SUPPLEMENTARY INFORMATION

How to assess the potential of emerging green technologies? Towards a prospective environmental and techno-economic assessment framework

Gwenny Thomassen,[a,b,c,d] Miet Van Dael[a,b], Steven Van Passel[a,c] and Fengqi You[e]

Environmental hotspot matrix: elaboration of the example of an algal-based biorefinery

As the algae are only produced in the second life cycle stage, the feedstock production, the first life cycle stage cannot specifically be modelled, as there is no foreground process in this life cycle stage. Therefore, general categories of inputs (material and energy), outputs (waste and coproducts), equipment and transport have been filled in, and their quantity and impact are indicated in blue. The second stage is the feedstock production stage. Water is required in a relatively high quantity, but has a low environmental impact on most indicators. However, for resource efficiency, freshwater consumption can be important. Salt is also required in a relatively high quantity, and can also have an intermediate impact on resource efficiency. Concerning the other indicators, the production of salt is not considered to have a high energy consumption or responsible for important emissions. Fertilizer is required in relatively small amounts, but the production has a relatively high impact. This is mainly translated into resource efficiency and emissions to air and water. As the algae grow in water, no relevant emissions to the soil are expected in the life cycle of the fertilizer. The expected consumption of electricity and heat is relatively low, but has a significant impact on resource efficiency. Heat production has also an important impact on air emissions. However, these impacts are assumed to be much less than the impacts from the fertilizers, and therefore indicated as orange. CO_2 is required in a relatively high quantity. When industrial waste or atmospheric CO_2 is used, this could have a positive environmental impact, which is indicated by the positive sign for air emissions. As the air emissions from CO_2 have an important impact on the environment, it is indicated with a red box. Wastewater is produced in the same quantities as the input water, but the wastewater treatment has a higher impact on air, soil and water emissions. The equipment will consist of a pond and harvesting equipment, which need to be of relatively large capacity, due to the low algae concentration. However, the impact of this equipment is estimated to be relatively low. The algae production and the further processing is assumed to be on one location. Therefore, transportation is assumed not to be included. In the manufacturing phase, solvent is required for the β-carotene extraction. In addition, energy is required as purification and drying are required, and waste will be produced. The solvent is assumed to be required in relatively high quantities and has a high environmental impact on the emission indicators and on the energy efficiency. It is assumed that no important resources are required as the solvent is usually a basic chemical component. The energy consumption is assumed to be relatively high, but with only a relevant impact on resource efficiency. Although it is assumed to be not much waste, as the properties of the waste product is unknown no estimations can be made concerning its environmental impact. Drying and purification equipment will be required, both having a relatively low environmental impact. The scale of the purification equipment will be lower than for the dryer, as water has been removed. In the distribution phase, a relatively high amount of plastic will be require for the fertilizer and β-carotene end products. The mode of transport is still unknown. Environmental impacts from transport are mainly related to air emissions, where air emissions from airplanes are assumed to have the most severe impact. The use phase is still unknown. As the main product is a food supplement, end-of-life impacts are assumed to be irrelevant. The different life cycle stages are also scored according to their relative relevance. The feedstock production stage is assumed to be the most relevant and has the most severe impacts on all indicators. This is mainly explained by the high throughput of the biomass and water fraction of this stage. The manufacturing stage is important as well, with intermediate severe impacts.

[f.] *UHasselt, Centre for Environmental Sciences, Agoralaan, 3590 Diepenbeek, Belgium.*
[g.] *VITO, Unit Separation and Conversion Technologies, Boeretang 200, 2400 Mol, Belgium.*
[h.] *University of Antwerp, Department of Engineering Management, Prinsstraat 13, 2000 Antwerp, Belgium*
[i.] *Ghent University, Research Group Sustainable Systems Engineering (STEN), Coupure Links 653, 9000 Ghent, Belgium.*
[j.] *Robert Frederick Smith School of Chemical and Biomolecular Engineering, Cornell University, Ithaca, New York 14853, United States.*