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Toward a more sustainable biochemical industry

Early stage assessments and methodological overlaps between life cycle- and techno-economic assessments of biochemicals

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1. Introduction

Existing Life cycle assessment (LCA) studies of biochemicals reveal that there are challenges that need to be overcome in order to reach an overall high sustainability performance. While in some cases biochemicals have lower global warming impacts compared to fossil-based chemicals, other impacts may become higher, like eutrophication, which is directly related to fertilizer use in the feedstock production of biochemicals. One of the major sources of environmental impacts of biochemicals is the growing of biomass, which in most cases today is corn [1]. This has led to investment in assessing opportunities of using side streams, like leftover agricultural lignocellulosic biomass, or non-cultivated biomass like algae, as carbon source [2]. Lignocellulosic biomass is an interesting feedstock because it introduces the potential for utilizing the entire biomass and not only the corn, and the economic feasibility of using lignocellulosic biomass has been assessed to some extent with techno-economic assessments (TEA) [3]. Presently, most of the processes are conceptually designed for economically viable operation, utilizing all the three major fractions of biomass such as, cellulose, hemicellulose and lignin, for biochemical and utility production at the biorefinery facility. Macro-algae is one such potential source given that they grow without being farmed, and that benefits are put in relation to algae filtering N and P from the ocean and use these compounds for growing, while simultaneously being an important sink for CO_2 [4].

The objective of this study is to identify trade-offs between assessed environmental impacts and possible burden shifting between macro-algae compared to more conventional feedstock´s like maize and lignocellulose.

While it is imperative that any change in process configuration reflects in TEA and LCA, there are very few studies which couples these two assessment demonstrating the trade-offs for improved decision support. Hence, the focus of this contribution is to explore methodological overlap between the two assessments strategies and develop a framework, supported by a proof-of-concept

2. Methodology

Assessing the opportunities of using macro-algae compared to maize and corn-stover, as carbon source, relies mainly on data availability and derivation of data representing a scaled up biorefinery. When working with less evolved feedstock, such as macro-algae, we need methods for scaling up of laboratory data to assess the actual sustainability and optimization potential of bio-based chemicals before large investments in new processes take place.

The approach used to bridge the data gap for the biorefinery process is applying techno-economic assessments (TEA) on the three different feedstocks, macro-algae, corn and corn-stove.

Applying TEA provides an insight if it is technologically and economically feasible to utilize alternative feedstock sources for biorefineries, which is today the main driver if money should be invested in developing new production pathways of chemicals from biorefineries. If the TEA then gives a feasible outcome, performing an LCA will complement that information by addressing the possible environmental impacts of the new chemical production process which otherwise are not a part of a TEA and would therefore not be considered as being relevant for related decisions. TEA and LCA are described further in more detail in the following paragraphs.

TEA accounts for all costs incurred due to the mass and energy flows, operational expenditures and capital investment required for scaled up production of biochemicals. In order to compare the economic impact of three generations of biobased feedstock, a proof-of-concept is performed for targeted production of lactic acid. The tools used for this appraisal is a widely used process simulator, Aspen Plus® and complementary modules from AspenTech® [5].

The LCA is a cradle-to-gate and a cradle-to-grave assessment with the focus on the environmental hot-spots associated with the production of bio-based lactic acid, and derived (poly)lactic acid (PLA) plastic bottles from macro-algae, corn and corn-stover. The functional unit of the study is *one single use PLA-plastic bottle to contain 500 milliliters of water*.

The scope of the study ranges from the extraction of the raw material for all the three generations of feedstock. Followed by the processes of their resin production, through bottle formation, followed by their use stage and end-of-life disposal. The assessment includes the following impact categories of global warming, ozone formation, ozone depletion, ionizing radiation, particulate matter formation, human toxicity, ecotoxicity, acidification, eutrophication, land use, indirect land-use change, water use, resource use and energy demand. The LCA is a consequential LCA applying system expansion.

3. Results and discussions

When contrasting current results from the TEA and LCA cradle-to-gate study, some interesting trends were observed. The TEA show that it´s biggest hot-spots are identified as feedstock cost which is a function of growing, transportation of biomass and if drying is taking place at the refinery site or closer to the harvesting sites of the feedstock. Whereas, the LCA shows the biggest environmental hot-spots occur in relations to growing of biomass, if it requires external application of nutrients and intensity of chemical pretreatment.

4. Conclusions

Today decisions on if chemicals are further developed companies mostly rely of results from TEAs. Our results show that the methodological overlap between TEA and LCA are of that magnitude that justifies the appraisal of this integrated methodology.

Introducing LCA as a decision support tool would integrate sustainability requirements in development of technology and solutions. All technologies and products have a life cycle, and by analyzing their impacts, we put numbers on sustainability and benchmark the solutions.

5. References

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