Marine biomass for circular nutrient economies in Sweden: remediating eutrophication and securing phosphorus futures

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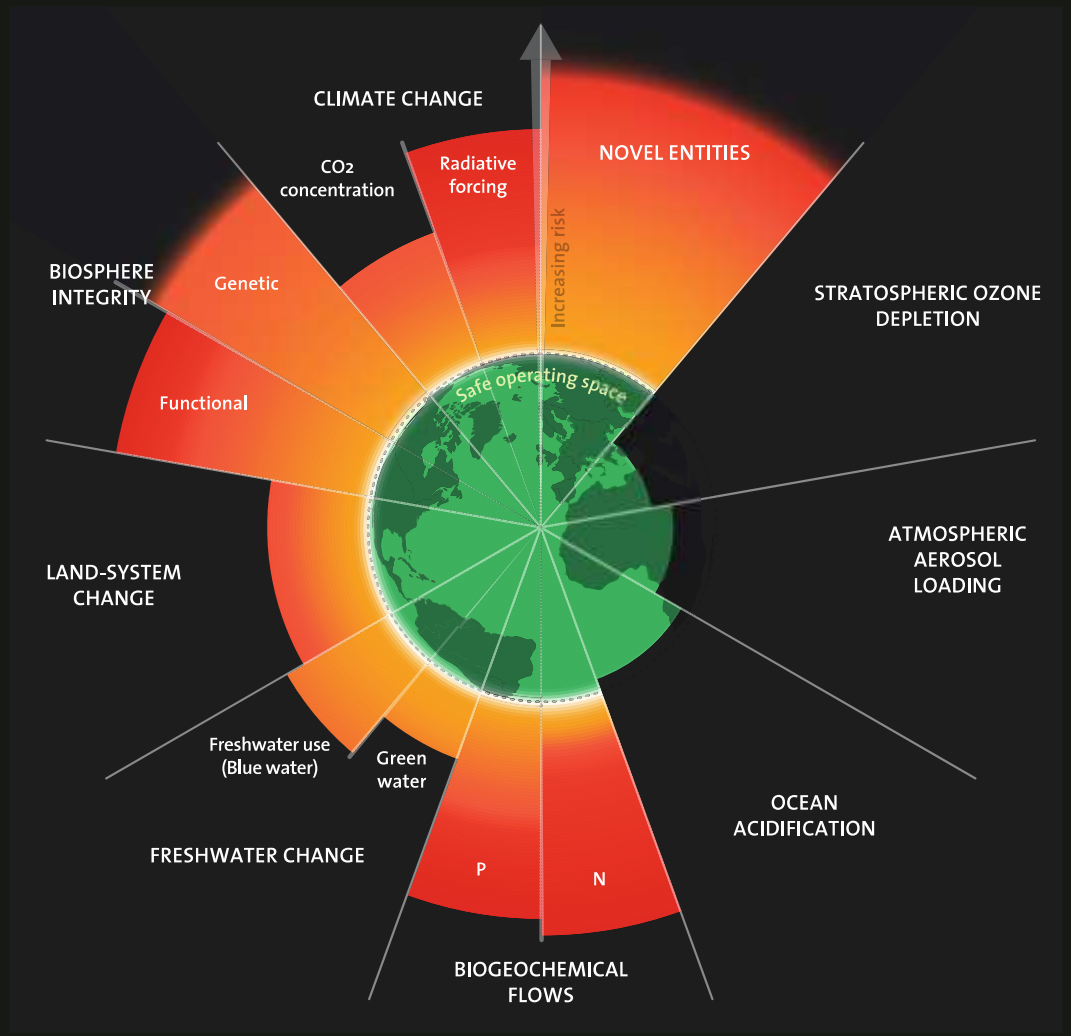
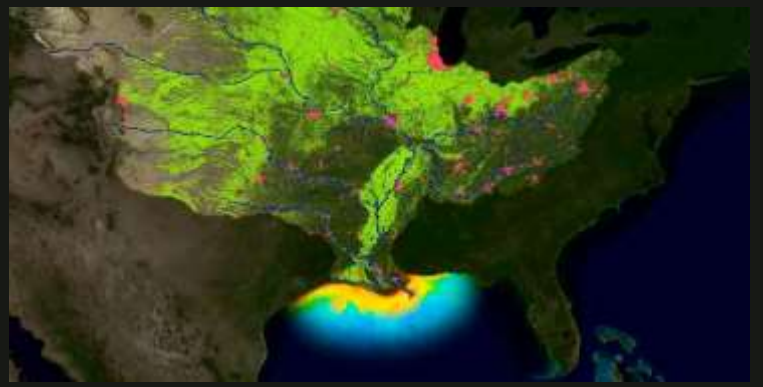


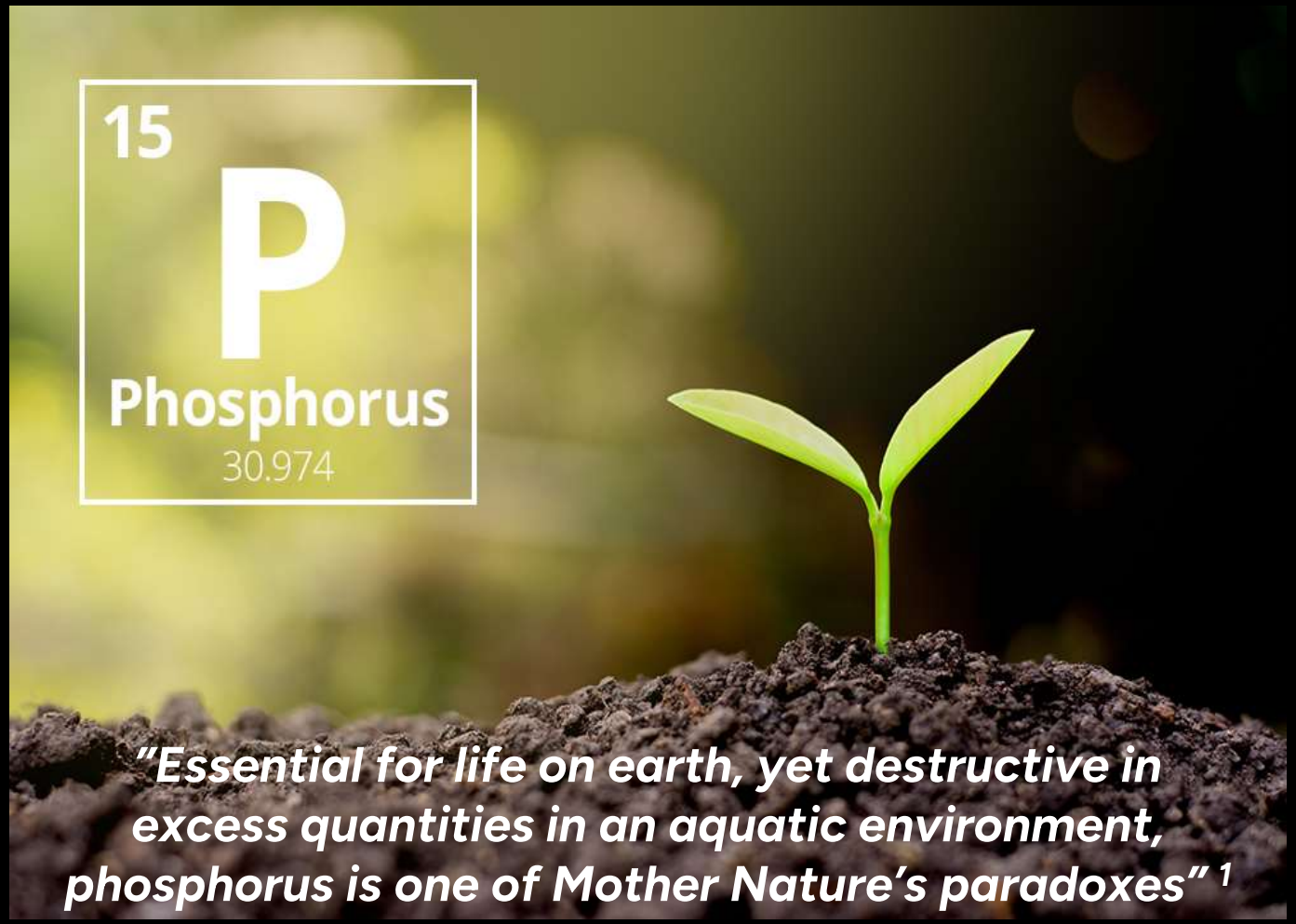
Below boundary (safe)
In zone of uncertainty (increasing risk)
Beyond zone of uncertainty (high risk)

https://www.stockholmresilience.org/research/planetary-boundaries.html
Rockström, J., et al., *A safe operating space for humanity*. Nature, 2009; Steffen, W., et al., *Planetary boundaries: Guiding human development on a changing planet*. Science, 2015.

