public value is generated, but not recognized in public or private finance

Monetizing ES is a first step to bridge this gap.

But we need **collaboration of** key players such as **policymakers and investors.**

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Promising payment mechanisms

Mechanism	What it pays for	Maturity for EU seaweed	Most likely to...
Nutrient trading schemes	Tradable N/P credits, mainly in eutrophicated areas	**Med (pilot)**	Be applied in EU soon
Public-Private-Partnerships	Multi-year funding & ES delivery; co-location (e.g. with offshore wind)	**Med (ready)**	To scale seaweed cultivation in the EU
Blue/blended finance	MRV set-up; risk-sharing	**High (now)**	To scale seaweed cultivation in the EU

Remaining barriers

- Lack of clear methodologies (MRV) and quantification protocols, especially for carbon sequestration and biodiversity enhancement
- Not one-size-fits-all methodology, very site specific so no average numbers
- The ES benefits of seaweed are not yet widely recognised
- No EU-wide, standardised marine ES payment system

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Recommendations for industry upscaling

- Streamline and scale up **data collection** (MRV), creating uniform methodologies. We can learn from practices outside EU.
- Use **nutrient trading schemes** as the first payment mechanism for ES, but consider **public-private partnerships** and **blue/blended finance** to scale the industry on the long term.
- Financial mechanisms for seaweed only will not get the sector to expand – at the same time, **harmful subsidies to other sectors should be phased out** as well.

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Recommendations for industry upscaling

- Tailor financial mechanisms to **local needs**, because there is **not a one-size-fits-all** methodology.
- **National policymakers** are key actors; encourage their engagement and enthusiasm for support.
- Improve **education and communication** on the ES benefits of seaweed, to increase knowledge and demand.

Thank you!

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SEAMARK

Seaweed-based Market Applications

Scaling Regenerative Marine Industries:

What's needed for a successful transition?

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Seaweed cultivation produces measurable environmental value while supporting new bio-based products and industrial applications

Why has scaling not occurred despite technological progress and policy ambition?

SEAMARK Seaweed-based Market Applications

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What SeaMark has demonstrated

Technology	Environment	Market
Mechanisation	Nutrient removal	GTM pathways
Upscaling potential	Carbon benefits	Product validation
Processing advances	LCA improvements	Customer testing

The building blocks of a restorative industry now exist

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Europe's Seaweed Sector is approaching a Critical Transition Threshold

The industry has overcome the first valley-of-death (technology) now it is entering the second (commercialization)

The sector now has

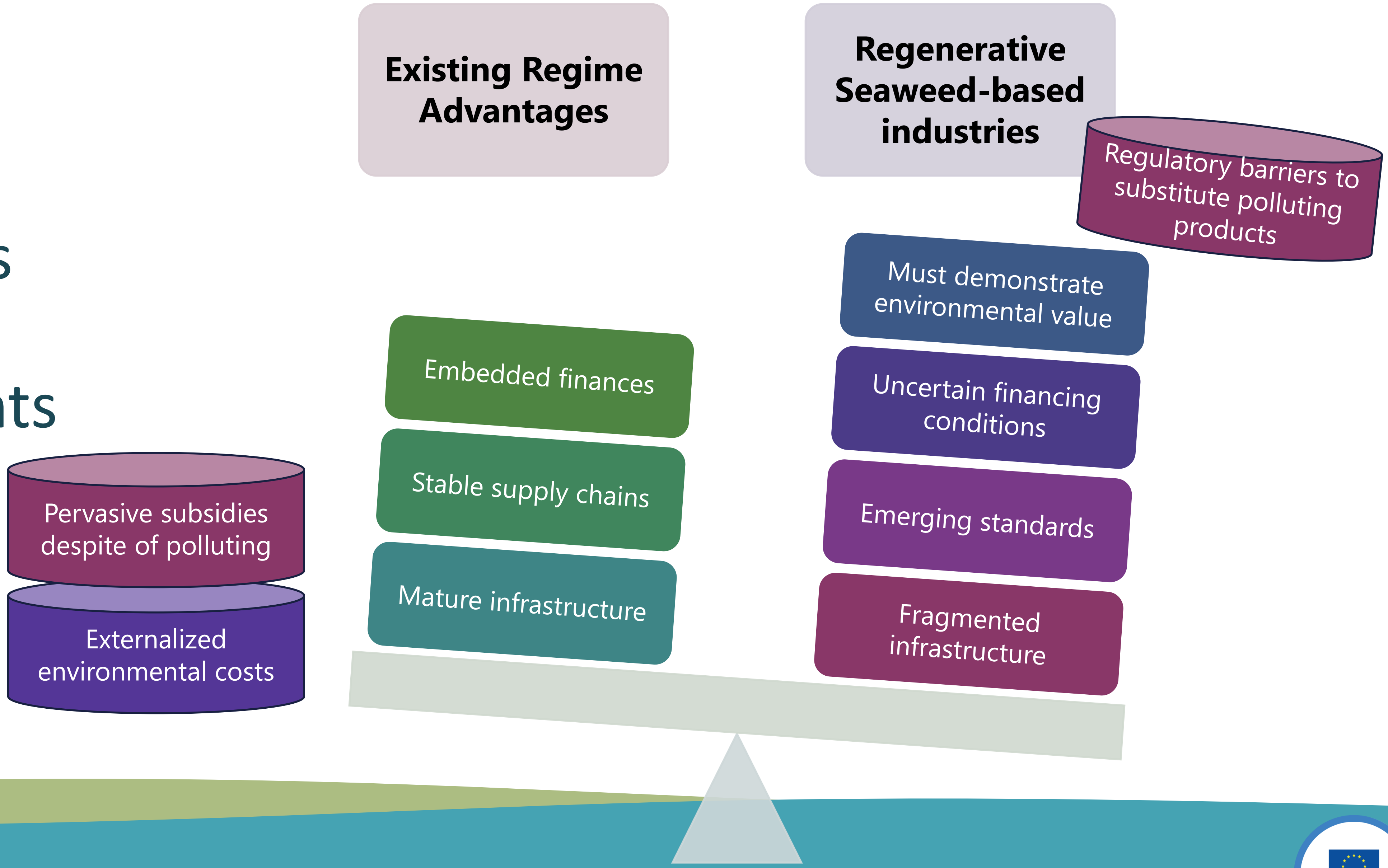
- Technological readiness
- Environmental legitimacy
- Product pathways

