Towards Carbon Neutrality: Early-Stage Assessment of Zero Emission Biotechnologies

G. J. A. Brouwer[a], J. A. Posada[a]

[a]*Department of Biotechnology, Delft University of Technology (TU Delft), Van der Maasweg 9, Delft, 2629HZ, The Netherlands*

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Abstract

Drastic action is required to curb greenhouse gas emissions and safeguard our planet. This entails adapting our lifestyles and innovating within current value chains to reduce our carbon footprint. Industrial biotechnology, identified as one of the six key technologies to combat climate change (European Commission, 2017), offers sustainable alternatives to fossil fuel-derived products and a way to achieve net-zero CO_2 emissions by 2050 (Horowitz, 2016). However, true sustainability can only be obtained with circularity (Lieder & Rashid, 2016) and non-competition with food resources. Therefore, new value chains are required with processes that can convert CO_2 into products using renewable energy sources (e.g., green electricity and green H_2). So called, zero emission biotechnologies (ZEBs) like syngas fermentation recently commercialized by LanzaTech (Köpke *et al*., 2020) or microbial electrosynthesis (Jourdin *et al*., 2020) can be instrumental technologies to achieve zero emission in the long-term. Unfortunately, the road from invention to commercial production is long in industrial biotechnology, and most biotechnologies that look promising after laboratory development fail to cross the valley of death and reach industrial scale (Kampers *et al.,* 2021). Therefore, it is important to be able to identify, early-on, promising ZEBs for industrial scale. However, comparison of different technologies at an early-stage is a challenging task, and scientific literature has been limited to heterogeneous catalytic or other types of fermentative processes (Posada *et al*., 2013, Moncada *et al*., 2015 & Moncada *et al*., 2017). Therefore, an early-stage sustainability analysis framework was developed to assess novel ZEB concepts with different biotechnology-product combinations. The ZEB concepts assessed were 1. microbial electrosynthesis (CO_2 to chemical building block: ethanol), 2. enzymatic conversion (CO_2 to chemical building blocks: CO and formic acid), 3. co-culture (from CO_2 to high value products), 4-5. mixed culture (CO_2 or formic acid to high value products) and 6. monoculture to convert ethanol to a high-value product like single-cell protein. The early-stage sustainability analysis was done to first identify the technical, economic and environmental bottlenecks and opportunities, and then select the ZEB concepts with the largest potential to achieve carbon neutrality for large scale production. Results comprise of both a framework for the early-stage sustainability assessment of (zero emissions) biotechnologies and a ranking (from 'most promising' to 'least promising') of the six different biotechnology–product combinations assessed.

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