BLUEBIO ON LIFE CYCLE ASSESSMENT

PlastiSea

MASSIMO PIZZOL, 21 May 2024



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Massimo Pizzol Prof.

- **Env. Scientists**
- 15 more years in LCA
- Prospective assessment of technology
- **Uncertainty analysis** •
- Green and blue bioeconomy
- Teacher

UNIVERSITY

Profile
 Profile

https://vbn.aau.dk/en/persons/117459/projects/

Dep. Sustainability and Planning **Aalborg University** https://www.en.plan.aau.dk/





Today

- LCA in PlastiSea
- Constraints to seaweed supply
- LCA of pilot scale system
- LCA of upscaled system
- Overall reflections



Credits



Maddalen Ayala

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- Ayala, M., Arlov, Ø., Nøkling-Eide, K., Sœther, M., Dore, C., Vidal, J., Zhou, Q., Wang, S., Michalak, L., Kyvik, A., Jolain, B., Aubel, L., Strand Jacobsen, S., & Pizzol, M. (2024). A supply-chain perspective on producing and upscaling bioplastic from cultivated brown seaweed. *Journal of Cleaner Production*, 444, 141248. https://doi.org/10.1016/j.jclepro.2024.141248
- Ayala, M., Thomsen, M., & Pizzol, M. (2023a). Life Cycle Assessment of pilot scale production of seaweed-based bioplastic. *Algal Research*, 71, 103036. <u>https://doi.org/10.1016/j.algal.2023.103036</u>
- Ayala, M., Thomsen, M., & Pizzol, M. (2023b). Using quantitative storytelling to identify constraints in resource supply: The case of brown seaweed. *Journal of Industrial Ecology*, 27(6), 1567–1578. <u>https://doi.org/10.1111/jiec.13440</u>
- Ayala, Goosen, Michalak, Thomsen, Pizzol, Prospective LCA of brownseaweed-based bioplastic: Upscaling from pilot to industrial scale. Algal Research (under review).

LCA in PlastiSea

Context

- Prospective LCA of bioplastic from seaweed - at industrial scale
- Support in early R&D stage within
 PlastiSea project. (ERA-NET Cofund BlueBio, grant no. 9082-00011)



PlastiSea - Novel enhanced bioplastics from sustainable processing of seaweed



https://www.sintef.no/en/projects/2020/plastisea-novel-enhanced-bioplastics-from-sustainable-processing-of-seaweed/

Seaweed-based plastic

- Some advantages (no land-use)
- Alginate-based, extracted from feedstock
- Emerging technology proven at lab scale
- Unclear life-cycle trade-offs and impact at pilot and industrial scale







What are the **environmental consequences** of the novel brown **seaweed-based bioplastic** from a **life cycle** perspective?









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Constraints to seaweed supply

Marginal suppliers

- Identify the brown seaweed suppliers that are growing in the market and can respond an increase in the future demand
- Current methods rely on large amount of data
- Data sources on seaweed production are not reliable

 \rightarrow Need for a different approach

Quantitative storytelling



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Seaweed cultivation Marginal suppliers

- Consequences of increase in demand in a global market
- Marginal mix derived from semiquantitative survey: suppliers expected to increase production without
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 Chi
- Validated ("fairly good match")

Using quantitative story telling to identify constraints in resource supply: the case of brown seaweed. Ayala M, Thomsen M, Pizzol M (<u>under review</u>, Journal of Industrial Ecology)



LCA of pilot scale system

Processes to produce the bioplastic



Pilot scale - system boundaries



Ayala M, Thomsen M, Pizzol M (2023) Life Cycle Assessment of pilot scale production of seaweed-based bioplastic. Algal Research 71:103036. <u>https://doi.org/10.1016/j.algal.2023.103036</u>

System boundaries Base scenario



System boundaries Co-product recirculation



Carbon balance Cellulose and mannitol recirculation



LCA results



Results: Uncertainty analysis

- Pedigree matrix + Monte Carlo
- Remove effect of foreground system
- Foreground system still very high uncertainty
- "artificial" procedure but suggest to be conservative in deriving conclusions
- Paired sampling → only significant (<5%) diff between inc. and comp.</p>



LCA of upscaled system

Upscaling methods

Expert-based interviews

- Techniques to increase productivity
- Prospects to upscale, constraints
- Insight on challenges and opportunities
- → Marginal mix & upscaled <u>cultivation</u> LCI
- **Detailed process simulation**
- Biorefinery and film fabrication in Aspen Plus
- Assumptions supported by expert knowledge
- → upscaled LCI of <u>biorefinery</u>



Process simulations



BIOREFINERY

LCA results Global warming





Wrap up

- Use of mix methods:
 - Interviews: Seaweed cultivation
 - Process simulations
- Lower impacts when upscaling
- Difference including and excluding biogenic C
- First study addressing the prospective impacts

of a seaweed-based bioplastic



Overall reflections



Challenges

- System Boundaries: Different level of data detail for the various stages (commercial scale for cultivation, vs pilot / lab for processing vs hypothetical for EoL). Unclear if at large scale other inputs.
- Functional Unit: plastic in theory same functionalities as fossil one but some degree of uncertainty on this. Clear goal to compare with existing plastics (although all are on weight basis)
- Product Complexity: able to model different sidestream valorisation and end-of life options.
- Scope Differences: biogenic carbon accounting a key issue





Thank you







