Life Cycle Assessment of alternative biowaste to ethanol conversion systems in comparison to conventional biowaste management methods

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The aim of this study was to assess the life cycle impacts of the full scale implementation of the innovative biowaste management system for the production of ethanol, with the application of the bioconversion process that was developed in the framework of the LIFE project WASTE2BIO. To achieve this, Life Cycle Analysis (LCA) was applied to a number of alternative bioconversion scenarios concerning the potential process products. The fixed system components include the bioconversion unit, the distillation unit, the anaerobic digestion unit and the combustion plant.

For LCA to be conducted, a specialized LCA software on waste management (EASETECH) was used while the system expansion method was applied in order for the benefits (avoided impacts) from the substitution of conventional products with the system products, to be also taken into account. In order for the results to be comparable for all impact categories, normalization was applied to “Persons Equivalent, PE”.

Besides bioethanol, the potential system products that were also examined include the energy (electricity and heat) from biogas production and from the combustion of the solid residues of the process, the production of soil conditioner from the digestate, the production of methane fuel from biogas and, the production of animal feed from the process stillage. The impact of different process substrates of higher energy content on the potential for bioethanol production was also investigated.

Furthermore, in the framework of this study alternative biowaste management methods, such as landfilling, composting, anaerobic digestion and incineration, were examined and compared to the ethanol production method.

As regards the LCA results for the waste to ethanol scenarios examined (main scenario S1 and its variations Σ1A-Σ1E), it was shown that all scenarios have a quite satisfying performance with respect to the environmental and health impacts investigated. The net emissions to the environment, i.e. the positive emissions minus the avoided (negative) emissions from the substitution of production and use of products, are relatively low while in many impact categories they are negative. In specific, the net emissions in the impact category “Climate change (global warming)” are negative for all examined scenarios. Negative net emissions are also observed for almost all scenarios for the impact categories “Stratospheric ozone depletion”, “Toxicity”, “Ionising

radiation" and "Depletion of abiotic resources". Positive net but low emissions are observed for all scenarios with respect to the categories "Acidification" and "Eutrophication" which are mainly related to the application of the digestate to the soil (Figure 1).

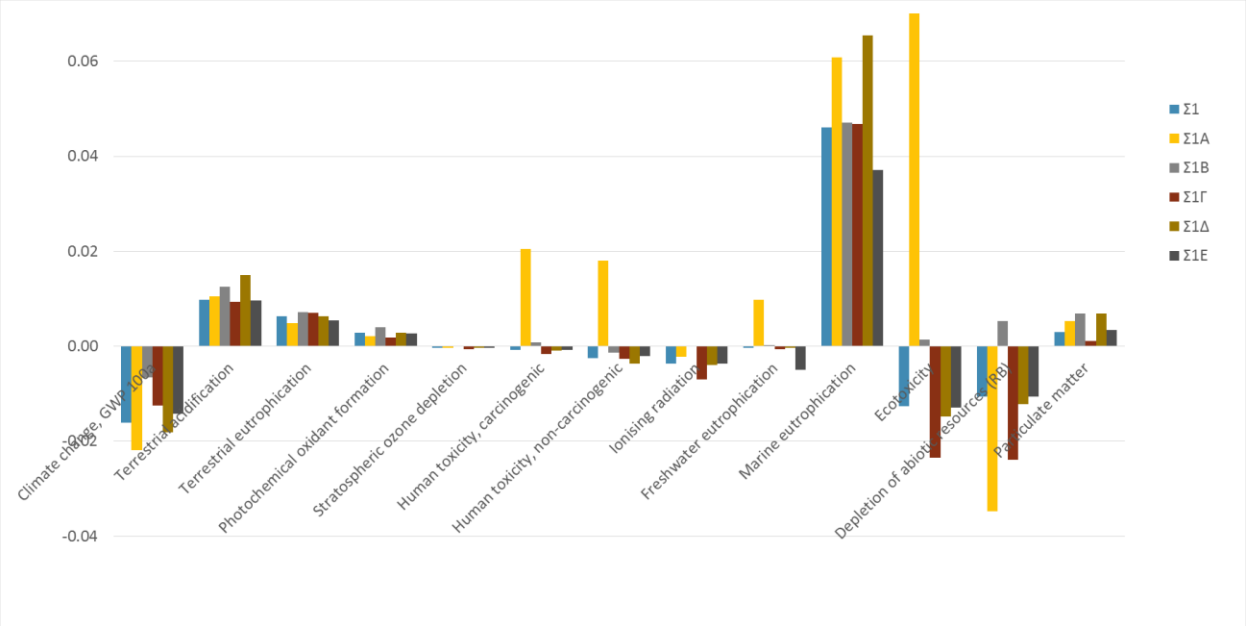

Figure 1: LCA for the main scenario Σ1 and its variations Σ1A-Σ1E (net impacts, in PE)