Satelite picture showing Baltic algae blooms



Gulf of Mexico "dead zone" forecast for 2019, NOAA



Source
- Phosphate rocks
- Mined: stocks estimated to last 50-100 years [2-5]

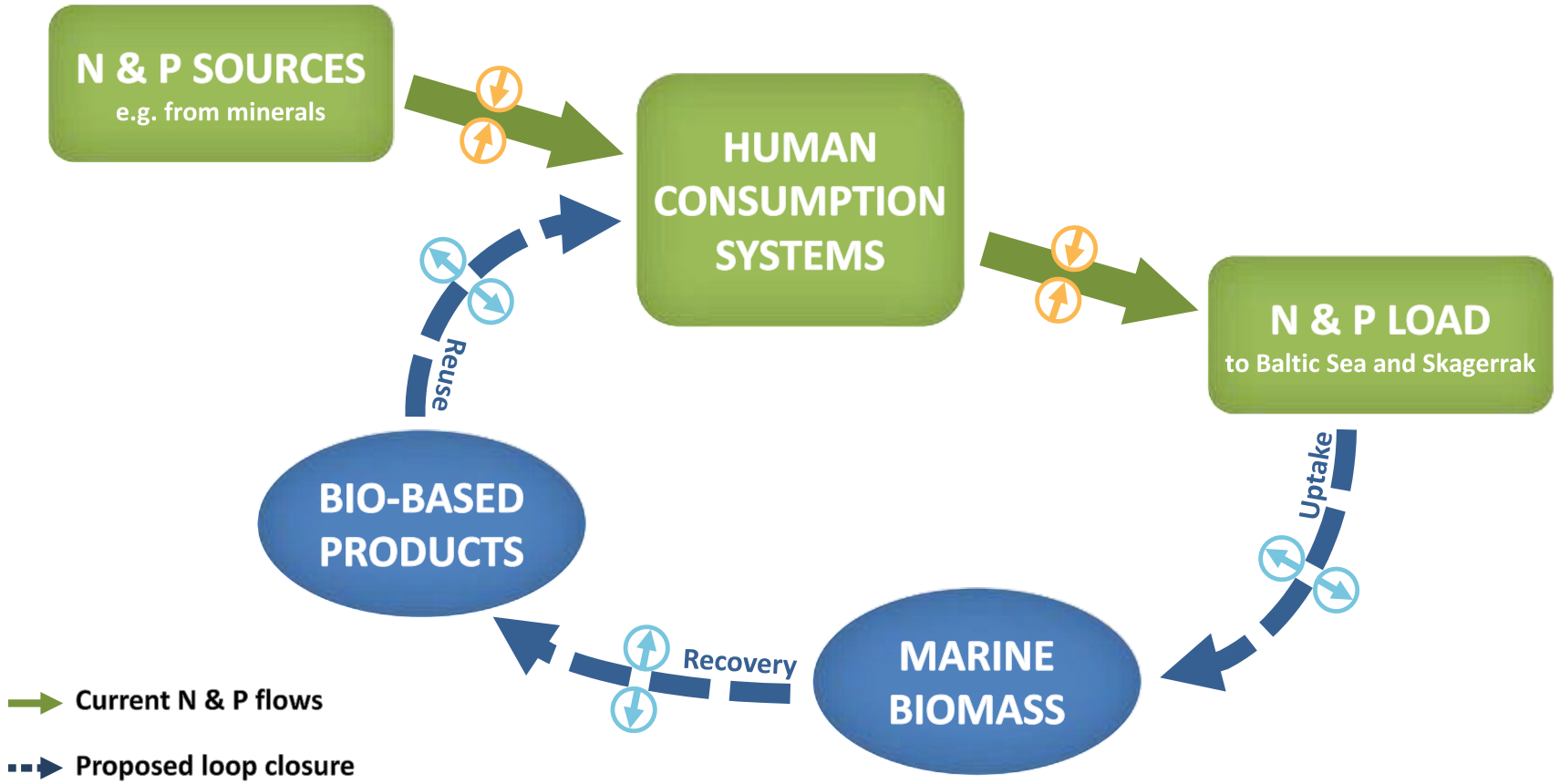
Use
- Fertiliser for food and feed
- Industrial uses (minor use)

Loss
- Agricultural runoff
- Sewage sludge and waste water

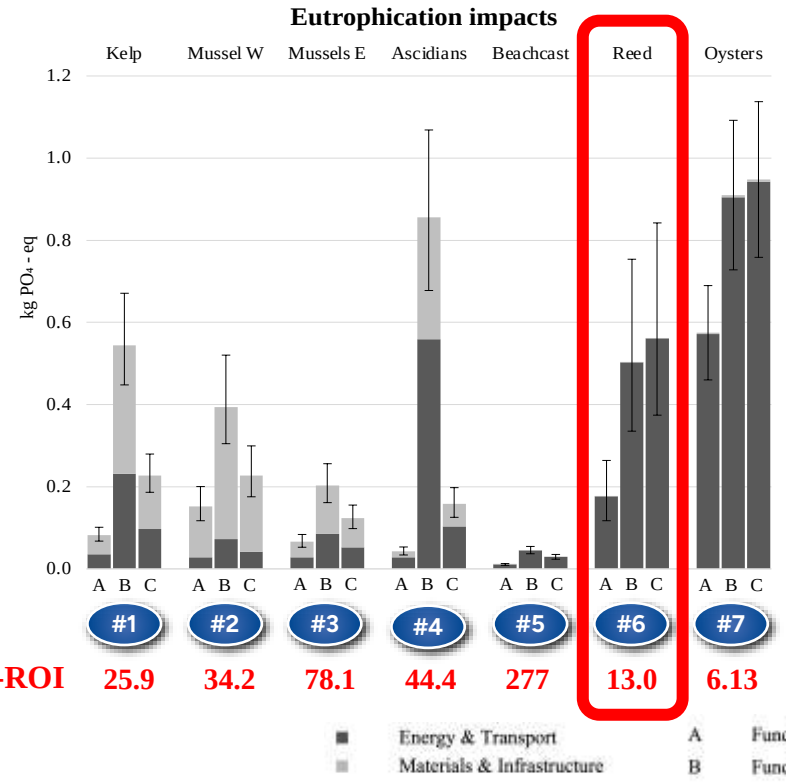
Sink
- Soil stocks
- Marine environments

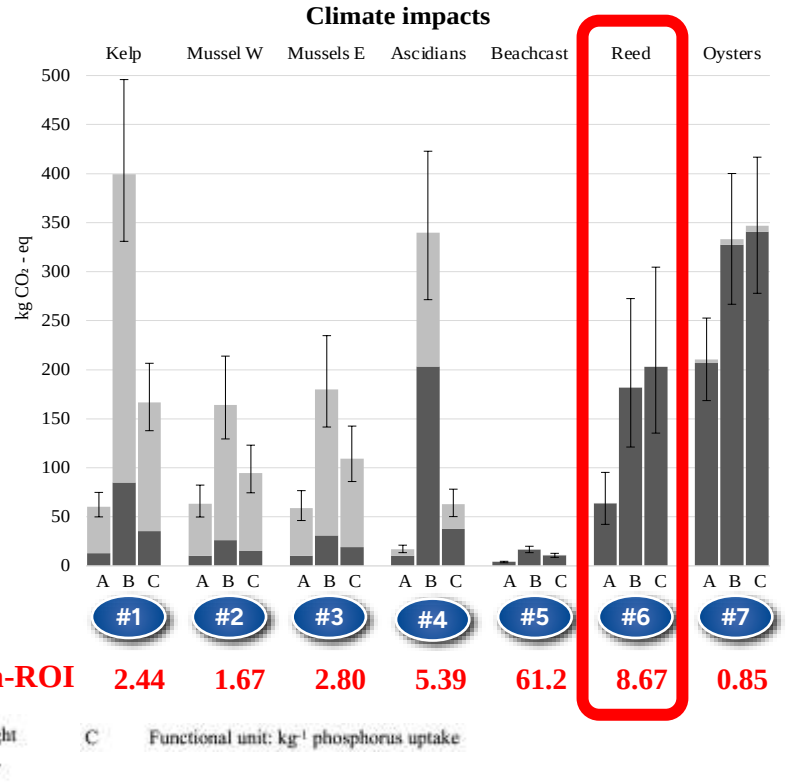
[1] EcoSanRes, *Closing the Loop on Phosphorus*. 2003, Stockholm Environment Institute (SEI) funded by SIDA Stockholm (2003): Stockholm
[2] Cordell, D., J.-O. Drangert, and S. White, *The story of phosphorus: Global food security and food for thought.* Global Environmental Change, 2009. **19**(2): p. 292-305.
[3] Elser, J. and E. Bennett, *A broken biogeochemical cycle.* Nature, 2011. **478**(7367): p. 29-31.
[4] Steen, I., *Phosphorus availability in the 21st century: management of a non-renewable resource.* Phosphorus Potassium, 1998. **217**: p. 25-31.
[5] Cordell, D. and S. White, *Life's Bottleneck: Sustaining the World's Phosphorus for a Food Secure Future.* Annual Review of Environment and Resources, 2014. **39**(1): p. 161-188.