But still lacks

- Embedded market structures
- Investment stability
- Institutional coordination

Regenerative industries are emerging within markets that still largely price products as if environmental degradation were free

Systemic Asymmetries and Misalignments



The puzzle is to understand how environmental innovations emerge and evolve and what's needed to enable them to ***replace, transform or reconfigure*** *existing systems* (Geels 2011)

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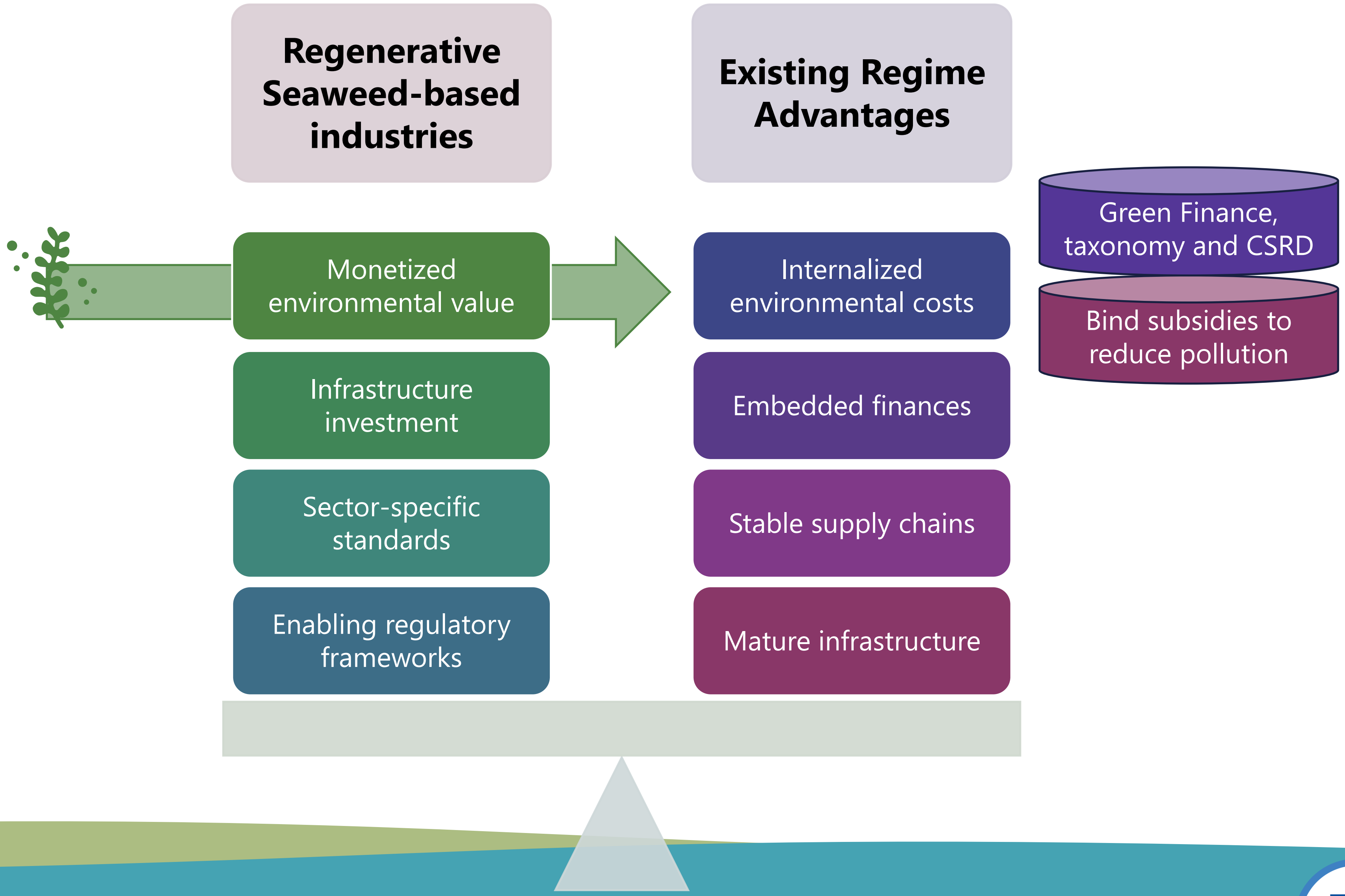
Enabling a sustainable transition through Ecosystem Services



Priority actions to enable transition by relevant stakeholder group

Regulatory alignment

- Streamline permitting
- Bind harmful subsidies to sustainable transition
- Align public procurement to climate objectives

De-risking through sustainable finance

- Internalize restorative value
- Reduce transition asymmetry
- Improve capital mobilization

Value Chain Integration

- Selective breeding
- Infrastructure coordination
- Stabilize demand in target market and seasonal supply

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The challenge is not whether the European seaweed industry can scale - but whether the surrounding system can evolve to support it.

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