Life cycle assessment of electromicrobial production of renewable hydrocarbon fuels

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Introduction

As agricultural production of energy crops has a limited capacity, it cannot completely substitute fossil fuels without severely undermining food security and decreasing biodiversity. Thus, biofuels wouldn‘t be a fully sustainable option for the future. Therefore, innovative renewable transport fuels are now in the focus of attention, including advanced biofuels from lignocellulosic material and e-fuels from resources that are essentially unlimited and that are independent of agricultural or forestry land use.

E-fuels can either be produced electrochemically or electromicrobially, i.e. in an electro-biorefinery that uses electricity, water and microorganisms to convert CO_2 into renewable hydrocarbon fuels.

This presentation focuses on the life cycle environmental impacts associated with the production and use of e-fuels for transportation compared to gasoline as well as to biofuels.

Methodology

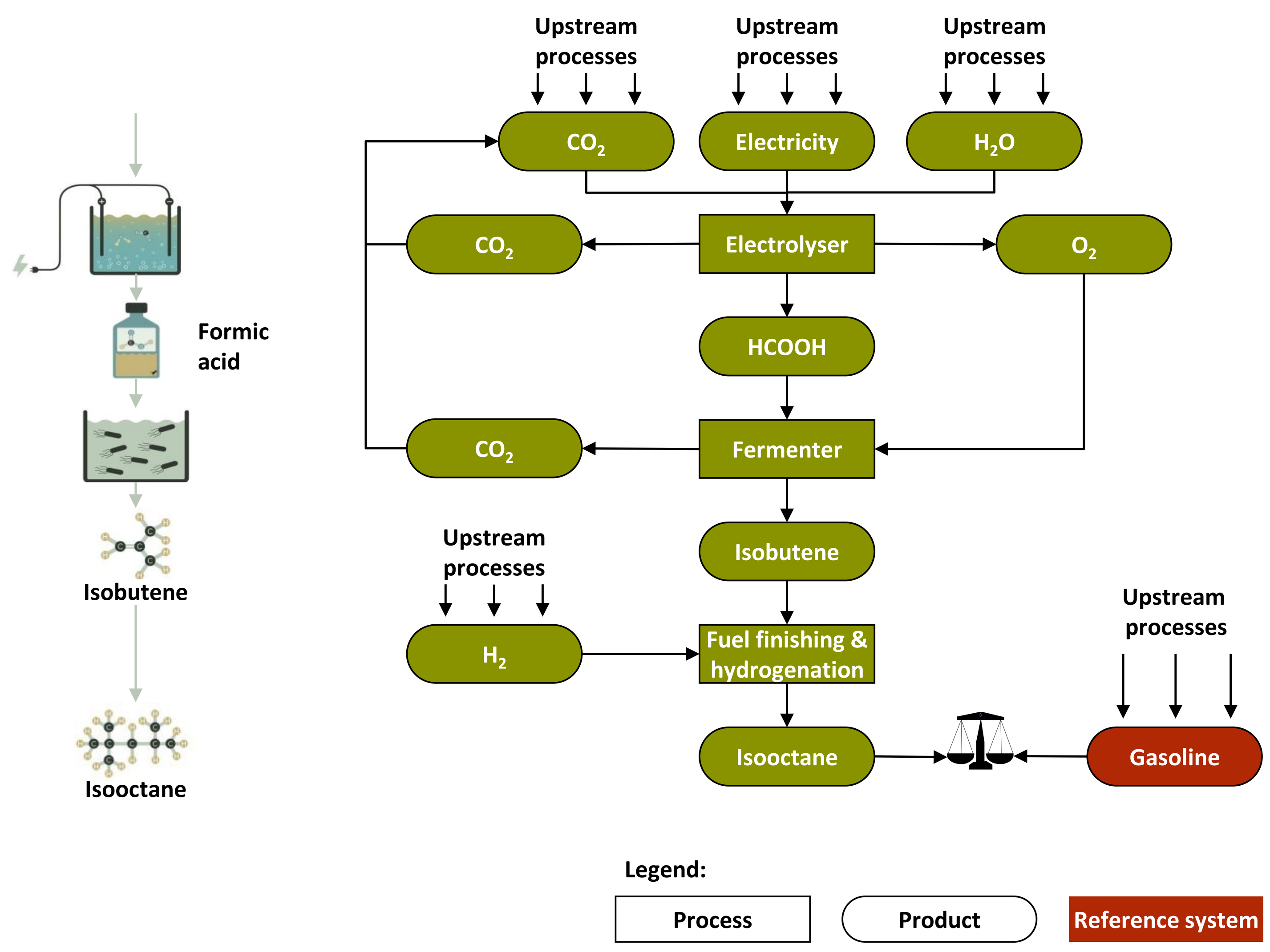

Fig. 1 displays one possibility to produce e-fuels based on a microbial conversion of an electrochemically produced organic intermediate.

Our screening life cycle assessment (LCA) is taking into account ISO standards 14040 & 14044 on product life cycle assessment as well as the LCA4CCU guidelines. It quantifies the environmental impacts of the investigated products along the entire life cycle, compared to those of functionally equivalent reference products (Fig. 1). Important features include:

- LCI modelling for scenarios representing industrial-scale and mature technology in 2030
- LCI data: IFEU’s database (2021), ecoinvent 3.7.1 & Liebich et al. (2021)
- LCIA according to Detzel et al. (2016) plus 3 additional impact categories: land use Fehrenbach et al. (2019), phosphate rock use Reinhardt et al. (2019) & water use Boulay et al. (2018).

Fig. 1 Exemplary, simplified life cycle comparison scheme for an electromicrobially produced e-fuel compared to gasoline