Marine bioeconomy for circular nitrogen and phosphorus flows in Sweden: Alternatives, hurdles and policy tools



Life Cycle Assessment (results: cradle-to-gate)





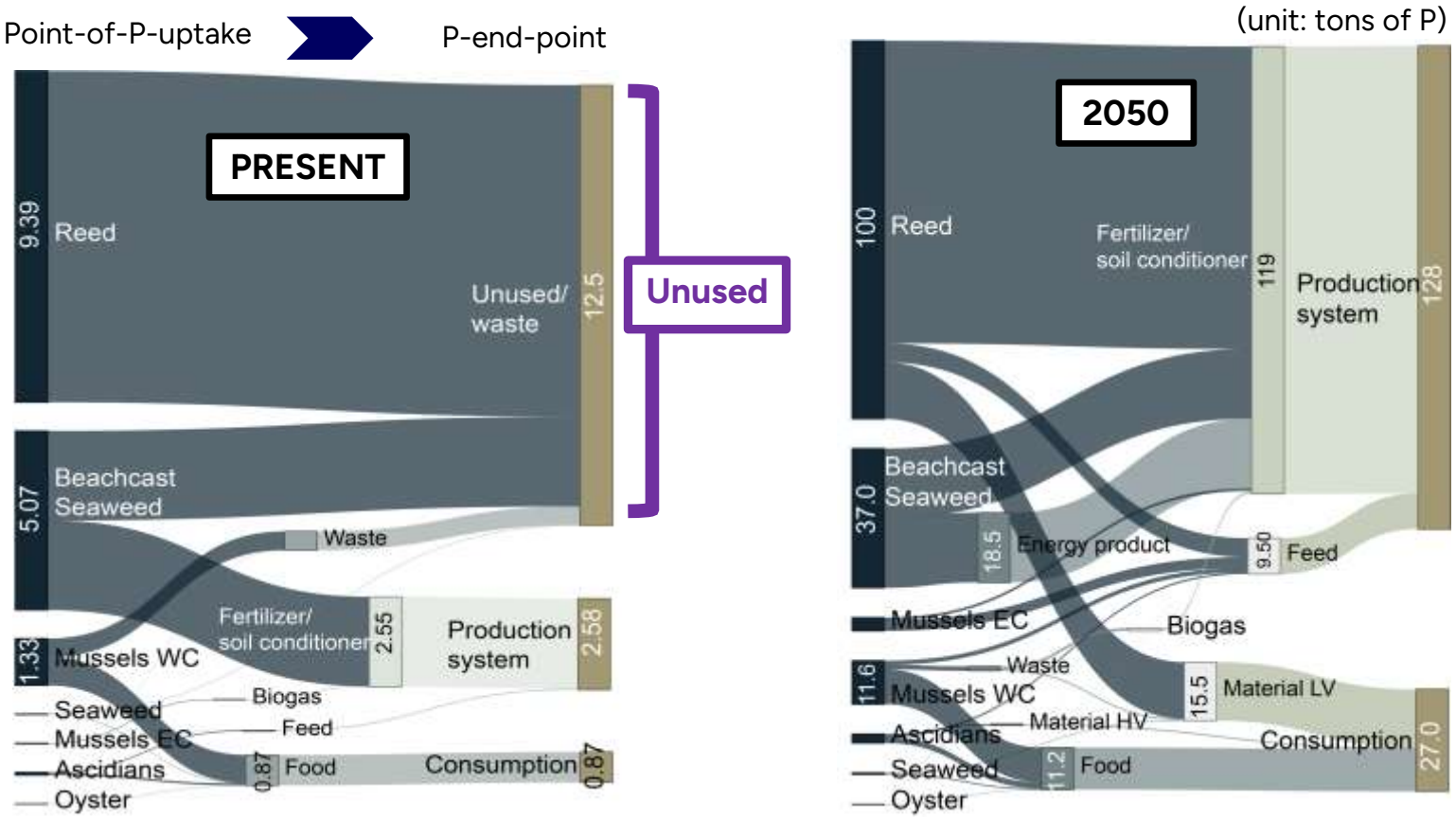
	#1	#2	#3	#4	#5	#6	#7
Nutrient-ROI	25.9	34.2	78.1	44.4	277	13.0	6.13
Carbon-ROI	2.44	1.67	2.80	5.39	61.2	8.67	0.85

Energy & Transport
Materials & Infrastructure

A Functional unit: ton^{-1} fresh weight
B Functional unit: ton^{-1} dry matter
C Functional unit: kg^{-1} phosphorus uptake

- ✓ **All studied cases "close-the-loop" on N and P** (N-ROI > 1) contributing to phosphorus security and some degree of local eutrophication mitigation, *especially #5 and the low-trophic extractive aquaculture cases #1-4*
- ✓ All cases also performed well from a carbon perspective (C-ROI), *especially #5 and #6*

Element Flow Analysis (mapping biomass uses for P "loop closure")

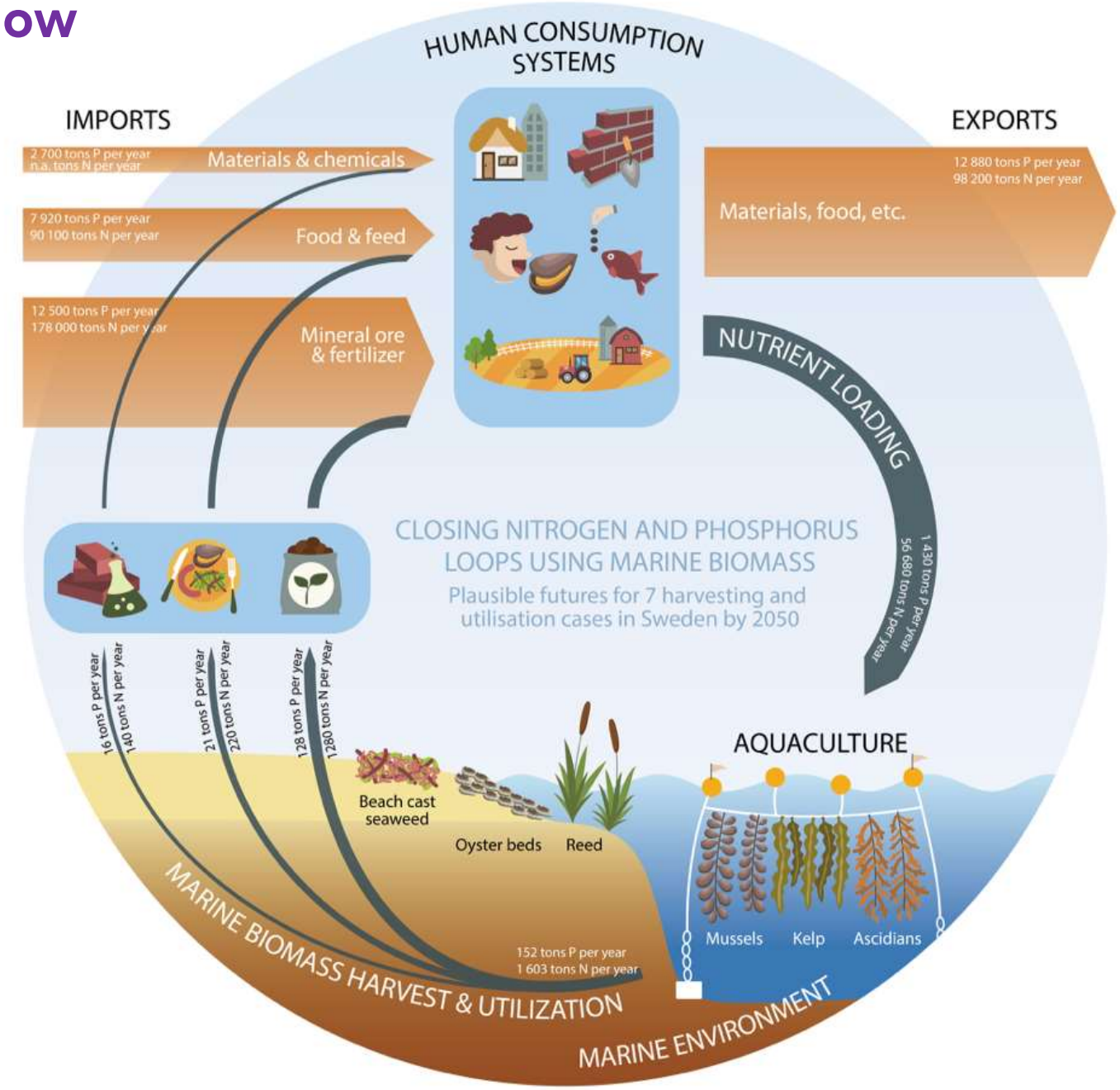


- ✓ **Reed and beachcast were largest potential source of P but are mostly unused today, with potential mostly lying in their use as fertilizers and feed**
- ✓ **Shellfish cases mostly recover P as food and feed products**

Element Flow Analysis

✓**As much as 5.7% and 10.1% of P emissions could be recovered by 2030 and 2050, respectively***

* Assuming Sweden adopts a "blue-growth enabling environment" to support and nurture blue industries and communicate the many benefits of this sector (health, environmental, sustainable rural economic growth, etc.)



