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

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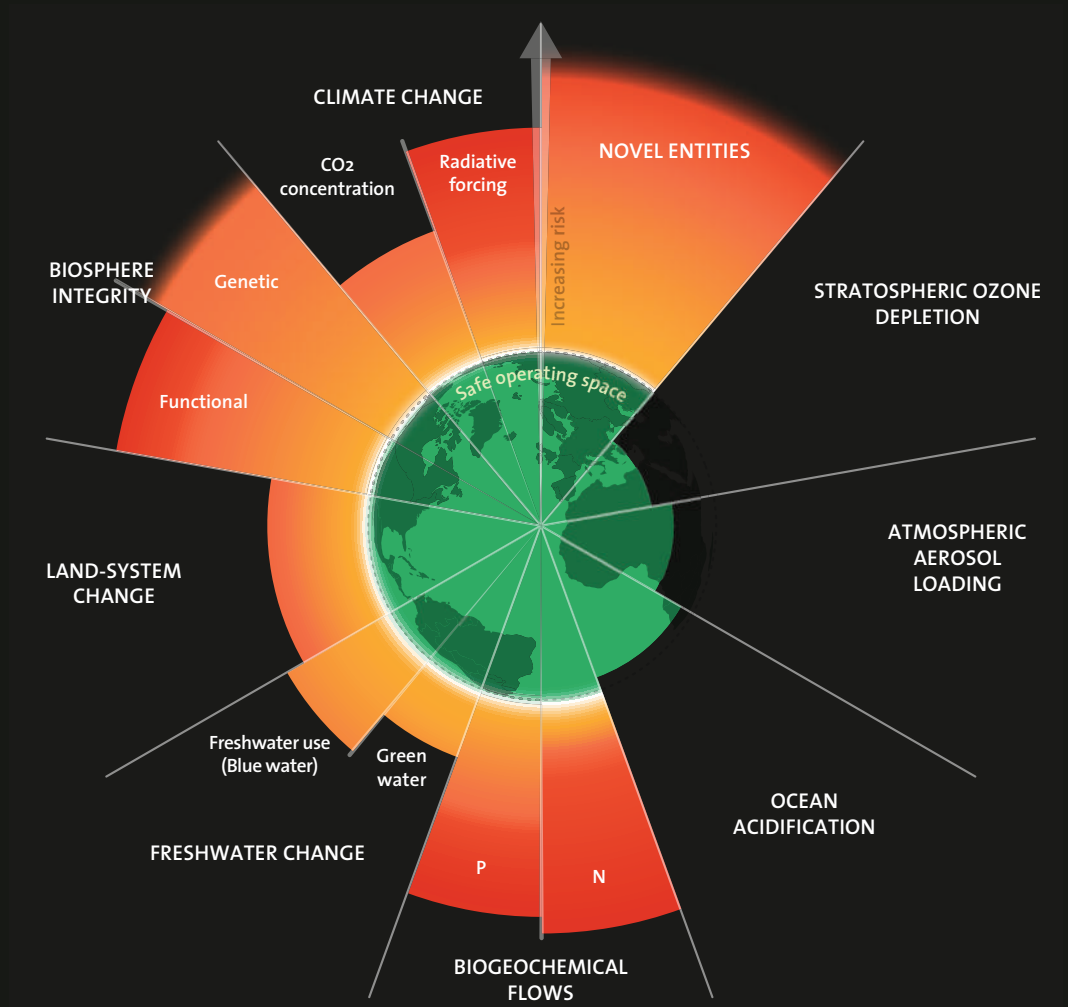
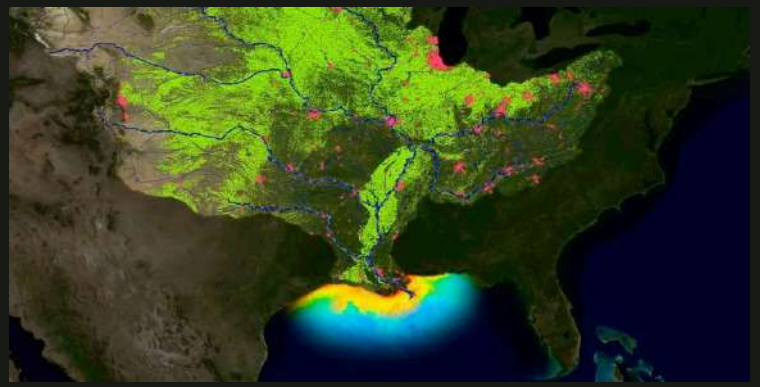


