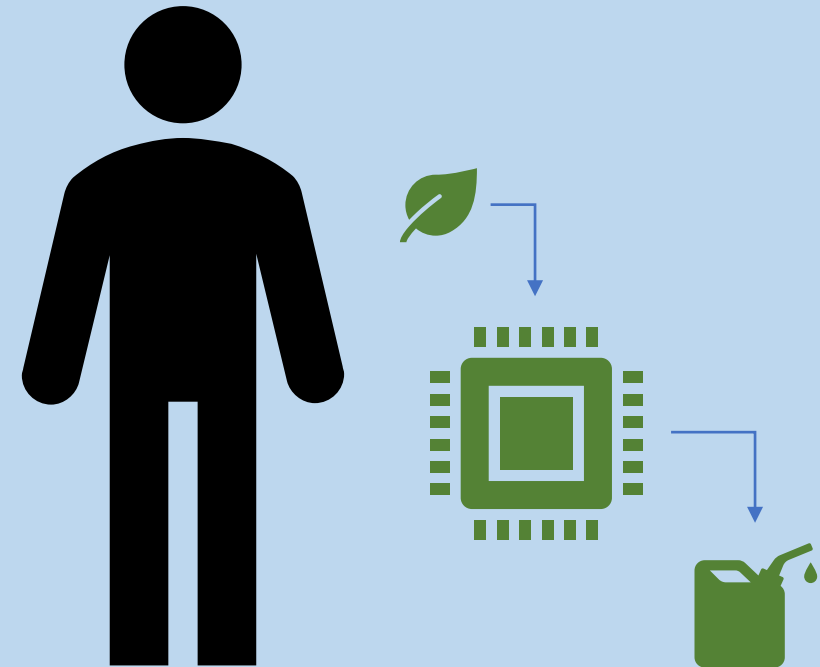


Decentralized production of green fuel from surplus algae oil

**BFE-Project «GREAT» - GReen Energy from Algae with
microreactor Technology**

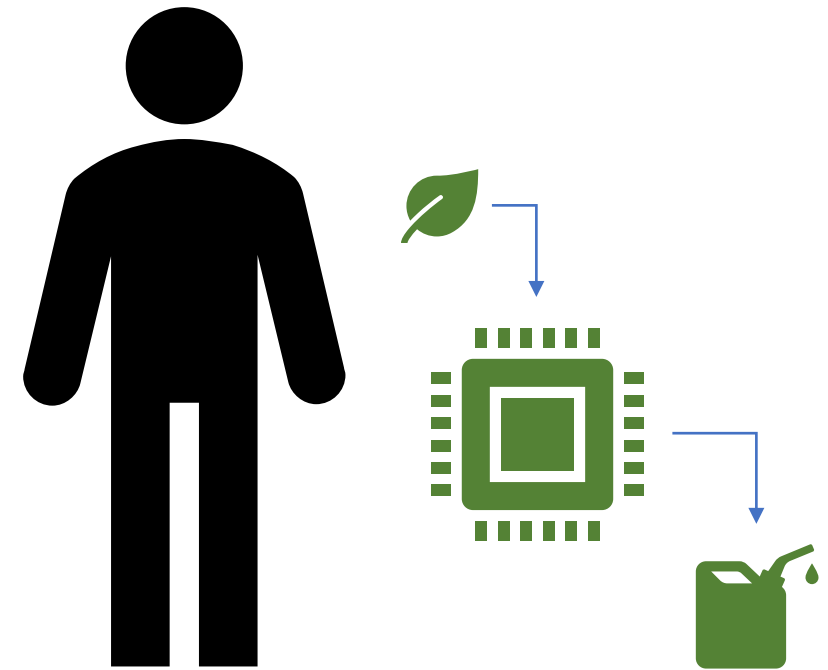
Prof. Dr.-Ing. Wolfgang Riedl
Dr. Alan Pérez