The reed innovation system: stakeholder landscape, potential product pathways and their benefits – **Elea Juell-Skielse's master thesis**

Scientific publication coming soon

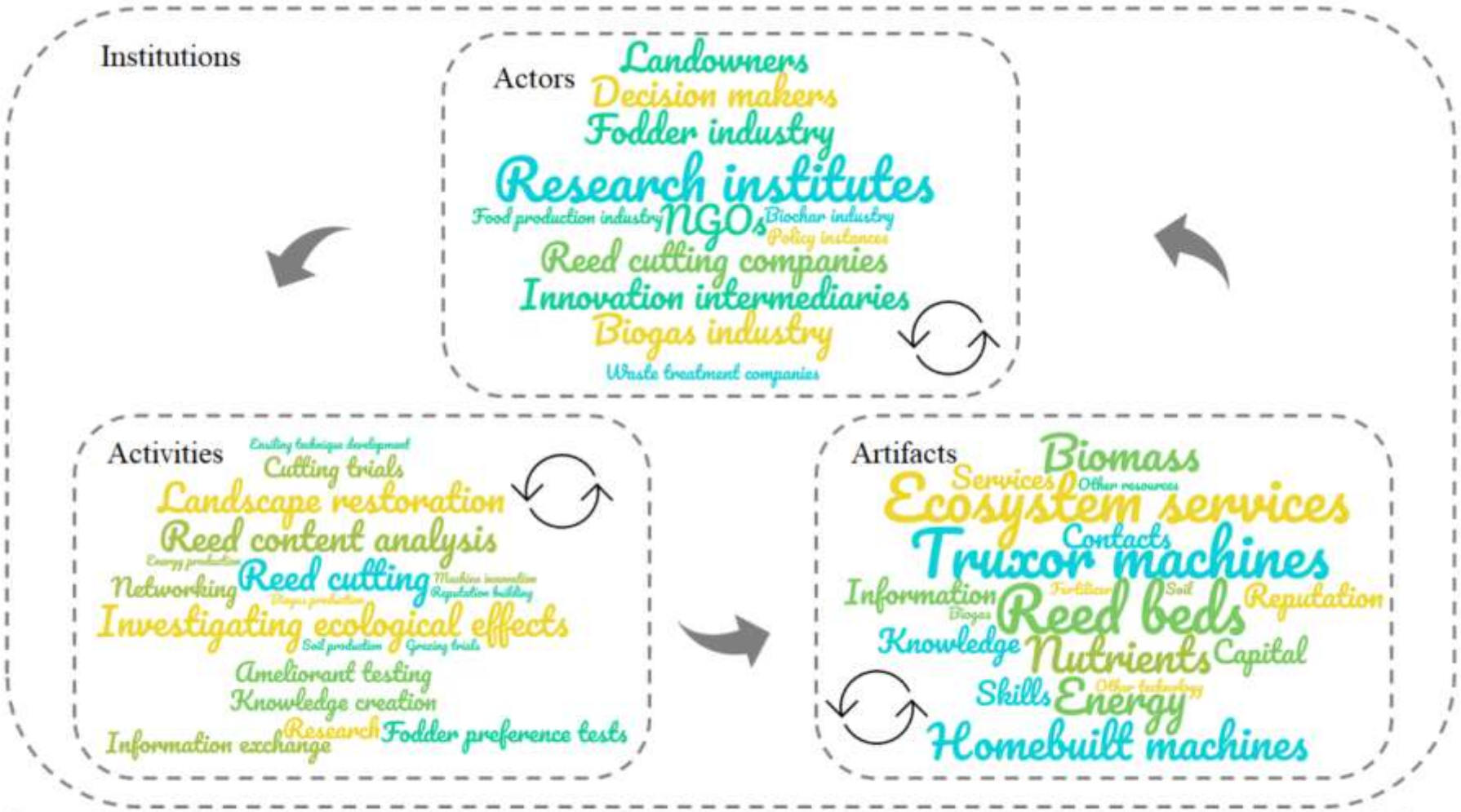
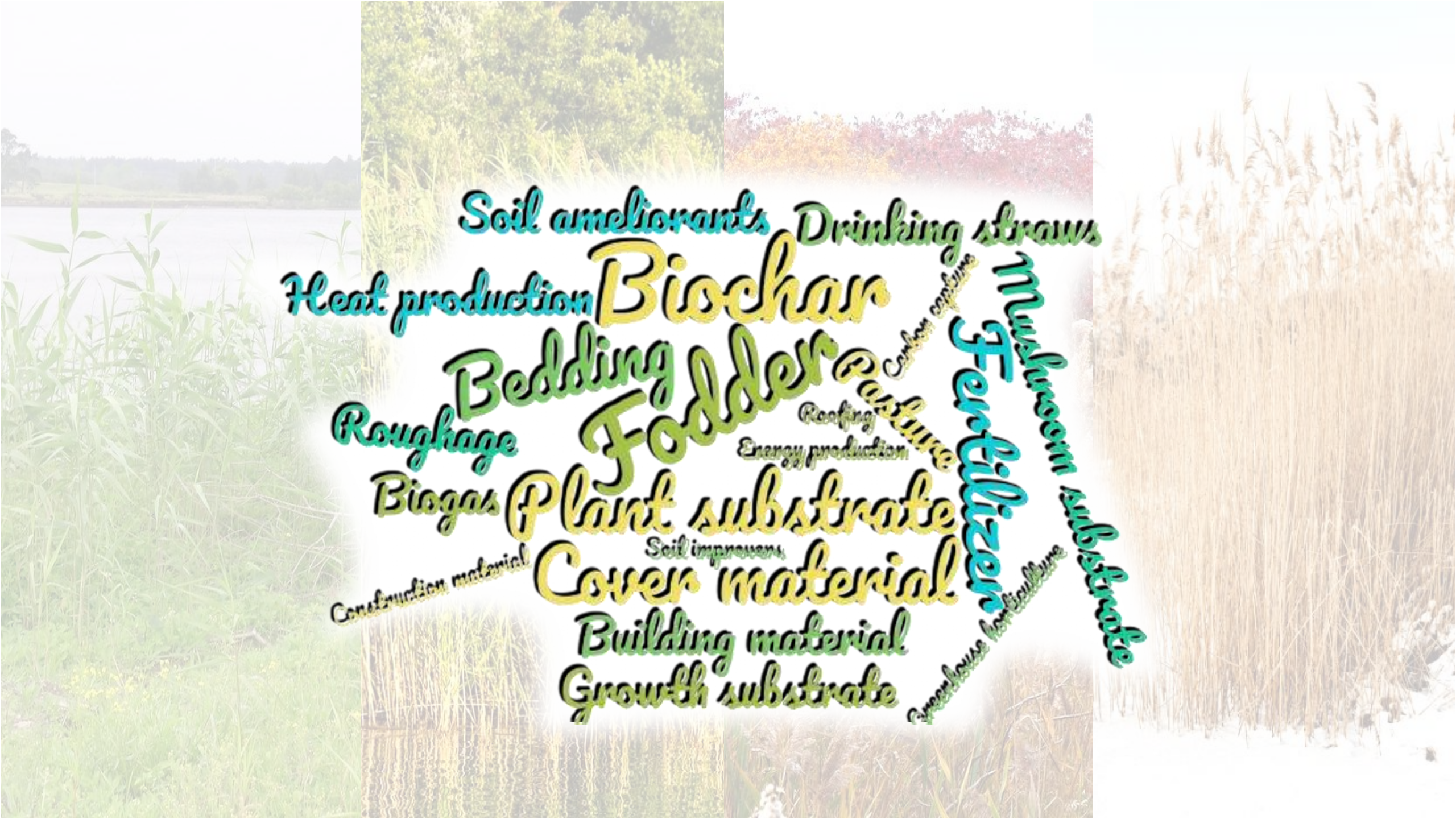


Figure 10: Current reed innovation system. Actors, artifacts, and activities interact within the boundaries of the institutions of the system. Inspired by Granstrand and Holgersson (2020).


