



Delft University of Technology

#### Document Version

Final published version

#### Citation (APA)

Brouwer, G. J. A., & Posada, J. A. (2025). *Towards Carbon Neutrality: Early-Stage Assessment of Zero Emission Biotechnologies*. Abstract from European Symposium on Biochemical Engineering Science ESBES 2024, Copenhagen, Denmark.

#### Important note

To cite this publication, please use the final published version (if applicable).  
Please check the document version above.

#### Copyright

In case the licence states "Dutch Copyright Act (Article 25fa)", this publication was made available Green Open Access via the TU Delft Institutional Repository pursuant to Dutch Copyright Act (Article 25fa, the Taverne amendment). This provision does not affect copyright ownership.  
Unless copyright is transferred by contract or statute, it remains with the copyright holder.

#### Sharing and reuse

Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

#### Takedown policy

Please contact us and provide details if you believe this document breaches copyrights.  
We will remove access to the work immediately and investigate your claim.

*This work is downloaded from Delft University of Technology.*

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

G. J. A. Brouwer<sup>a</sup>, J. A. Posada<sup>a</sup>

<sup>a</sup>*Department of Biotechnology, Delft University of Technology (TU Delft), Van der Maasweg 9, Delft, 2629HZ, The Netherlands*

**Keywords:** CO<sub>2</sub> Conversion, Circularity, Industrial Biotechnology, Biorefinery, Technology Assessment.

## 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<sub>2</sub> 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<sub>2</sub> into products using renewable energy sources (e.g., green electricity and green H<sub>2</sub>). 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<sub>2</sub> to chemical building block: ethanol), 2. enzymatic conversion (CO<sub>2</sub> to chemical building blocks: CO and formic acid), 3. co-culture (from CO<sub>2</sub> to high value products), 4-5. mixed culture (CO<sub>2</sub> 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.

## Acknowledgement

This research is part of the "Zero Emission Biotechnology" Programme funded by Department of Biotechnology at the Delft University of Technology (in the Netherlands)..

## References

- European Commission. (2017). Key enabling technologies. [Online] Available at: [research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/key-enabling-technologies\\_en](https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/key-enabling-technologies_en) [Accessed: 06-07-2023].
- Horowitz, C. A. (2016). Paris agreement. *International Legal Materials*, 55 (4), 740–755. doi: 10.1017/S0020782900004253
- Jourdin, L., Sousa, J., van Stralen, N., & Strik, D. P. B. T. B. (2020). Techno-economic assessment of microbial electrosynthesis from CO<sub>2</sub> and/or organics: An interdisciplinary roadmap towards future research and application. *Applied Energy*, 279, 115775. ISSN 0306-2619. doi: 10.1016/j.apenergy.2020.115775.
- Kampers, L. F., Asin-Garcia, E., Schaap, P. J., Wagemakers, A., & dos Santos, V. A. M. (2021). From innovation to application: Bridging the valley of death in industrial biotechnology. *Trends in Biotechnology*, 39, 1240-1242. doi: 10.1016/j.tibtech.2021.04.010.
- Köpke, M., & Simpson, S. D. (2020). Pollution to products: recycling of 'above ground' carbon by gas fermentation. *Current Opinion in Biotechnology*, 65, 180–189.
- Lieder M, Rashid A. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *J Cleaner Prod* 2016;115:36–51. doi: org/10.1016/j.jclepro.2015.12.042.
- Moncada J., Posada JA, Ramirez A. (2015). Biofuels, Bioproducts and Biorefining 9, 722–748.
- Moncada J., Posada JA, Ramirez A (2017). *Bioresource Technology*, 241, 44-53
- Posada JA, et al. (2013) *Bioresource Technology*, 135, 490-499.