24 April 2023



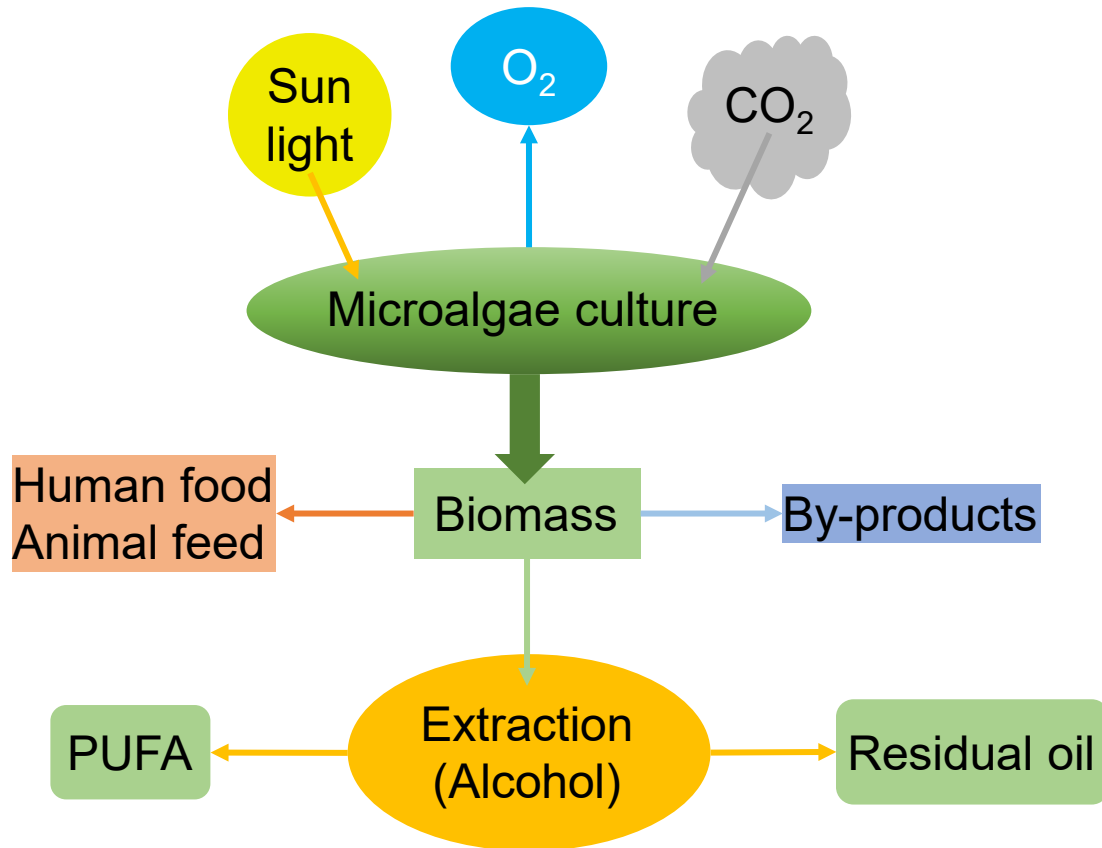
Agenda

1. Motivation
2. Microreactors for biodiesel production
3. Process transfer
4. Results
5. Conclusions
6. Acknowledgments



MOTIVATION

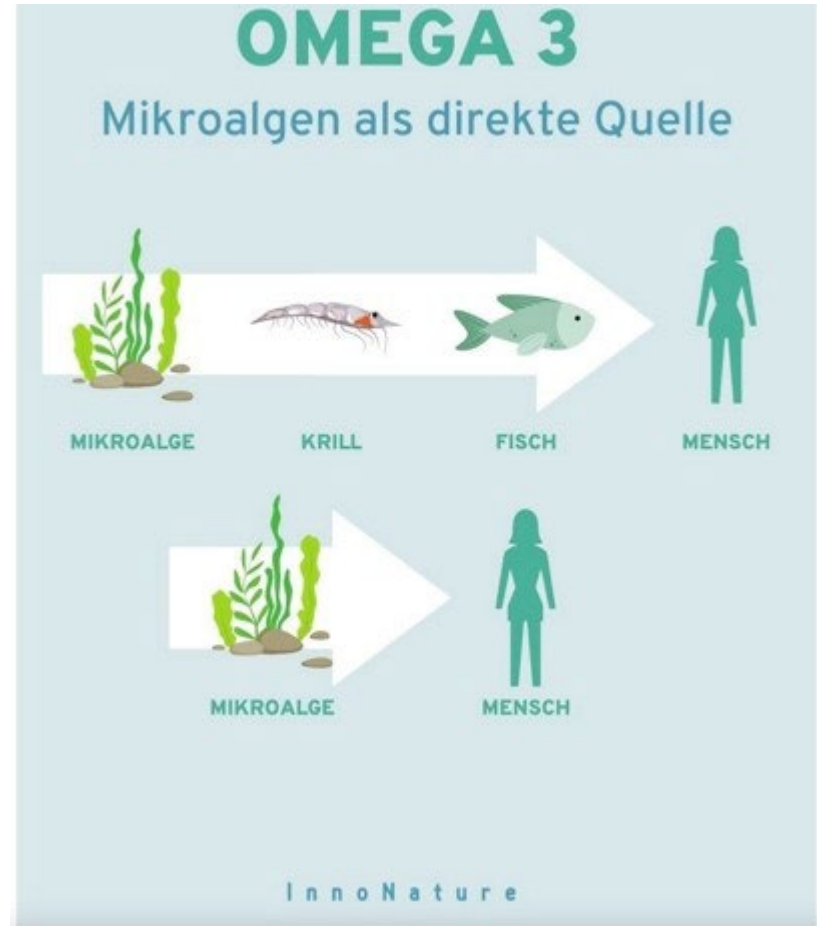
Microalgae



Food and feed products from microalgae: Market opportunities and challenges for the EU

„Although the research activities on micro-algae-based nutrients are very promising, the products currently on the market are still limited. There are two main categories of food market products obtained from micro-algae (Enzinget al., 2014). The first category is **dried algae** (in particular the micro-algae species **Chlorella** and **Spirulina**) with high nutrients content, especially of **vitamin B12, C and D2**. These micro-algal products can be directly sold as dietary supplements and have the potential to be used in bulk commodities as sources of proteins and carbohydrates. The second type is specialty **products isolated and extracted from the micro-algae** that can be added to food and feed to improve their nutritional value. These high-value compounds are pigments (e.g. **astaxanthin**), **antioxidants** (e.g. **β-carotene**), **proteins** (e.g. phycocyanin) and fatty acids (e.g. **omega-3**, docosahexaenoic acid - **DHA** and eicosapentaenoic acid **EPA**).“