Soil ameliorants
Drinking straws
Heat production
Biochar
Bedding
Fodder
Carbon capture
Pasture
Roofing
Roughage
Energy production
Mushroom substrate
Fertilizer
Biogas
Plant substrate
Soil improvers
Construction material
Cover material
Building material
Growth substrate
Greenhouse horticulture

Scientific publication coming soon

Figure 6: Word cloud with the concepts related to POTENTIAL BENEFITS OF AN INCREASED REED HARVEST which were most often mentioned by the participants. Word size correlates to word occurrence.

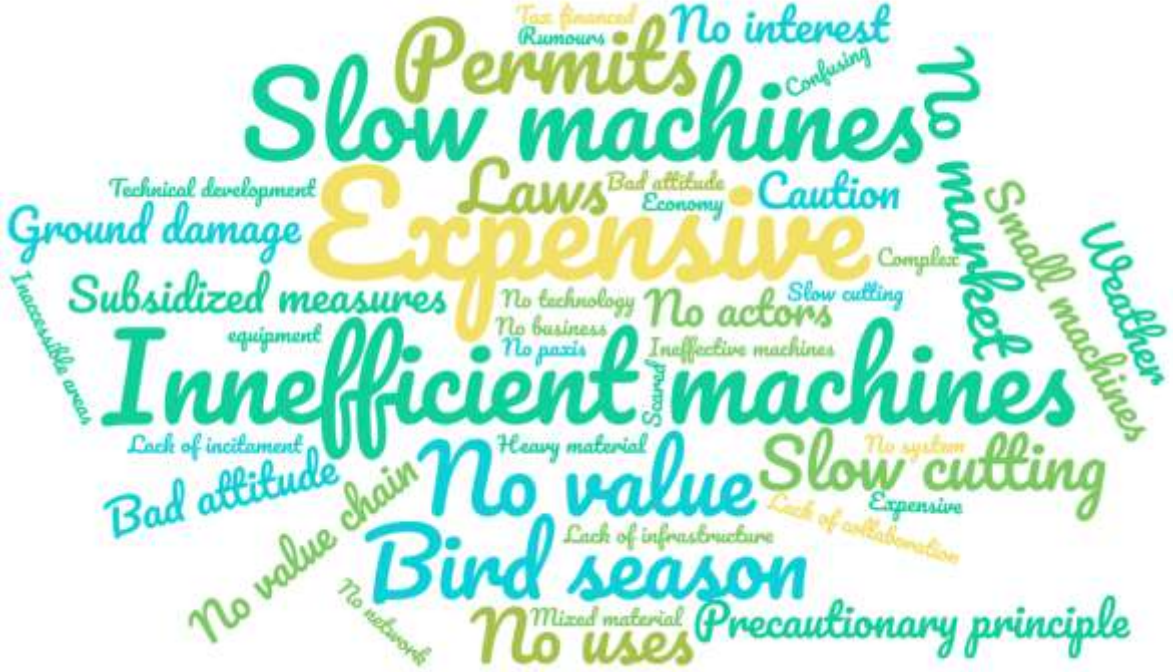


Figure 8: Word cloud with the concepts related to HURDLES which were most often mentioned by the participants. Word size correlates to word occurrence.

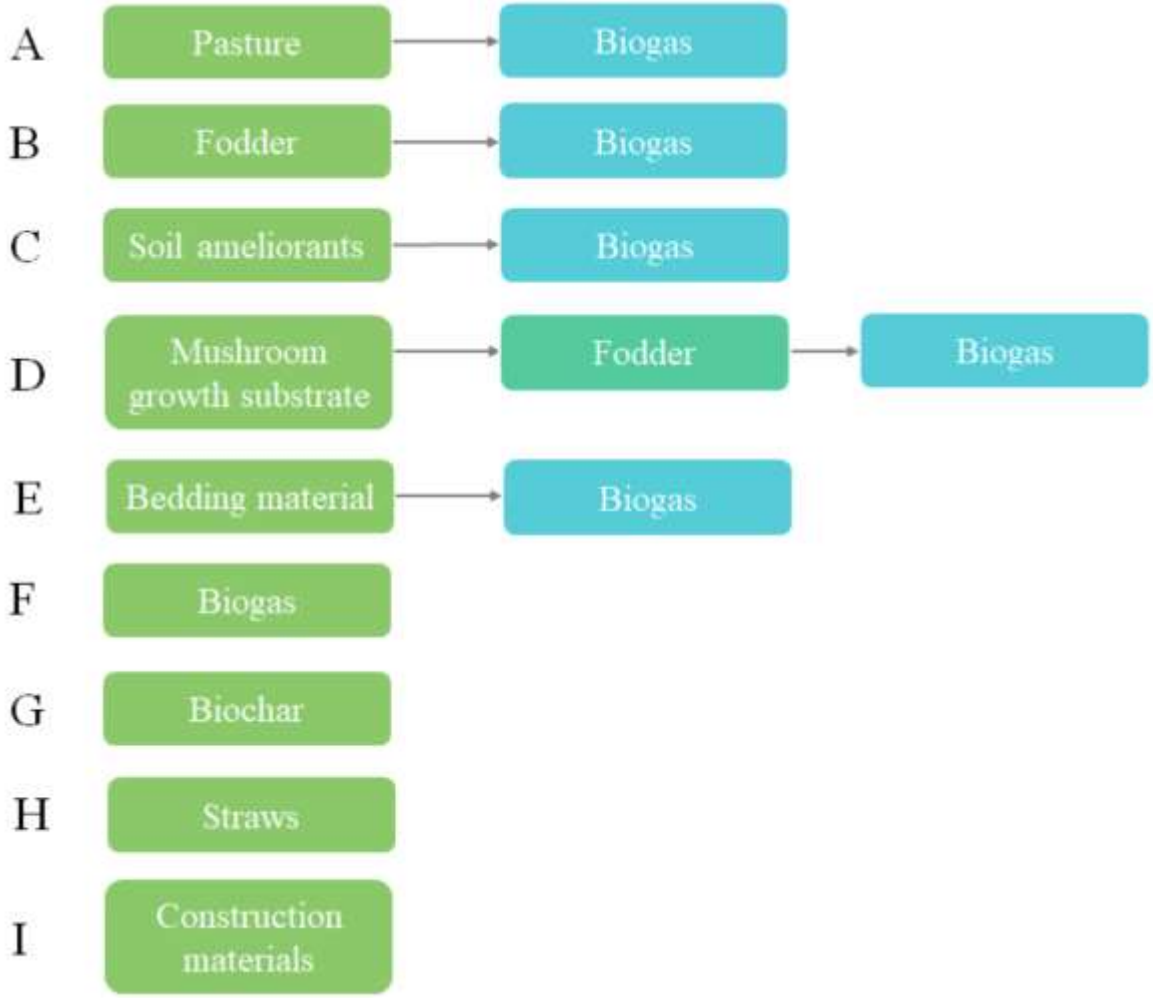
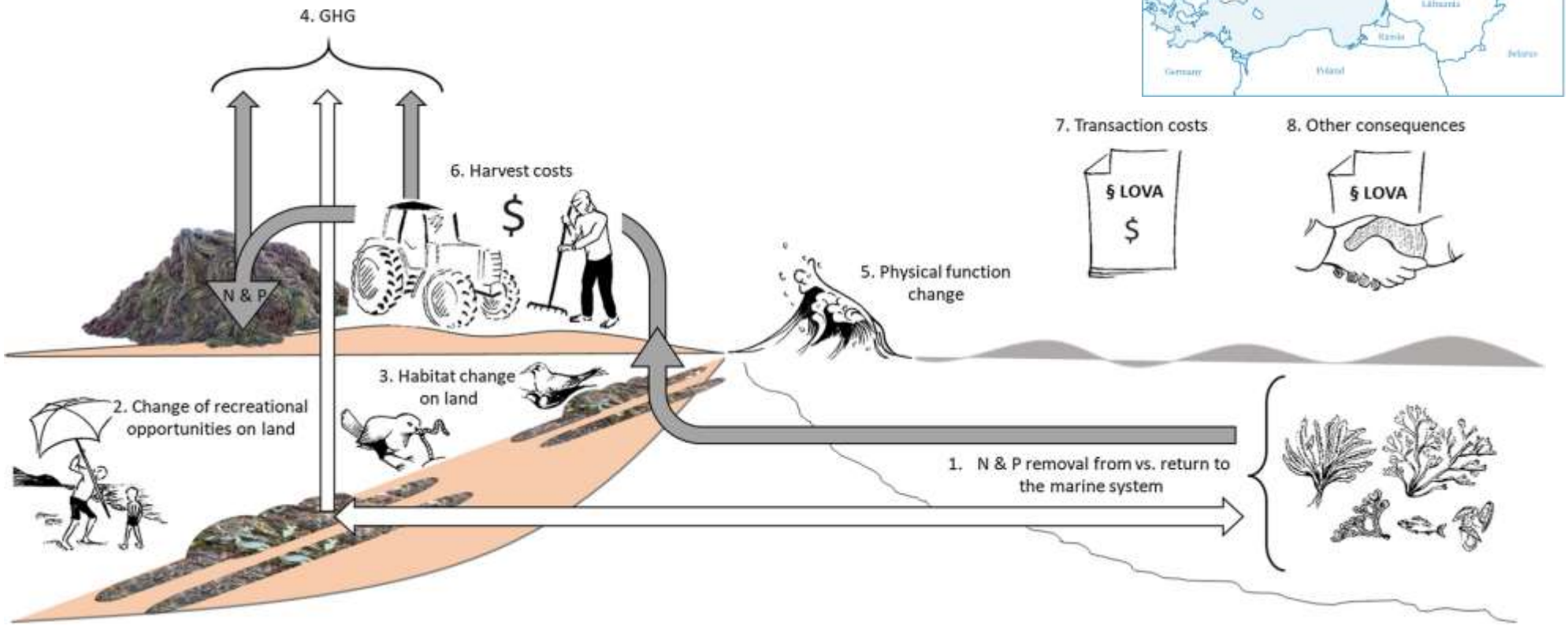