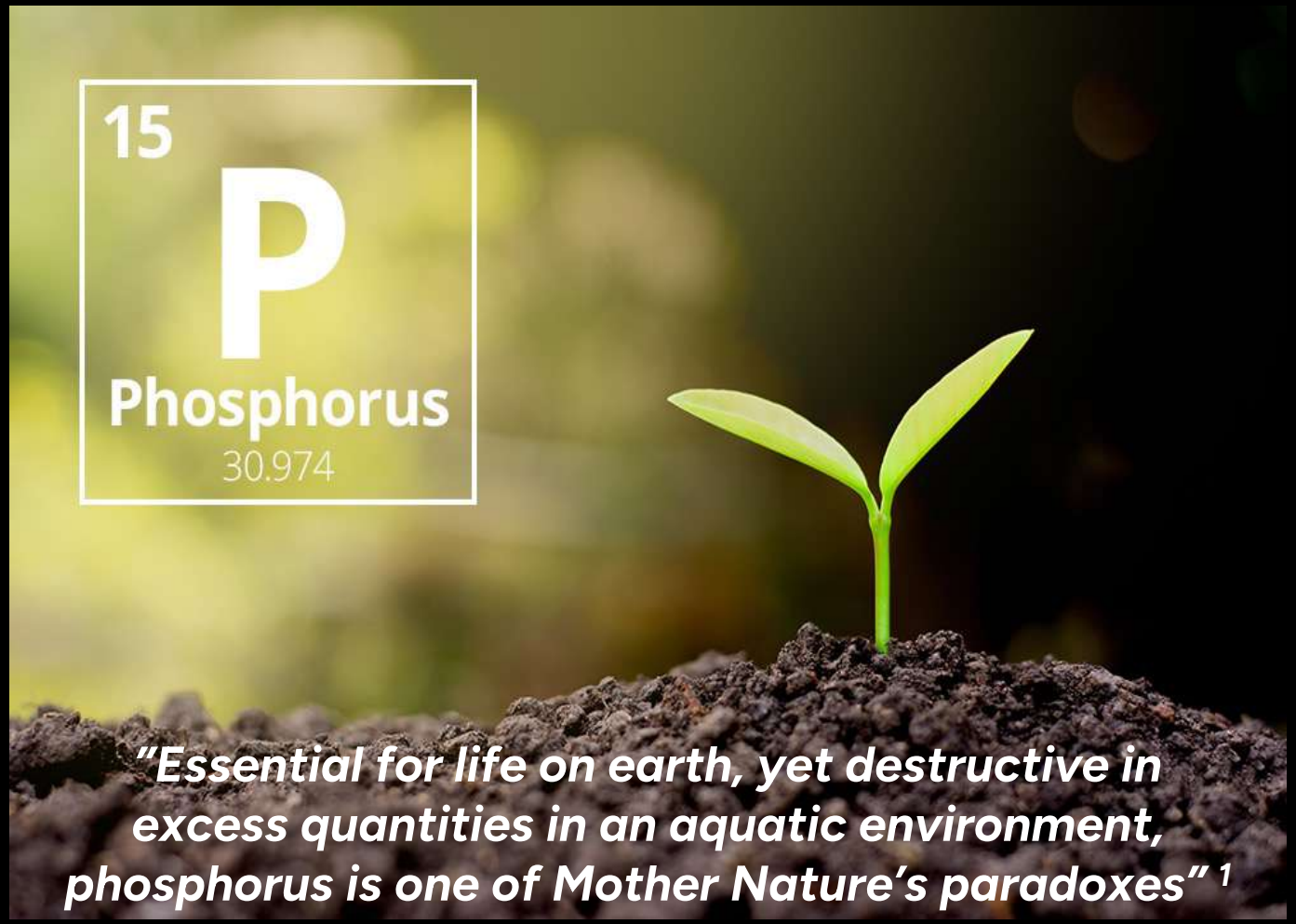
Below boundary (safe)
In zone of uncertainty (increasing risk)
Beyond zone of uncertainty (high risk)

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]