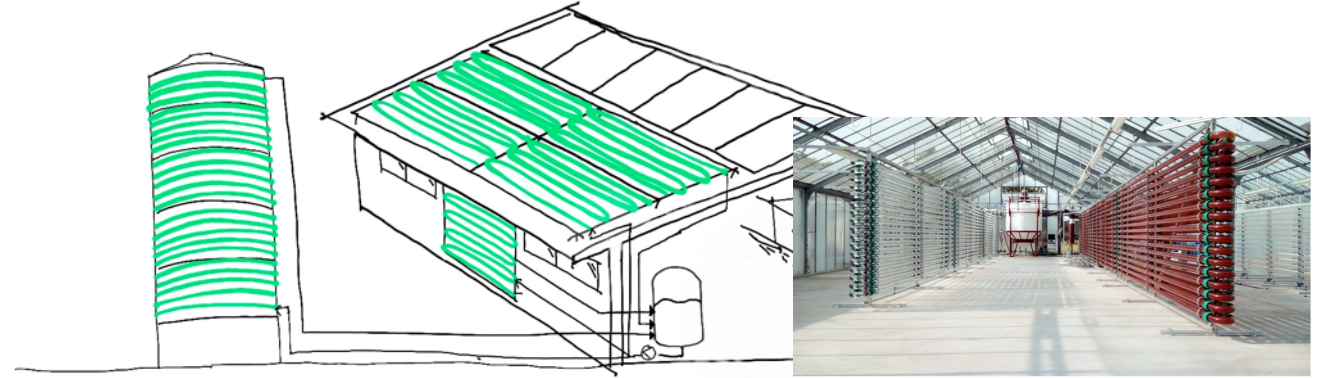
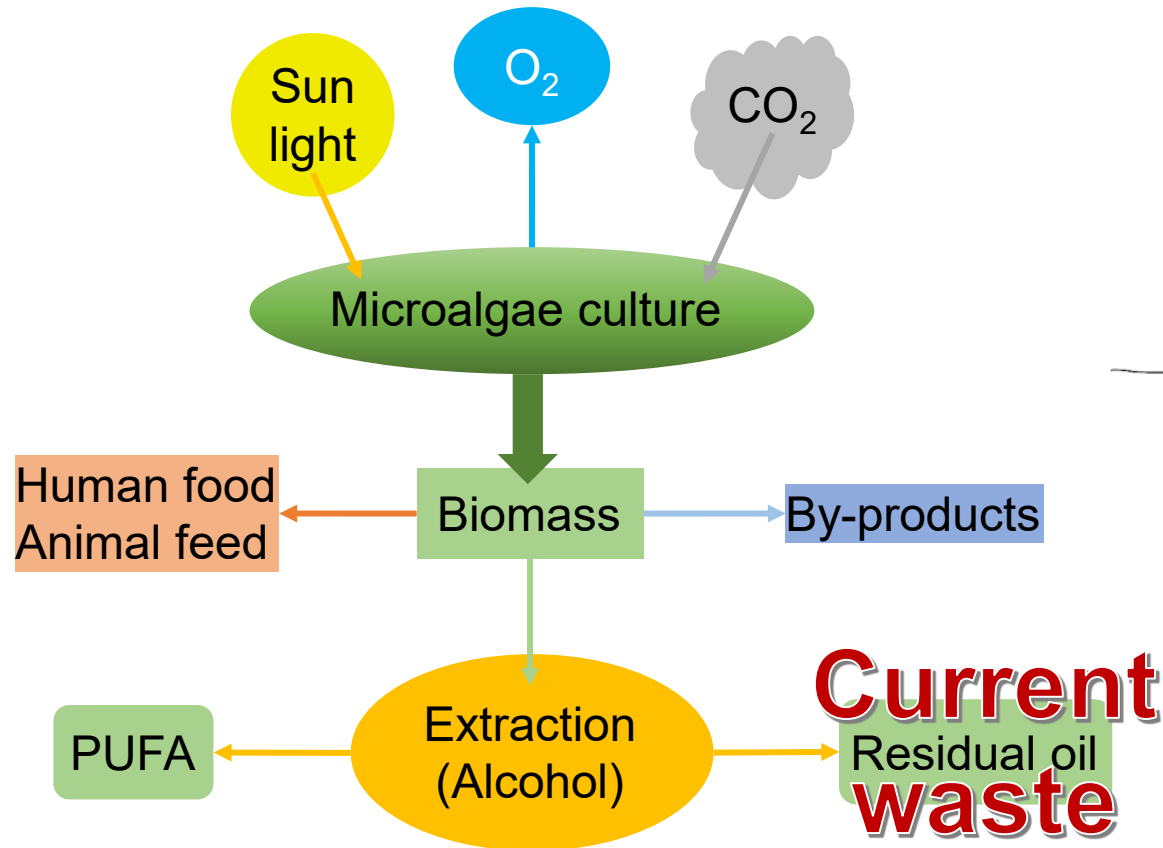
Microalgae high value products



Product	Price (USD Kg ⁻¹)
Omega-3 fatty acids	80 – 160
<i>Chlorella</i> biomass	44
Arthrospira biomass	42 €