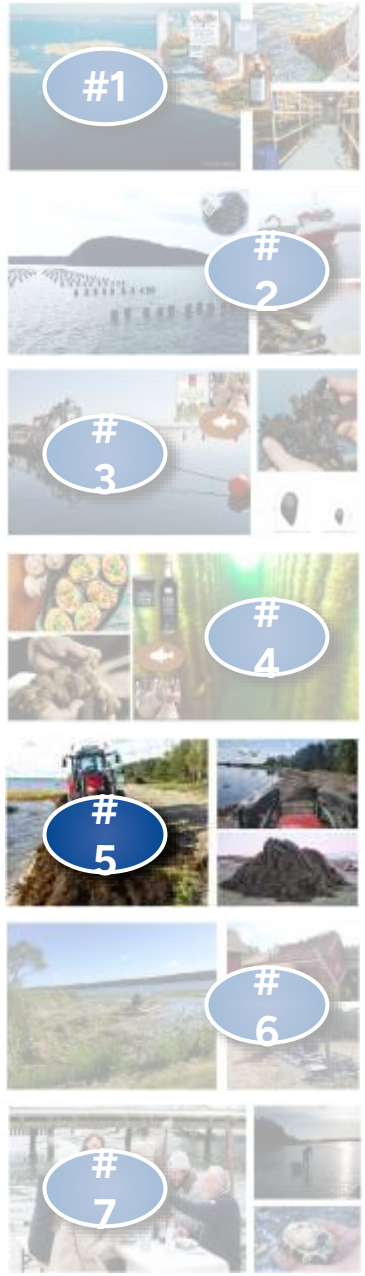
Figure 14: POSSIBLE CASCADING PRODUCTS

Figure 16: VALUE CHAIN A TO G ILLUSTRATED WITH ADDITIONAL BY-PRODUCTS AND BENEFITS. Note that none of the participants mentioned any by-products or benefits connected to value chains H and I, which have therefore been excluded from the figure.

Cost-Benefit Analysis of harvesting beachcast in Gotland

- ✓ **Is the harvest of beachcast worth the cost?** Evaluate all monetizable costs and benefits to determine profitability for society
- ✓ Data from beachcast removal carried out **as local water protection projects (LOVA)**, paid for by national government grants and the local municipalities (40 projects in period 2009-2018, ≈ 90 000 tons FW total)

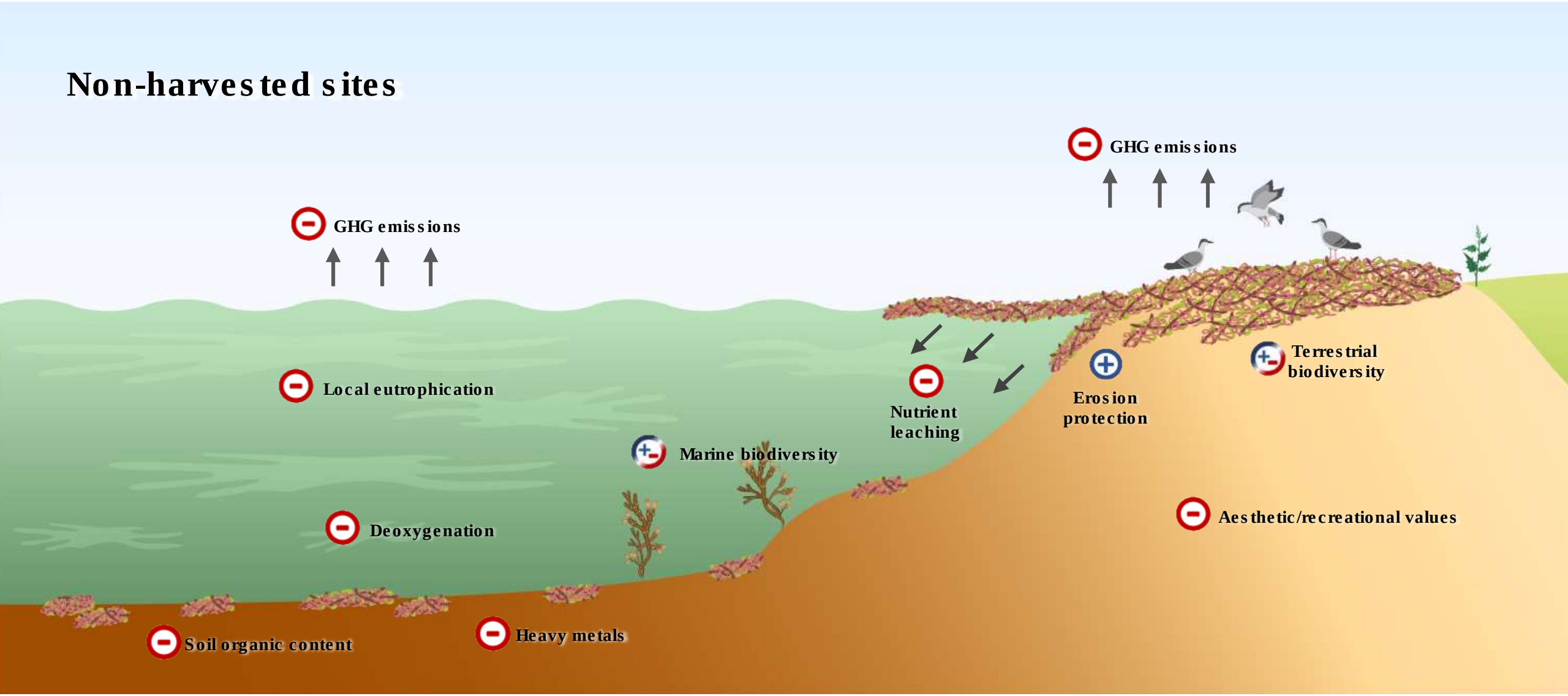




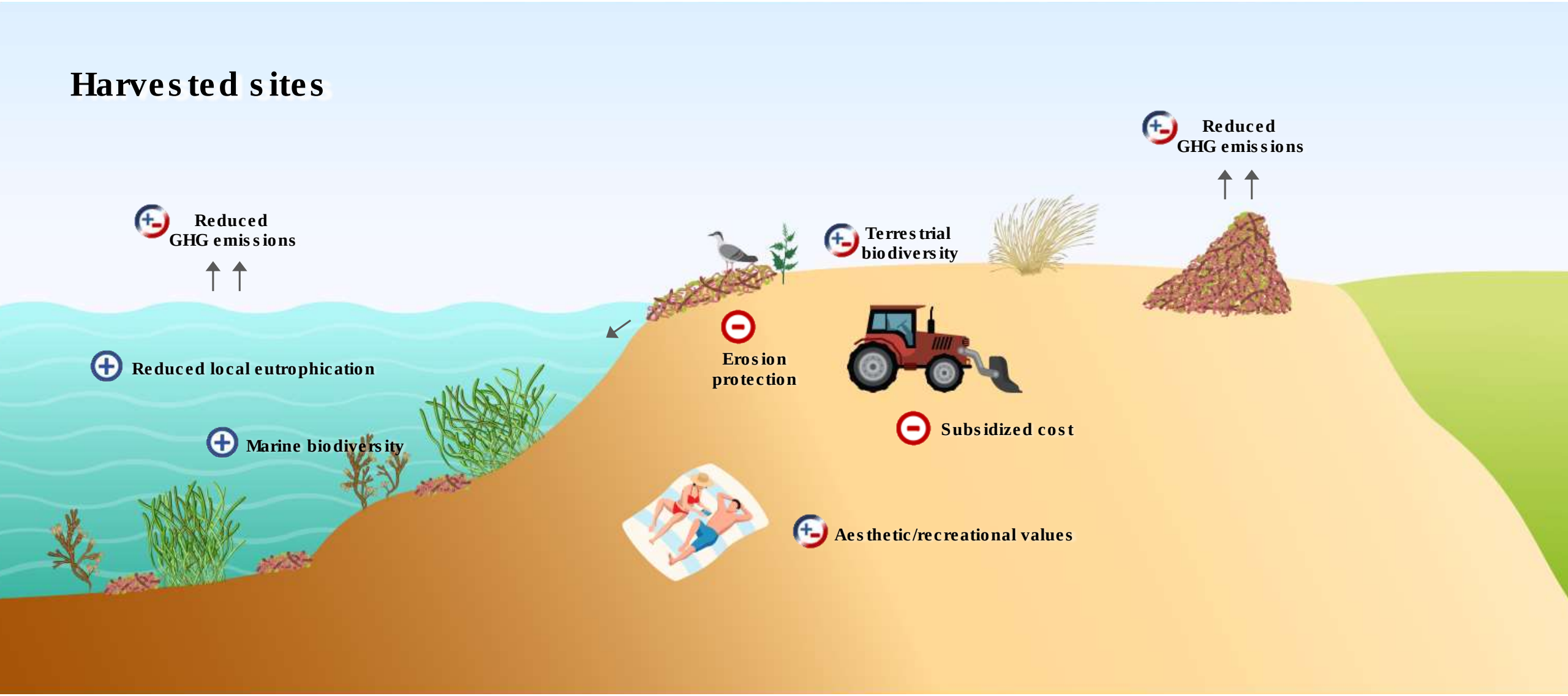
From: Green and golden seaweed tides on the rise