As regards the LCA results for the main waste to ethanol scenario (Σ1) compared to the alternative scenarios of current biowaste management methods (EΣ1-EΣ4), it was shown that Σ1 presents substantially higher performance in general for almost all impact categories or it is similar to the best performance of the other methods. In particular, the landfilling method (EΣ1) presents positive values for all impact categories, with the highest one being recorded in the impact category "Ecotoxicity" which are related to the disposal of treated leachates to surface water, as well as in the category "Climate change (global warming)", where the method presents the highest emissions of all other methods. The composting method (EΣ2) presents in general very low positive values in most of the impact categories, which can be considered negligible, while high values are observed to the categories "Acidification, soil", "Eutrophication, sea" and "Particulate matter", which are mainly attributed to the air emissions from the composting process. The anaerobic digestion method (EΣ3) it presents net benefit in many impact categories, at the same time it presents quite high values in some other categories ("Human Toxicity, non carcinogenic", "Ecotoxicity", "Eutrophication, sea"), which are related to the application of the digestate to the soil. The incineration method (EΣ4) performs well in general in all impact categories, which are similar to those of the main scenario Σ1,

but in contrast to Σ1, it presents environmental burdens in the category “Depletion of abiotic resources” (Figure 2).

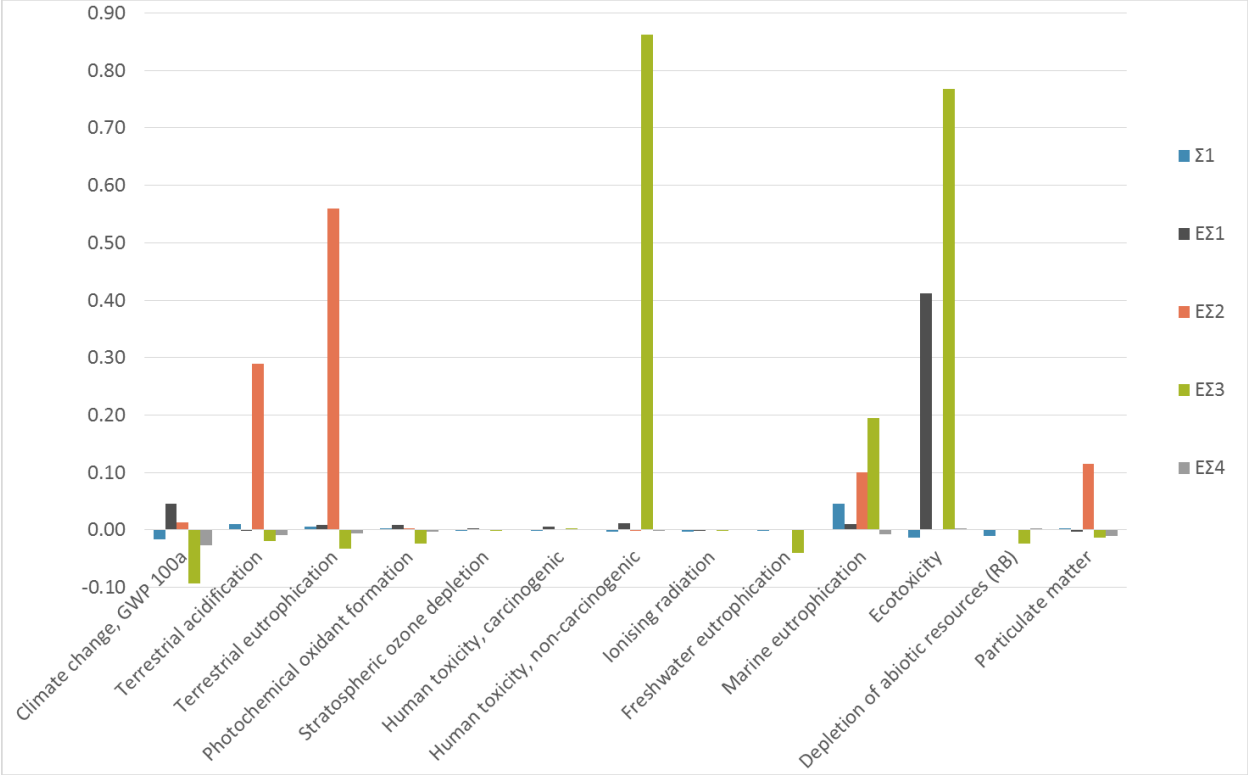

Figure 2: LCA for the main scenario Σ1 and the alternative scenarios EΣ1-EΣ4 (net impacts, in PE)