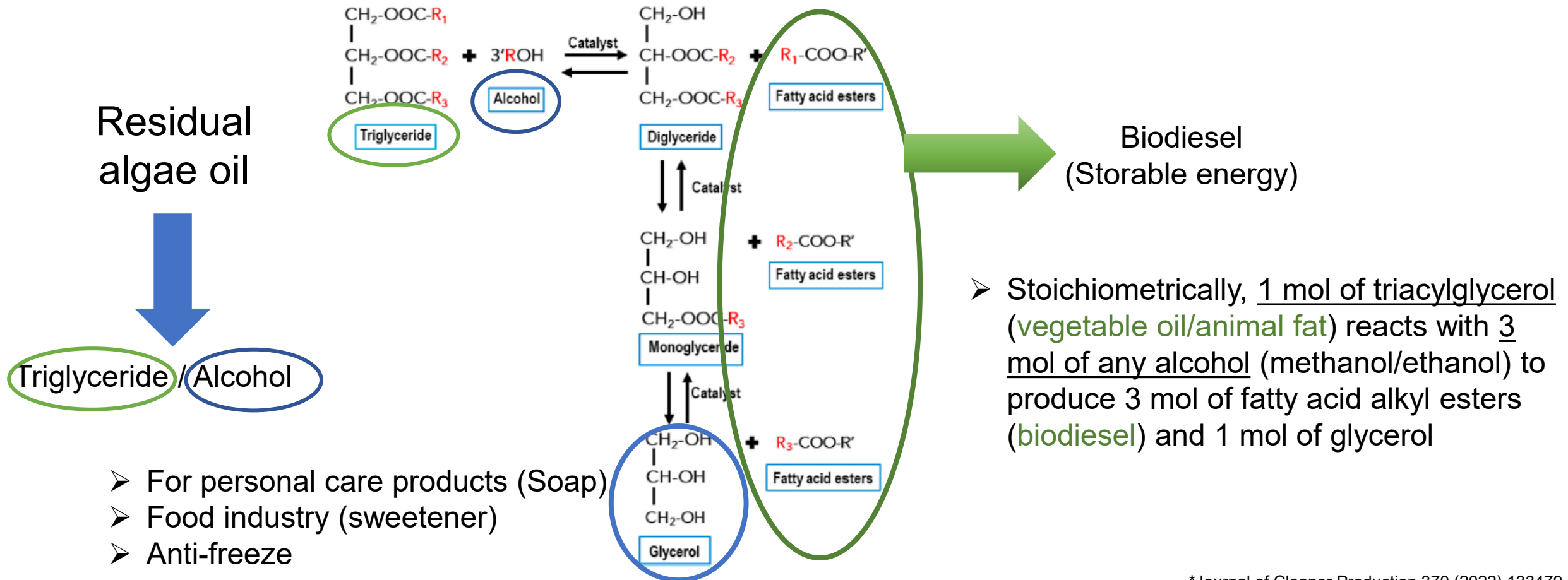


Microalgae culture potential business case (example)



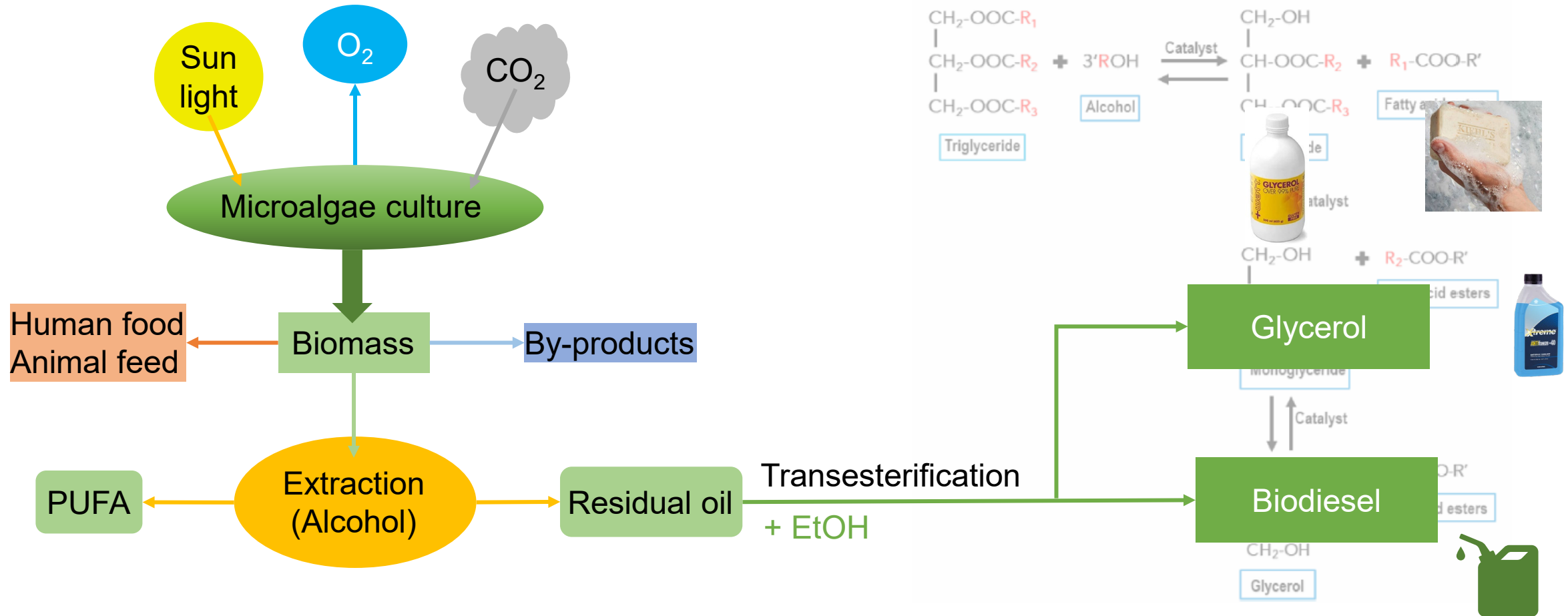
- Microalgae cultivation might be attractive for farmers – especially with „added-value“ (by producing e.g. PUFA from microalgae biomass, however:
- Residual oil/alcohol mixture is a „no-go“
- Good ideas for further treatment are required!

