Development of an LCA database for the environmental impact assessment of biorefinery products

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Process sustainability, expressed through economic, environmental and social dimensions, presents a challenge for engineers and environmentalists especially in the cases of the replacement of conventional fossil based products by biomass based products. The development of innovative production paths must fulfill the expectations of sustainability, targeting at the use of renewable resources and the minimization of the environmental impacts. Biorefineries emerge as promising complex systems that produce, similarly to conventional petroleum refineries, a wide range of chemicals (pharmaceutical constituents, plastics, food additives etc.), fuels and energy through the optimal use of biomass feedstocks, including processes like mechanical and physical pretreatment, fermentation, catalytic and enzymatic reactions, gasification etc.

The aim of this study is to present the methodological steps for the development of a database of the environmental impacts of biomass based production using the LCA methodology as described in the ISO norms. To perform the LCA assessment, a detailed gate-to-gate inventory analysis for the system under study was necessary including material and energy flows, and discharges in air, water and soil. The method is structured on knowledge gathered from literature references and data from pilot plants that provide detailed information about the process flowsheets (quality of raw material, specific design characteristics, energy/cooling demand etc.). In addition to detailed process information, the use of existing life cycle databases (e.g., Ecoinvent database, versions 2.2 and 3) and tools (e.g., Simapro 7.3.3) was necessary. Data gaps have also been filled, where necessary, by model based life cycle inventories of waste treatment processes.

The estimation of the life cycle impacts of the processes was performed using the Global Warming Potential (GWP), Cumulative Energy Demand (CED) and RECIPE methodologies. Since climate change and energy consumption are the main driving forces for the development of sustainable biorefineries, the methodologies of GWP and CED are well justified as appropriate LCA indicators. The RECIPE method provides a more holistic assessment of the environmental impact decomposed in diverse midpoint metrics, while also providing an aggregated end-point result.

The methodology was applied to a range of biorefinery configurations including all the impacts generated along the possible production pathways. In this analysis, not only the impacts of the main products are investigated but also the contribution of the co- and

by-products as it affects the overall environmental footprint. The database is, therefore, structured taking into account the multi-functionality of the biorefinery systems co-producing multiple energy and material products. For this reason, the impact of different LCA allocation methods on the environmental performance of a product has been investigated. The following allocation methodologies were applied: the system expansion (substitution method) and the partitioning methods according to the mass, thermal and economic values of the co-products. The developed database can be used as a source of information of environmental impacts for biomass based production considering various production paths and diverse process conditions in a systematic way and, therefore, facilitating a comparison of the products using a set of appropriate methodologies and indicators.