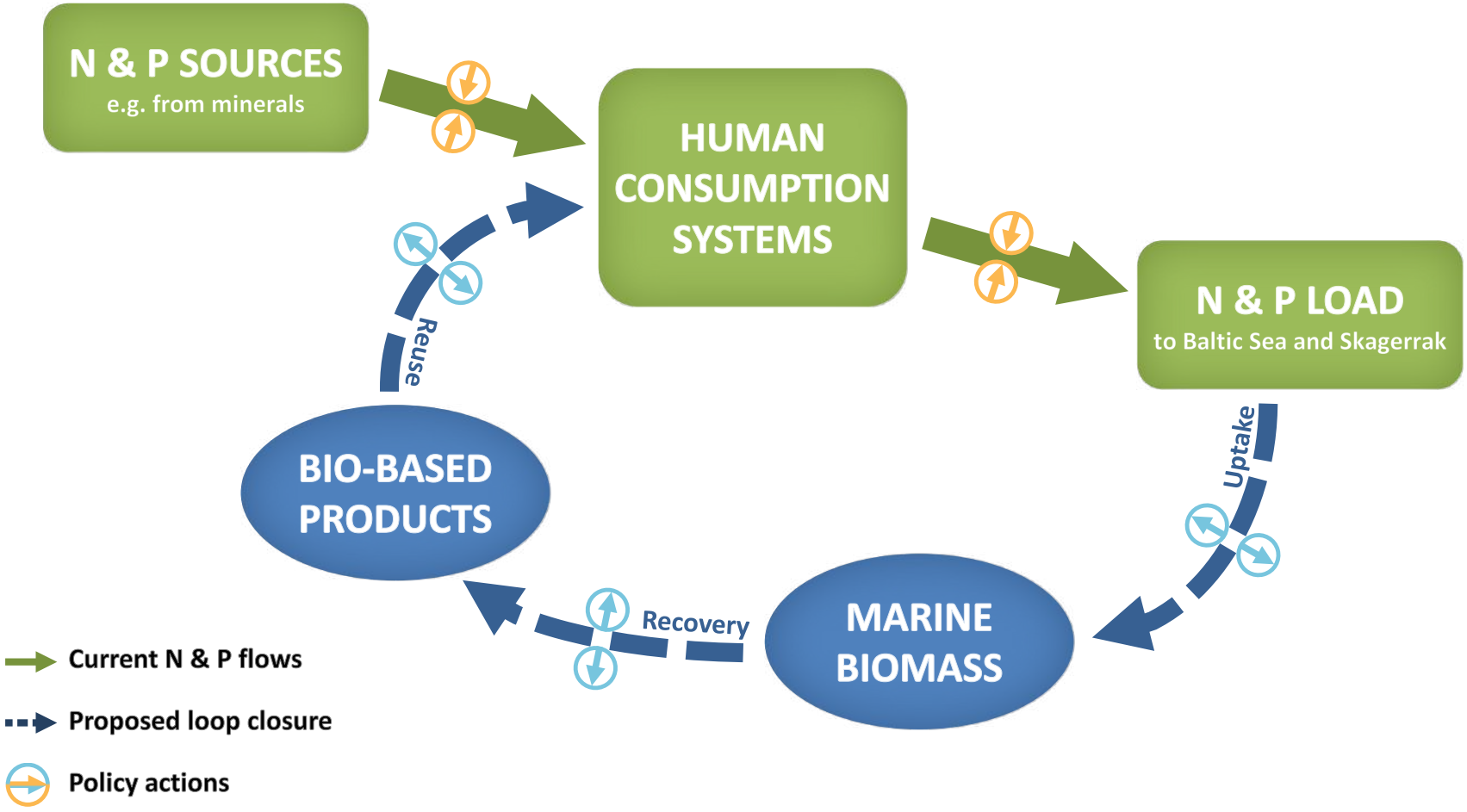
Use
- Fertiliser for food and feed
- Industrial uses (minor use)

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



Seven case studies: four cases of extractive (low-trophic) aquaculture

#1 **Sugar kelp** aquaculture on the west coast (Koster)

Photos: Eduardo Infantes, Koster Alg, JB Thomas

#2 **Blue mussel** aquaculture on the west coast

Photos: Scanfjord.se

#3 **Mussel** aquaculture in the Baltic (Sankt Anna)