Production of Storable energy (biodiesel from waste algae oil)



*Journal of Cleaner Production 370 (2022) 133479

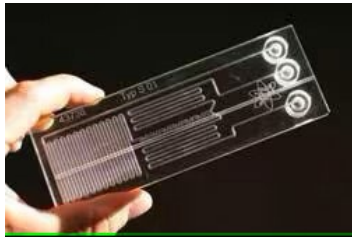
Microalgae (waste valorization)



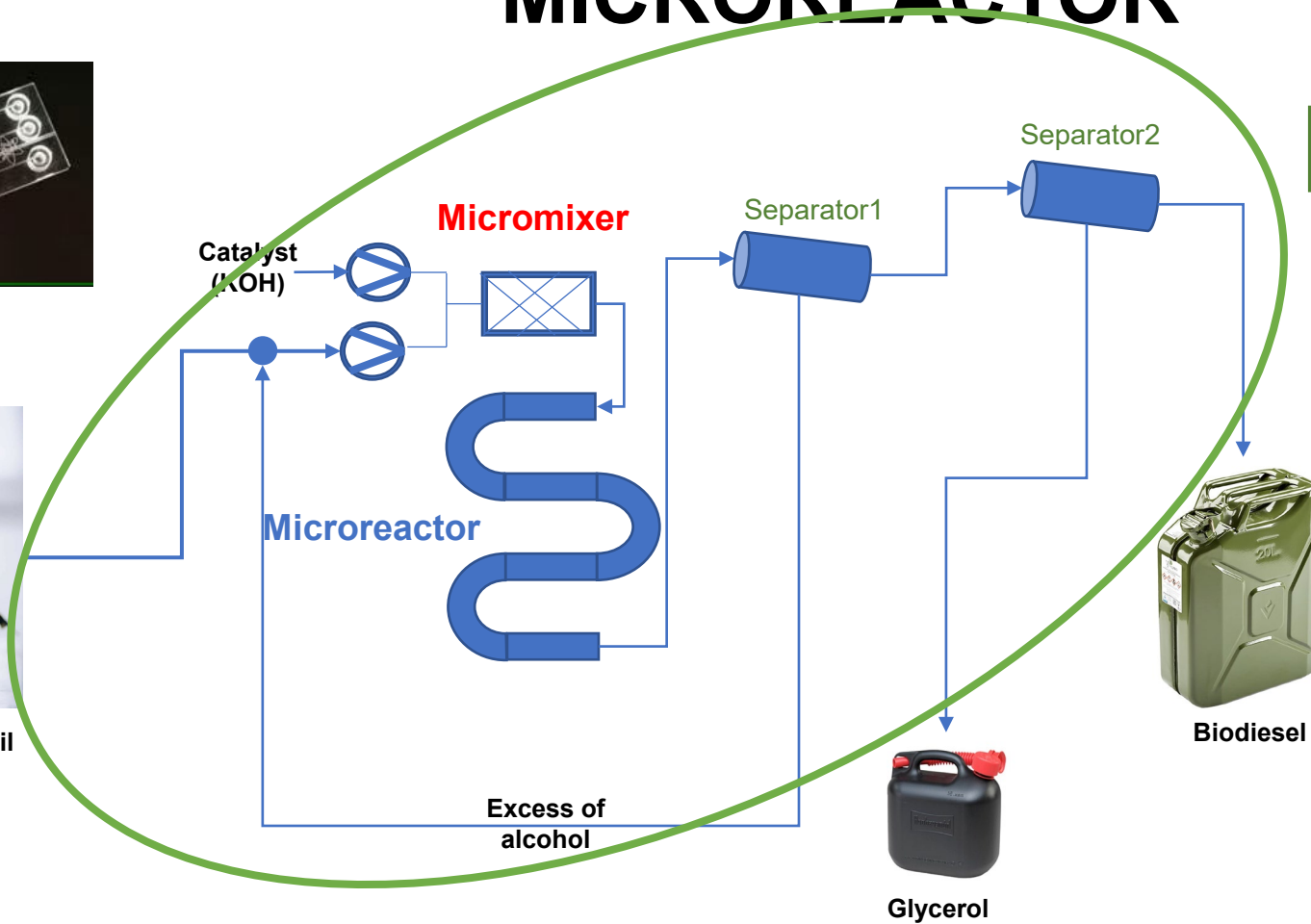
Decentralized biodiesel production – requires chemical reaction



