USE OF LCA DURING PROCESS DEVELOPMENT: THE CASE OF A NEW BIOETHANOL PRODUCTION PROCESS

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Introduction

The development of sustainable processes for the production of second generation biofuels is an ongoing effort. Not only does such a process need to be economically feasible, it also needs to show an improvement in its environmental impact compared to the production of first generation biofuels or fossil fuels. Current research efforts focus on the development of such a process using high gravity fermentation, i.e. a process with a high solids concentration in the fermentation reactor, for the production of ethanol [1–3]. Wood and straw are the feedstocks that are of interest in this research.

Objective

Life cycle assessment (LCA) is used for the evaluation of the environmental impact of the high gravity fermentation process along its development path. The objective of this paper is to highlight and discuss the methodological and case-specific considerations regarding the use of LCA along the development path of a biofuel production process.

Case considerations

There are several issues that need to be addressed with this LCA, both from a methodological and a case-specific perspective. Methodological considerations to be addressed include issues of scale [4, 5]. The development takes place at the lab scale and the generated data needs to be used to represent an industrial-scale process. This can be addressed using process simulation. Furthermore, the scale of market penetration and consequent feedstock use needs to be accounted for. As well, the time frame of the development will affect process performance data and there may be changes in the background system over time [4]. Moreover, the function of the product may change over time. For instance, ethanol may also be used as a base chemical in the production of bioplastics [6]. Lastly, the question of how to use the LCA results for guiding the technology development needs to be addressed.
Case-specific issues for biofuel production include accounting for biogenic CO_2 release (see e.g. [7]) and possible greenhouse gas emissions due to land use and land use change (see e.g. [8]). Although these issues are labeled as case-specific here, they also need attention from a methodological point of view. There is for instance still no consensus on how to account for land use and land use change in LCA [9]. As well, accounting for biogenic carbon releases is still a topic under debate [10].

System description

The system under study can be described in 3 steps: i) resource extraction, production of auxiliary material and energy, ii) production of biofuel and co-products, and iii) the use phase (Figure 1). Due to differences in the systems (feedstock cultivation practices, feedstock composition, transportation distances of the feedstock to the plants, and the biofuel production process upstream and downstream of the high gravity

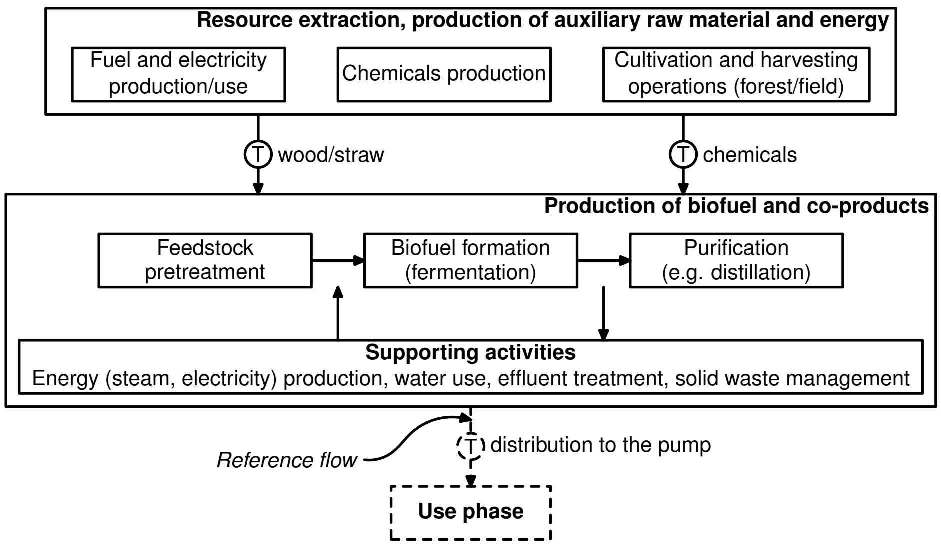

Figure 1: System considered in the LCA of the high gravity fermentation technology for production of fuel ethanol

fermentation process under study), the production of ethanol from straw and wood need to be considered separately.

The base case processes against which the process under development are compared are the IBUS process (straw) [11] and the E-Tech process (wood) [12]. It is assumed that the current locations of the plants using the IBUS (Kalundborg, Denmark) and E-Tech (Örnsköldsvik, Sweden) processes are representative for future industrial-scale plants producing ethanol from straw and wood, respectively. Both base case processes are able to process $500 \cdot 10^3$ tonnes of feedstock per year.

The reference year, i.e. the year for which the base case processes are defined, is 2012. However, it has been assumed that the new technology will be implemented at industrial scale in 2025.

Discussion of the LCA set-up

The use of lab-scale data in order to evaluate a future process at industrial scale results in uncertainty in the assessment results. This is due to uncertainty about how the high gravity process will scale up. One approach to reduce this uncertainty is to use data of industrial scale processes with similar characteristics [5], e.g. energy use data for the mixing of slurries with a high solid content in the case of the high gravity fermentation process. As well, lab-scale data are likely to change over time as the development takes place. Furthermore, access to data for the base case processes may be problematic. As well, uncertainty about the future background system, e.g. the electricity grid mix in 2025, or forestry and agricultural yields and practices, will contribute to the overall uncertainty of the assessment. Sensitivity and scenario analysis can be used to capture this uncertainty.

An attributional approach is taken in this LCA, because one of the main objectives is to identify opportunities for improvement while developing the new technology. The objective could also be formulated as to investigate what environmental impact a change in the design and/or operations of the technology during its development may have. Then, a consequential approach is more appropriate. The application one of these different approaches may lead to different results and may thus affect decision making along the technology development path.

The impact assessment is carried out using impact categories selected from the CML characterization method. The impact categories that are considered in this LCA are global warming, eutrophication, acidification and photochemical ozone creation potential. Furthermore, renewable and non-renewable energy use will be used as indicators. As well, the impact of land use and land use change, and of the release of biogenic carbon are incorporated in the impact assessment. Due to the current lack of consensus about the incorporation of these impacts into LCA, this must be handled carefully. This assessment does not take into account biodiversity, another potentially important environmental impact.

Conclusion

The use of LCA along the development path of a new production process or technology involves issues regarding scale and time that need to be addressed in the LCA methodology. As well, emissions due to land use and land use change, and accounting for biogenic CO_2 releases need to be included in the assessment when using renewable resources for producing e.g. energy, fuels or materials. LCA will thus help technology developers, researchers and industry decision makers to make well-informed and more sustainable decisions during all stages of the development of a new process.

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