



Scope, scenarios and criteria for the sustainability assessment of the production of value added components from seaweed

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Summary

The Macro Cascade project aims at developing a cascading macroalgal biorefinery. This is a production platform that covers the full valorisation chain, starting from cultivation of sustainable macroalgae biomass (seaweed) up to the production of highly processed, value added products. The concept aims at processing two species of seaweed towards producing a diversity of value added products for the food & feed, cosmetics, pharmaceuticals and fine chemicals industry.

The objective of the WP6 is to give an assessment of the technical and economic feasibility of the technology, to assess the environmental impact aspects as well as the social impact of the cultivation and production of value added components from seaweeds. This deliverable report D6.1 presents the starting points of the study, methodology and criteria that will be used for this assessment and provides a description of the main seaweed products aimed for in Macro Cascade. In addition this report discusses that milestone M6.1 'Sustainability analysis criteria set' has been successfully passed.

Table 1: List of targeted products and selected replacing component in LCA

Product	Selected replacing component in LCA
Seaweed products that can replace current products	
Alginate	Gelatin as a food thickener starch, pectine, agar, carrageenan.
Mannitol	Mannitol produced catalytically from starch by hydrogenation
Protein	Soy protein
Polyphenols	Butylhydroxytoluen (BHT)
Laminarin	Starch
Algal oligosaccharides	Polyacrylate, or detergent
Carotenoids	Astaxanthin
Novel products	
Fucoidan, FUS	-
Prebiotics, dietary fibers	-
Algal poly- and oligosaccharides	
Probiotics	
Cascading of residue streams: biogas, digestate / inorganics	
Biogas	Natural gas
Digestate/ Minerals/ash	Fertilizer plant feedstock

For the Macro Cascade project two representative species of seaweed have been selected: *Saccharina latissima* of the brown seaweeds and *Palmaria palmata* of the red seaweeds. The considered products are listed in Table 1. Not all of these products will be the object of the LCA study though; in combination with concrete data from laboratory tests on the various seaweed extraction and processing procedures, an LCA study will be carried out if sufficient data allows for the evaluation of the whole harvest and production chain from raw materials to a specific product.

A schematic for bio-refinery has been developed, depicting the processing and fractionation steps that are required. The scheme lists all routes considered and their possible combinations. The scheme will be evaluated as a superstructure scheme from which the various branches and sub-routes will be addressed separately, from which logical combinations can be recommended.

Starting points for the techno-economic evaluation have been determined. The system limits are from the construction and deployment of a seaweed grow-out unit up to marketable products after processing of the seaweed. The system size is taken as 10 kton_{dw}/yr of fresh seaweed. Large extrapolations from lab scale to industrial scale processes are required as well as a judgement on the impact of moving from laboratory techniques to industrial processes. The main simplifications made are a constant seaweed composition, and constant conversions using black-box models.

The techno economic evaluation (TEE) for assessment of these schemes will take a staged and iterative approach in which initial results from the evaluation will feed into update schemes and choices for the assessment. The results of the TEE will result in the mass balance of selected schemes, and in an estimation of the heat requirements, which will be used for process economics and LCA.

The economic evaluation will be based on a forthcoming publication by *Ocean Rainforest* for the seaweed cultivation and harvesting. For the processing section a section approach using estimations following from analogue processes will be used.

The criteria for technical feasibility are the anticipated yield in products, underlying uncertainties and the development status as well as development issues towards demonstration and commercialization. The main criterion for the yield assessment, is the weight based yield for a specific product considered per unit of dry weight seaweed feed to the processing plant.

For the process economics two criteria are proposed. Firstly, a comparison for between the allowed costs for seaweed (based on the product market prices and production cost) and the projected cost for seaweed cultivation cost. The second criterion are the product costs for each of the products, for which an allocation method needs to be assumed.

The goal of the LCA is the impact assessment of the cultivation and conversion of a yearly production of 10 kton (dry weight basis) seaweed, set as the *Functional Unit*. All units will be therefore expressed per ton dry seaweed. Chapter 5 presents the LCA criteria and methodology, as well defined by the *ISO 14040* standard, and incorporated in the major software packages that help carrying out environmental assessments.

The set of LCA criteria is a list of indicators of the environmental pressures in terms of e.g. climate change, resource depletion, acidification, human health effects, among others associated with the

environmental interventions attributable to the life-cycle of a product. In the Macro Cascade project a two stage approach will be followed. As a first stage, a set of novel seaweed-derived products will be assumed without assuming a reference product on the market. A contribution analysis will be carried out, which simply evaluates the extent each input (materials, transport, cultivation and harvest practices, chemicals, energy consumption pre-treatment) contributes to the total product burden. As a second stage LCA, selected seaweed products are assumed to replace current products on the market, evaluating the impact reduction of this replacement.

Finally, a framework for the social analysis has been presented where in a staged approach the impact of seaweed cultivation and processing is assessed on four criteria:

- Economy: financial issues regarding the main industry, the impacts on the up- and downstream supply chain and the impact on the broader society through demand and supply effects.)
- Employment (number of jobs created, types of jobs created, job stability, income levels and rate of unemployment)
- Demographics (population level, gender ratio and age structure)
- Environment (sustainability, pollution, waste production, damage on sea-floor).

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