CRISTINA BARROCA; ANSA/JIAN FENG; MAX FRELING; ANDREW HUCKBODY

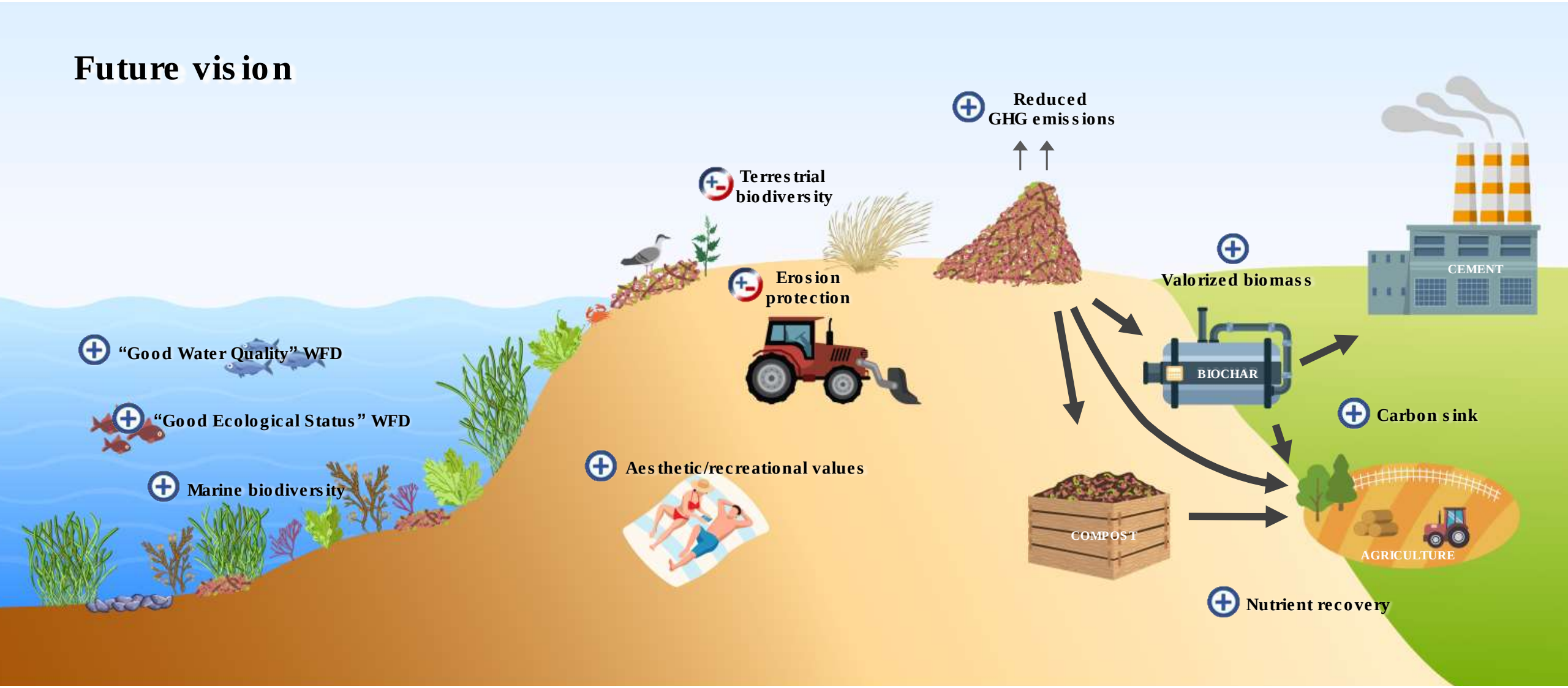
On the potential of Baltic beachcast



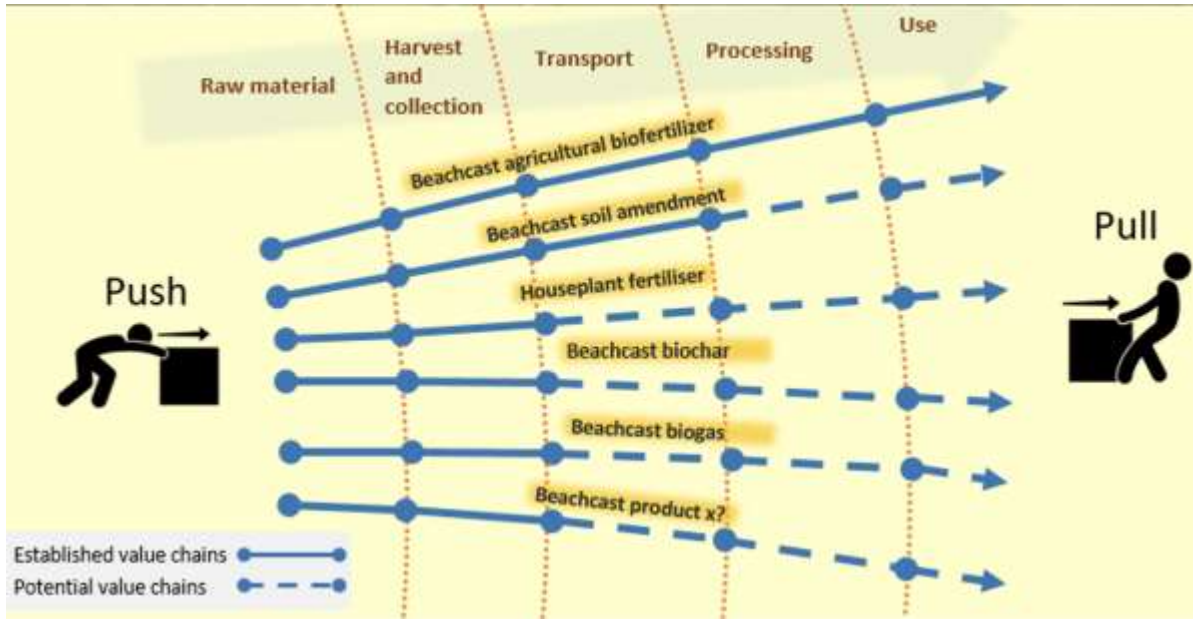
On the potential of Baltic beachcast



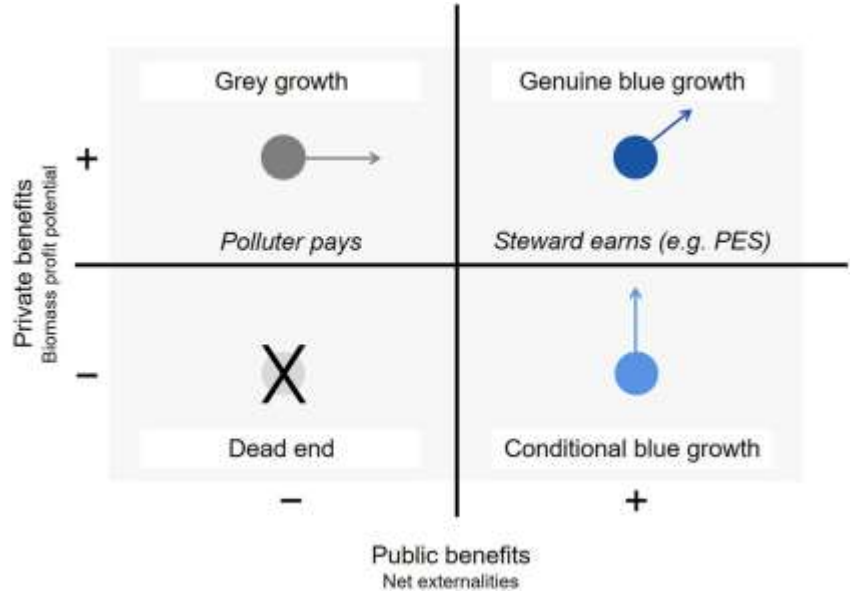
On the potential of Baltic beachcast



Cost-Benefit Analysis – socio-economic synthesis & policy landscape

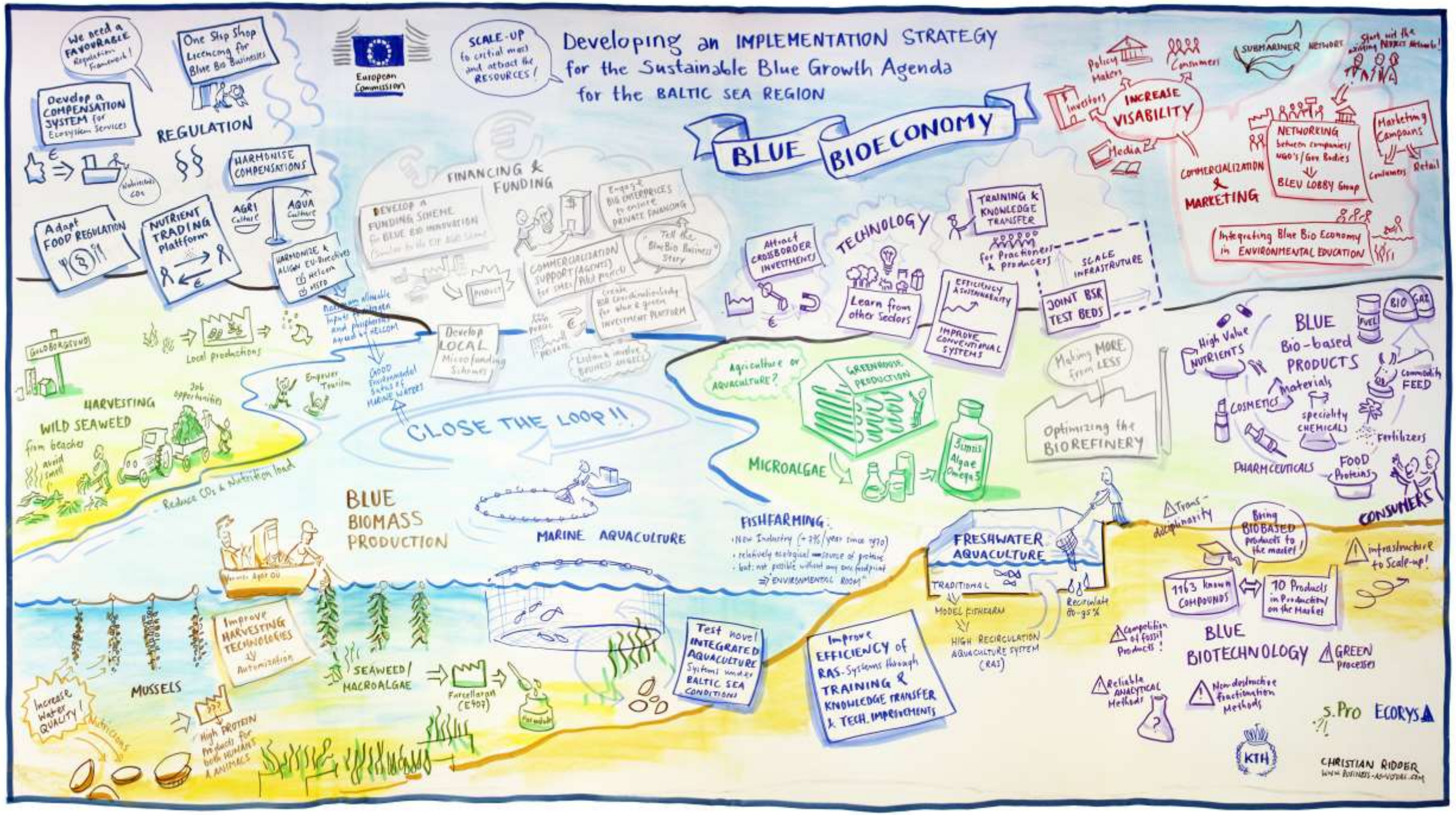


Hasselström and Gröndahl 2021. Payments for nutrient uptake in the blue bioeconomy – When to be careful and when to go for it



Biomass	Production costs	Revenue	Financial net	Value of N&P removal	Non-quantified negative externalities	Non-quantified positive externalities
Cultivated seaweed	10	20	+10 €	+3 €	Recreation	Habitat generation
Mussels W	5	12	+7 €	+6 €	…	…
Mussels E	7	2	-5 €	+4 €		
Ascidians	Uncertain	Uncertain	Uncertain	+10 €		
Beachcast	8	0	-8 €	+8 €		
Reed	4	0	-4 €	+4 €		
Pacific oysters	15	20	+5 €	+3 €		

Numbers made up for illustrative purposes


Developing an IMPLEMENTATION STRATEGY for the Sustainable Blue Growth Agenda for the BALTIC SEA REGION
BLUE BIOECONOMY
We need a FAVOURABLE Regulation Framework!
One Stop Shop Licencing for Blue Bio Businesses
European Commission
SCALE-UP to critial mass and attract the RESOURCES!
REGULATION
Develop a COMPENSATION SYSTEM for Ecosystem Services
Adapt FOOD REGULATION
NUTRIENT TRADING Platform
HARMONISE COMPENSATIONS
AGRI Culture
AQUA Culture
HARMONIZE & ALIGN EU-Directives
FINANCING & FUNDING
DEVELOP A FUNDING SCHEME
COMMERCIALIZATION SUPPORT (AGENTS)
Engage BIG ENTERPRISES to enhance PRIVATE FINANCING
Tell the BlueBio Business Story
Create BSR Coordinationbody for blue & green INVESTMENT PLATFORM
Develop LOCAL Microfunding Schemes
Attract CROSSBORDER INVESTMENTS
TECHNOLOGY
Learn from other Sectors
TRAINING & KNOWLEDGE TRANSFER for Practioners & producers