Selected results

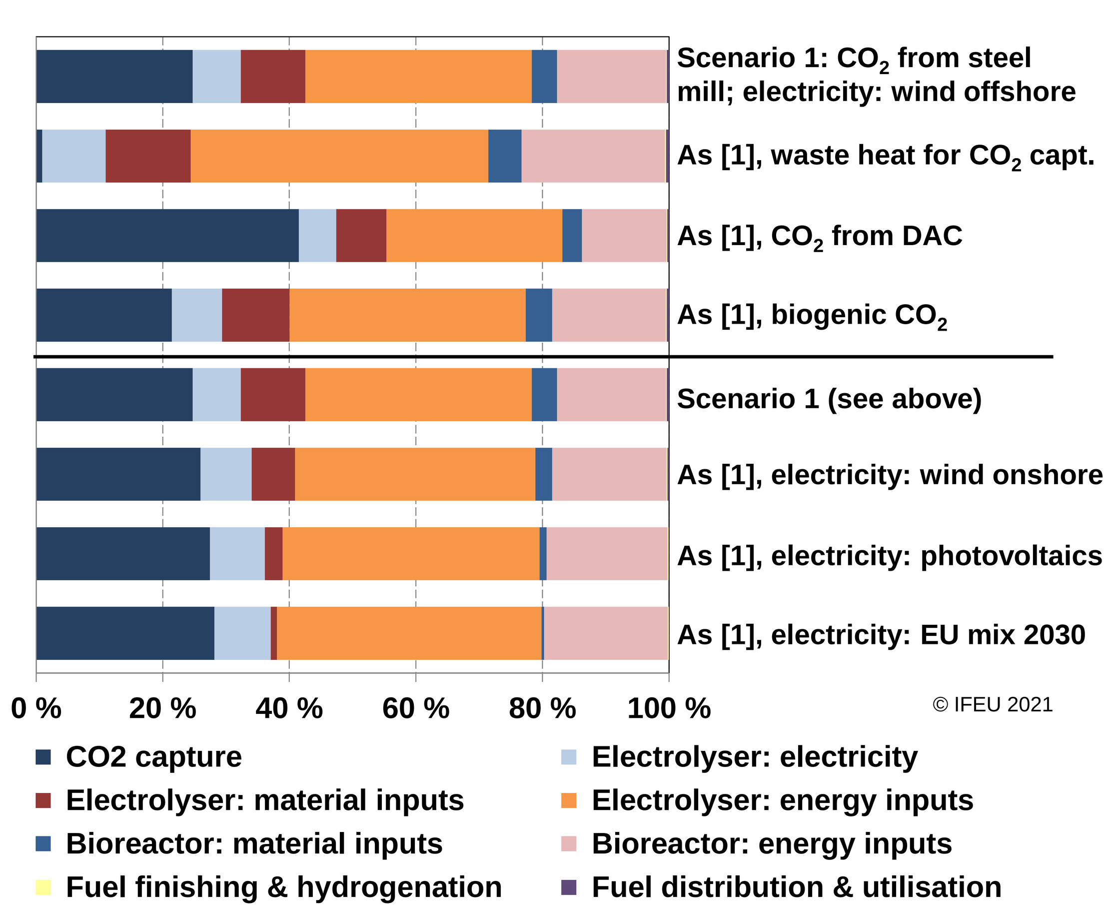

Fig. 2 Dominance analysis for the impact category climate change for an electromicrobially produced e-fuel for various background systems.

- In many cases, the so-called background system dominates the results, especially the impacts associated with the required electricity, process heat and capture of input CO_2 (Fig. 2).