Photos: Jason Bailey, Lena Tasse, Mats Emilsson

#4 **Ascidian** farming (seasquirts) on the west coast

Photos: Marin Biogas, Marin Taste

Seven case studies: three cases of wild-biomass harvesting

#5 Harvesting **beachcast seaweed**: Gotland

Photos: Smedberg's Gård AB

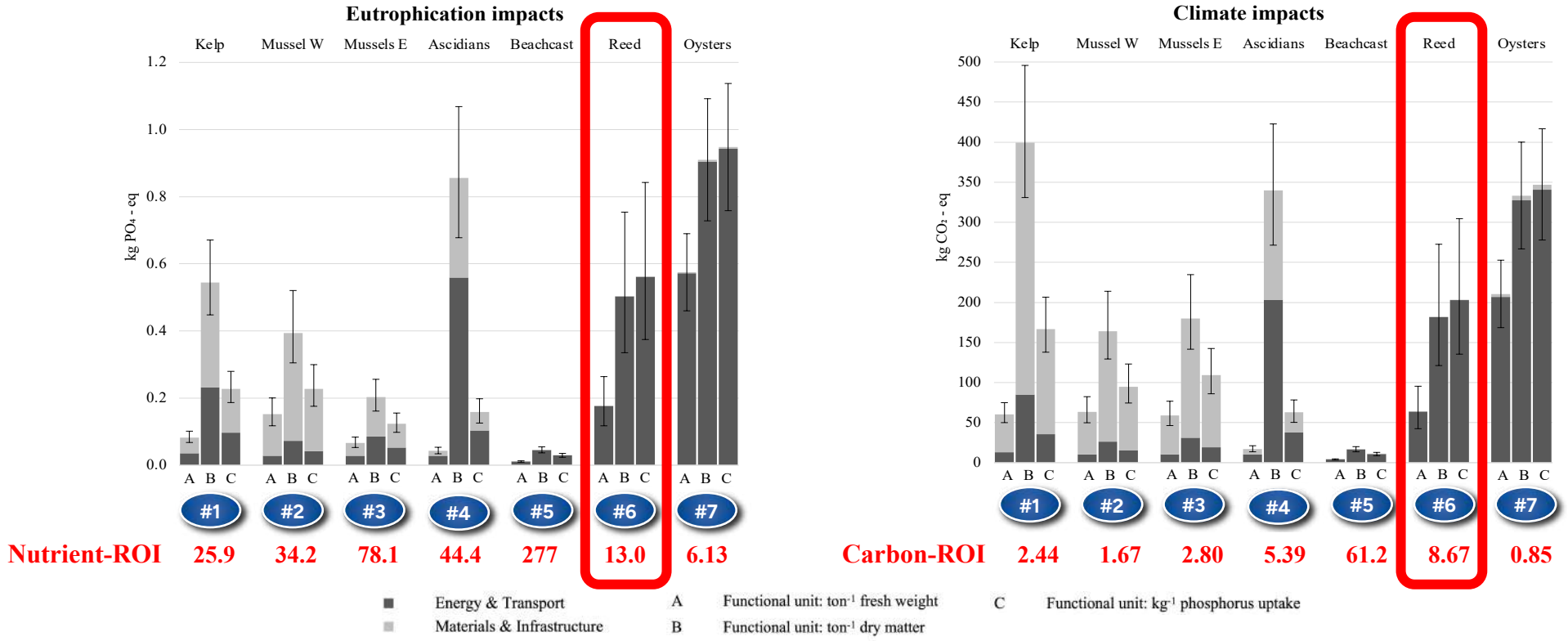
#6 Harvesting **reed**: Stockholm archipelago

Photos: Salavassklippning AB, Tore Söderqvist

#7 Harvesting invasive **pacific oyster**: west coast

Photos: Adriaan van de Plasse

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



- ✓ **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*

Life Cycle Assessment (LCA)

Impacts assessment method for products, services or systems, focusing on function

Quantifies impacts across a range of **impact categories**

Broad scope of analysis: across its entire (or part of) its life cycle, e.g. from raw material extraction to waste (cradle to grave) or from raw material extraction to supermarket shelf (cradle to gate).