EFFICIENCY & SUSTAINABILITY
IMPROVE CONVENTIONAL SYSTEMS
SCALE INFRASTRUCTURE
JOINT BSR TEST BEDS
INCREASE VISABILITY
Policy Makers
Consumers
Investors
Media
SUBMARINER NETWORK
Start with the existing Network!
COMMERCIALIZATION & MARKETING
NETWORKING between companies/ NGO's/ Gov Bodies
BLEU LOBBY Group
Marketing Campains
Consumers
Retail
Integrating Blue Bio Economy in ENVIRONMENTAL EDUCATION
CLOSE THE LOOP!!
Local productions
Empower Tourism
Good Environmental Status of MARINE WATERS
HARVESTING
WILD SEAWEED
from beaches
avoid smell
306 opportunities
Reduce CO2 & Nutrition load
BLUE BIOMASS PRODUCTION
MARINE AQUACULTURE
Agriculture or AQUACULTURE?
GREENHOUSE PRODUCTION
MICROALGAE
Simris Algae Omega 3
Making MORE from LESS
Optimizing the BIOREFINERY
BLUE Bio-based PRODUCTS
High Value NUTRIENTS
BIO GAS
FUEL
Materials
COSMETICS
specialty CHEMICALS
commodity FEED
Fertilizers
PHARMACEUTICALS
FOOD Proteins
CONSUMERS
FISHFARMING:
• New Industry (+7%/year since 1970)
• relatively ecological resource of protein
• but: not possible without any own footprint
⇒ ENVIRONMENTAL RISING"
FRESHWATER AQUACULTURE
TRADITIONAL
MODEL FISHFARM
HIGH RECIRCULATION AQUACULTURE SYSTEM (RAS)
Recirculate 80-95%
Trans-disciplinarity
Bring BIOBASED products to the market!
1963 known COMPOUNDS
10 Products in Production/ on the Market
Infrastructure to Scale-up!
BLUE BIOTECHNOLOGY
GREEN processes
Competition of fossil Products!
Reliable ANALYTICAL Methods
Non-destructive fractionation Methods
Improve HARVESTING TECHNOLOGIES
Automization
MUSSELS
Increase Water QUALITY!
Nutrients
SEAWEED/ MACROALGAE
Furcellaran (E407)
High PROTEIN products for both HUMANS & ANIMALS
Test novel INTEGRATED AQUACULTURE Systems under BALTIC SEA CONDITIONS
Improve EFFICIENCY of RAS-Systems through TRAINING & KNOWLEDGE TRANSFER & TECH. IMPROVEMENTS
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