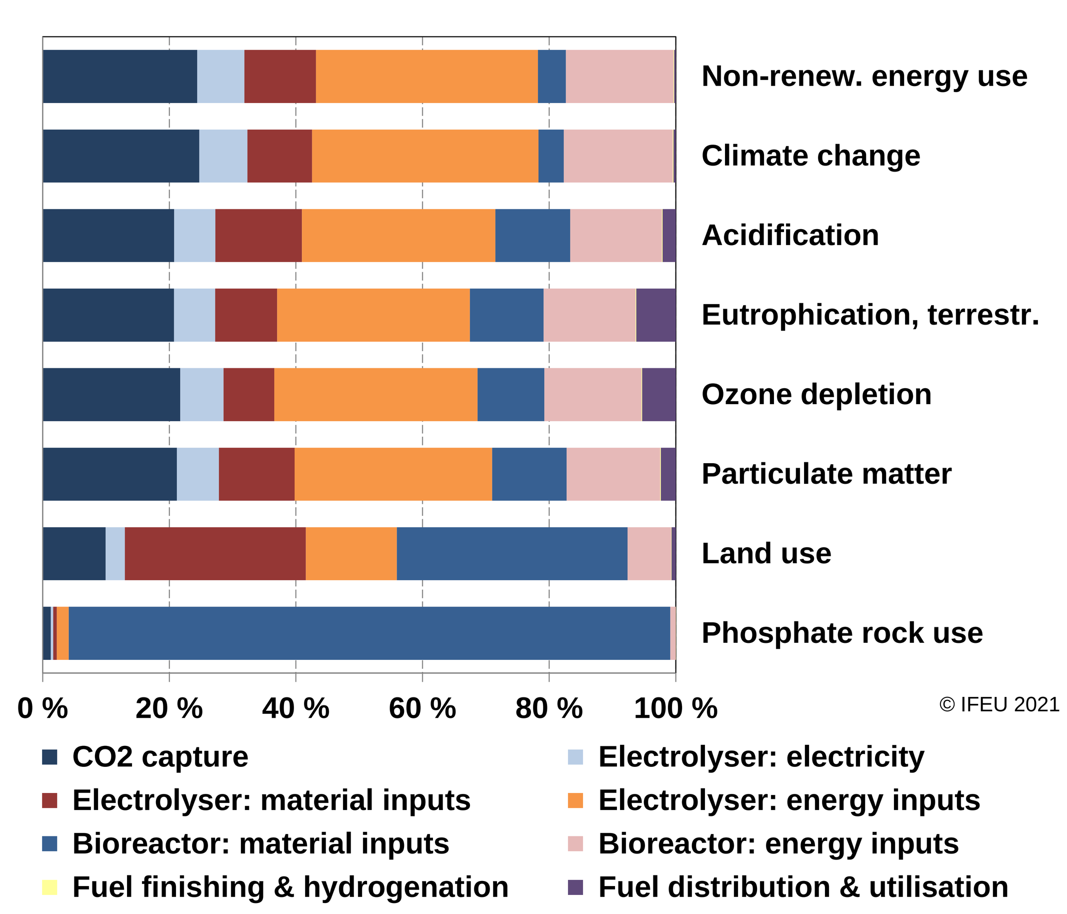

Fig. 3 Dominance analysis for eight environmental impact categories for an electromicrobially produced e-fuel.

- For most environmental impact categories considered, life cycle stages contribute similarly to the results. Contributions to the phosphate footprint are remarkably different (Fig. 3).

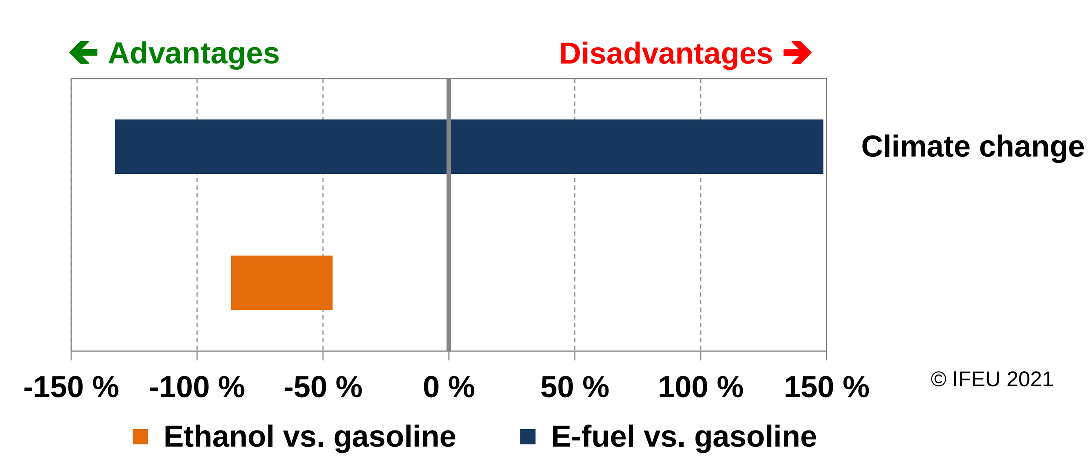

Fig. 4 Environmental advantages and disadvantages for the impact category climate change for e-fuels and biofuels, both compared to gasoline.

- Significant differences occur between e-fuels and biofuels in terms of CO_2 footprint (Fig. 4), land and phosphate footprint as well as ozone depletion (not shown).
- In many cases, the investigated e-fuels can only achieve CO_2 emission savings (compared to conventional fuels) if 100% renewable electricity is used and if all optimisation potentials (e.g. heat integration) along the entire value chain are fully tapped.

Conclusions

- Innovative e-fuels for transportation are not environmentally friendly *per se*, i.e. just because renewable resources are used for their production. Only optimistic scenarios for electromicrobially produced e-fuels lead to advantages over conventional (fossil) fuels and biofuels, respectively.
- LCA is a very versatile and suitable tool, not only to quantify environmental impacts of fuels, but also to identify hot spots and optimisation potentials to steer the development of e-fuels towards sustainability.
- A harmonised approach to solve methodological challenges in the field of LCA of carbon capture and utilisation (CCU) are truly beneficial for the scientific community, as are adequate background data, e.g. for the future electricity mixes, which should ideally be based on well-defined and accepted scenarios for selected reference systems.

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Acknowledgement: This work has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 763911 (eForFuel), 727698 (MAGIC) and 727463 (BioMates).
Further information: https://www.ifeu.de/en/projects/