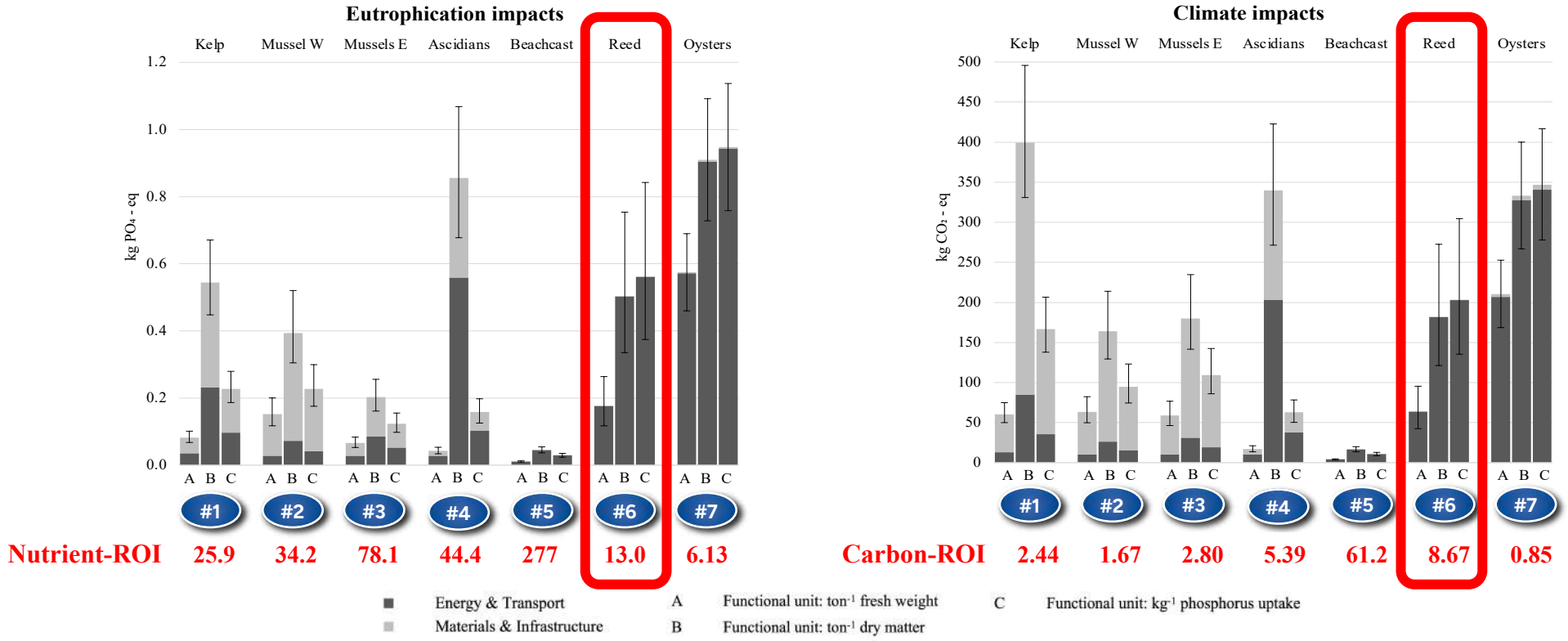
+ Provides a **holistic perspective of impacts and trade-offs** for more informed decision making

+ More scientifically accountable and detailed than carbon credit/trading methods or the GHG accounting protocol (see QR code: Arendt et al 2021)

- - More time and resource consuming than other methods

Arendt, Bach and Finkbeiner (2021); European Commission (2010) ILCD Handbook; ISO 14040-14044. Images: PRé-sustainability

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



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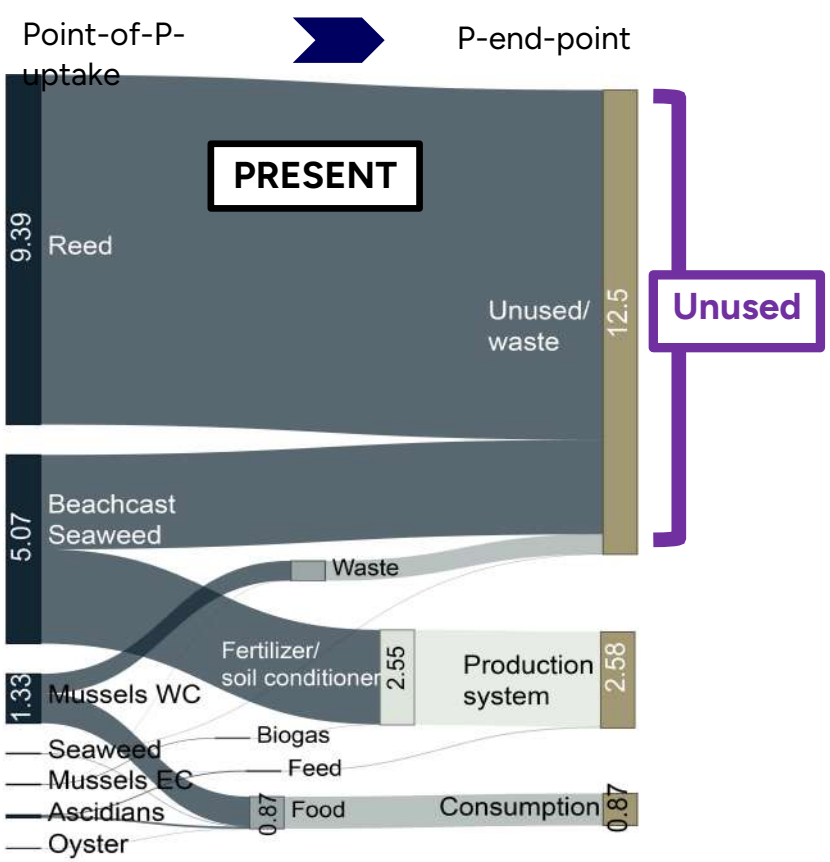
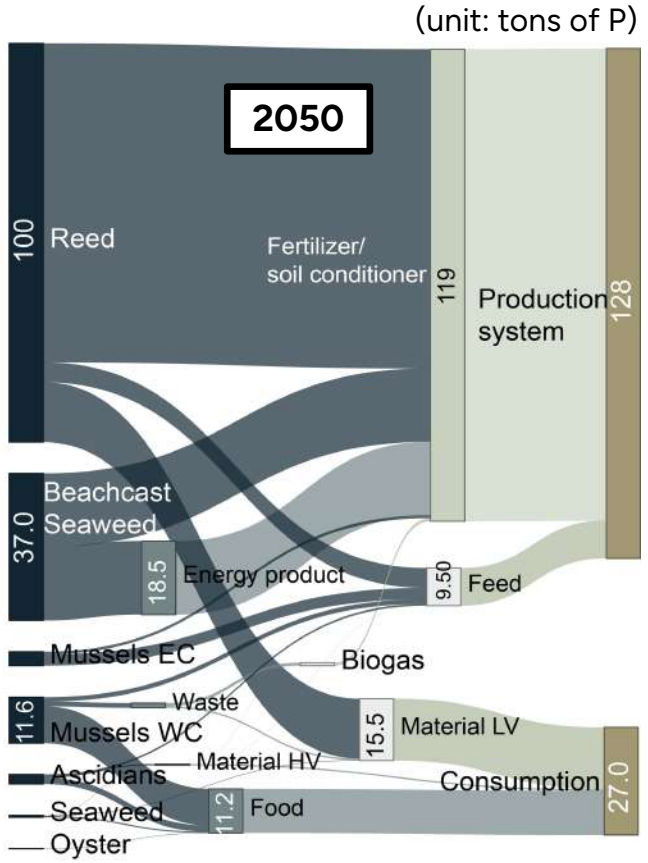
Element Flow Analysis (mapping biomass uses for P "loop closure")



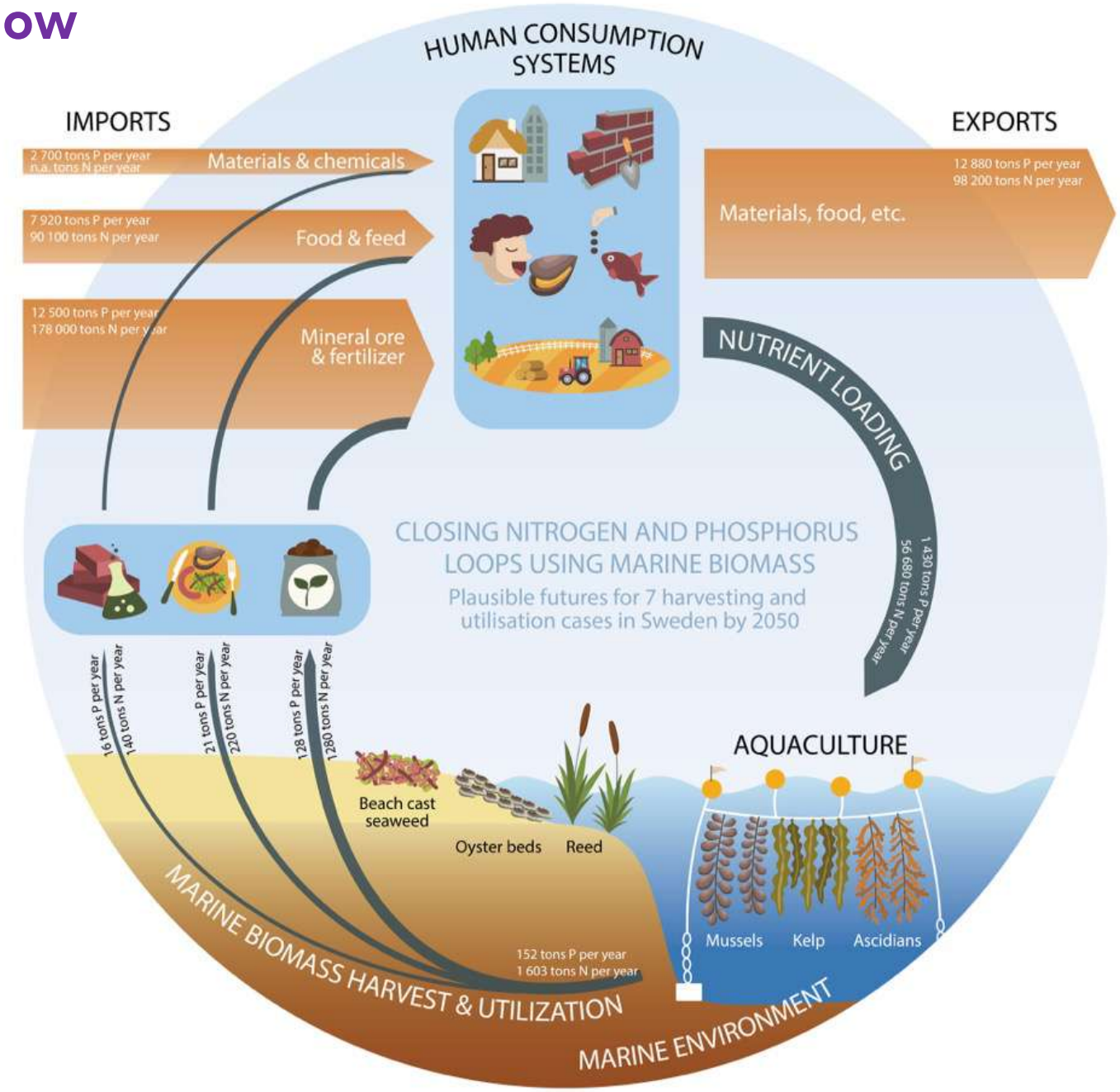


- ✓ **Reed and beachcast were largest potential source of P but are mostly unused today, with potential mostly lying in their use as fertilizers and feed**
- ✓ **Shellfish cases mostly recover P as food and feed products**

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

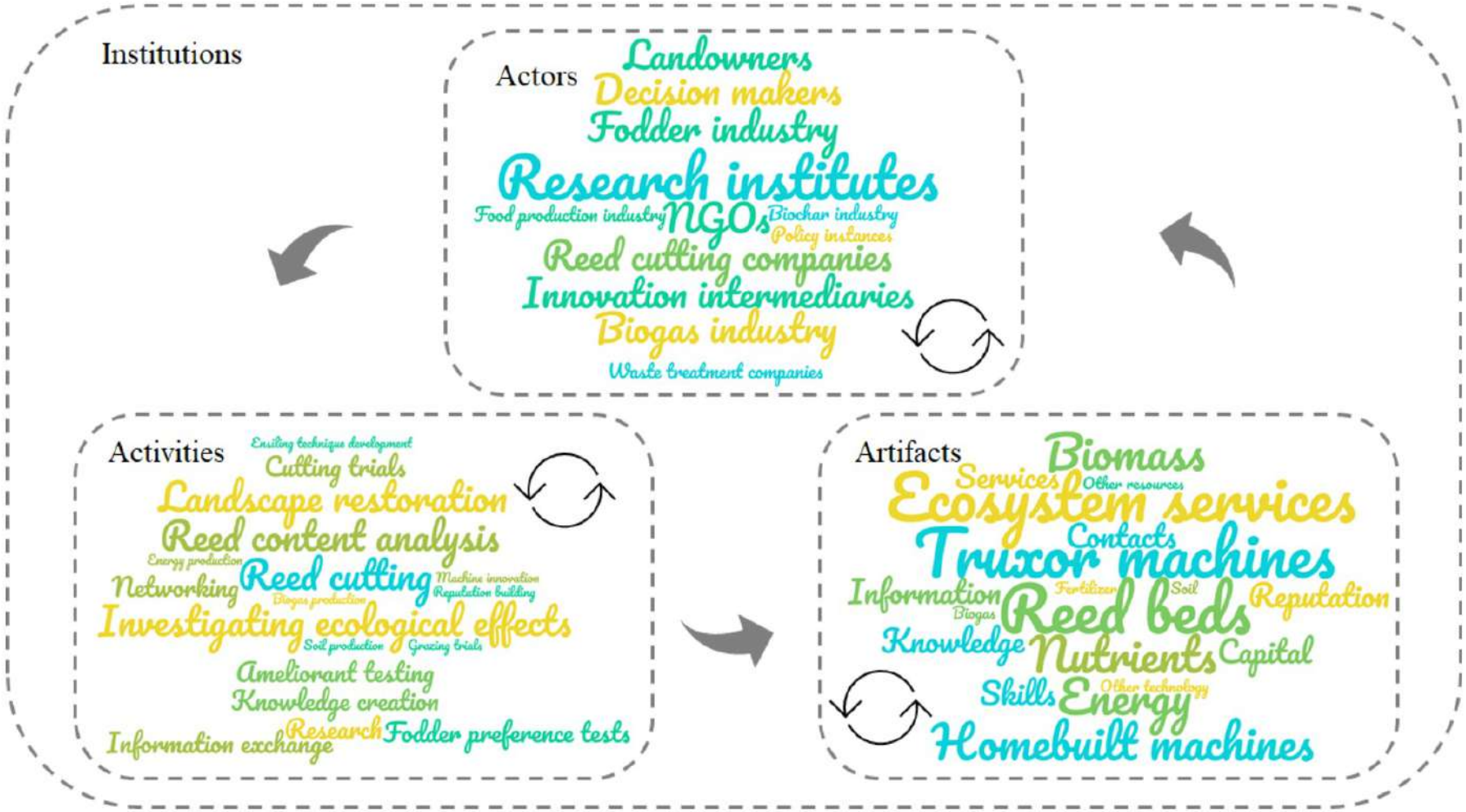
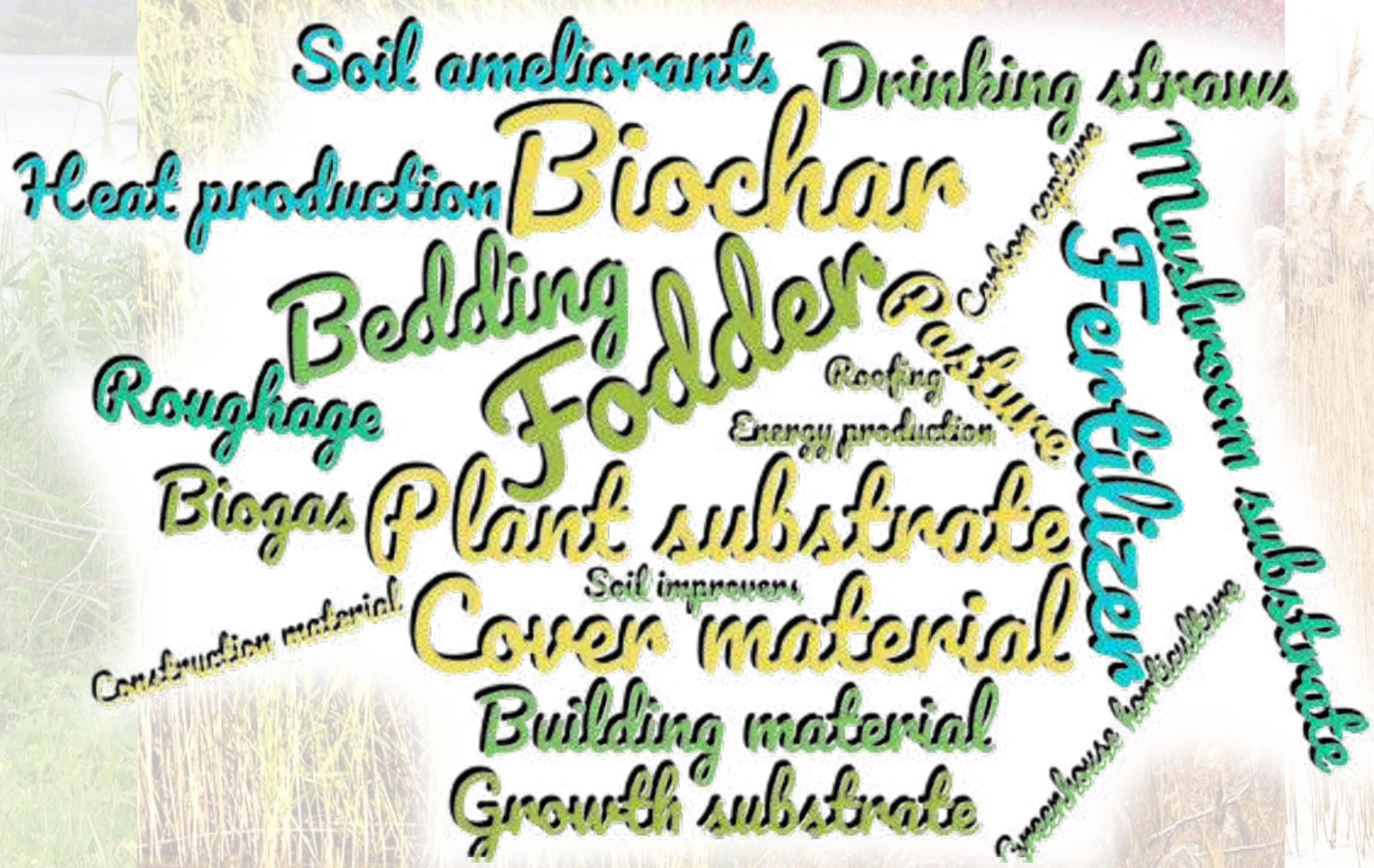


Figure 10: Current reed innovation system. Actors, artifacts, and activities interact within the boundaries of the institutions of the system. Inspired by Granstrand and Holgersson (2020).


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