MICROREACTOR



Residual algae oil
EtOH



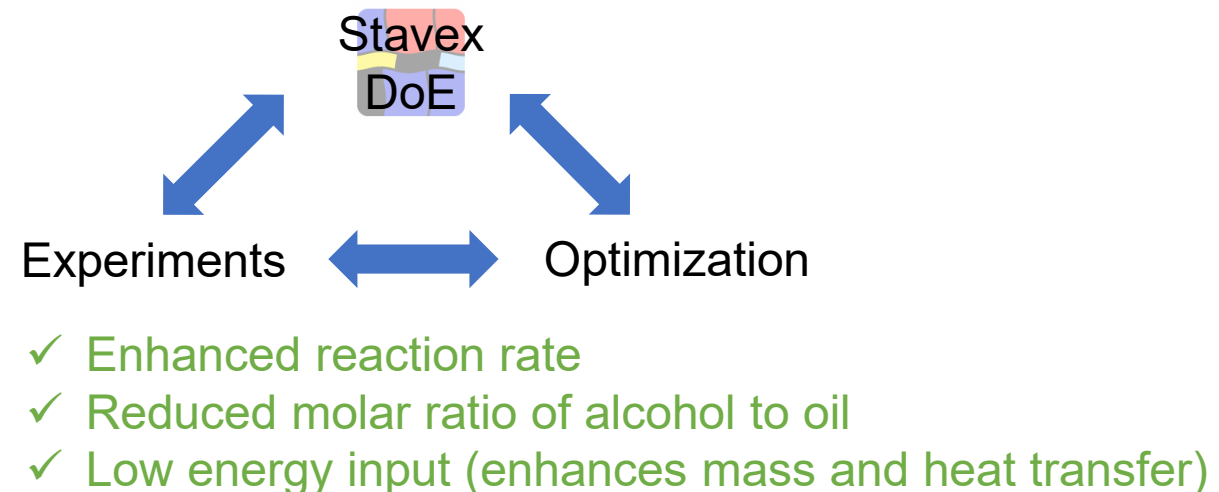
- Simple set-up
- Very low hold-up
- Robust equipment
- Minimum space requirement
- Fits well to the intended flow-rates (just a few l/h max.)

Mini-plant approach



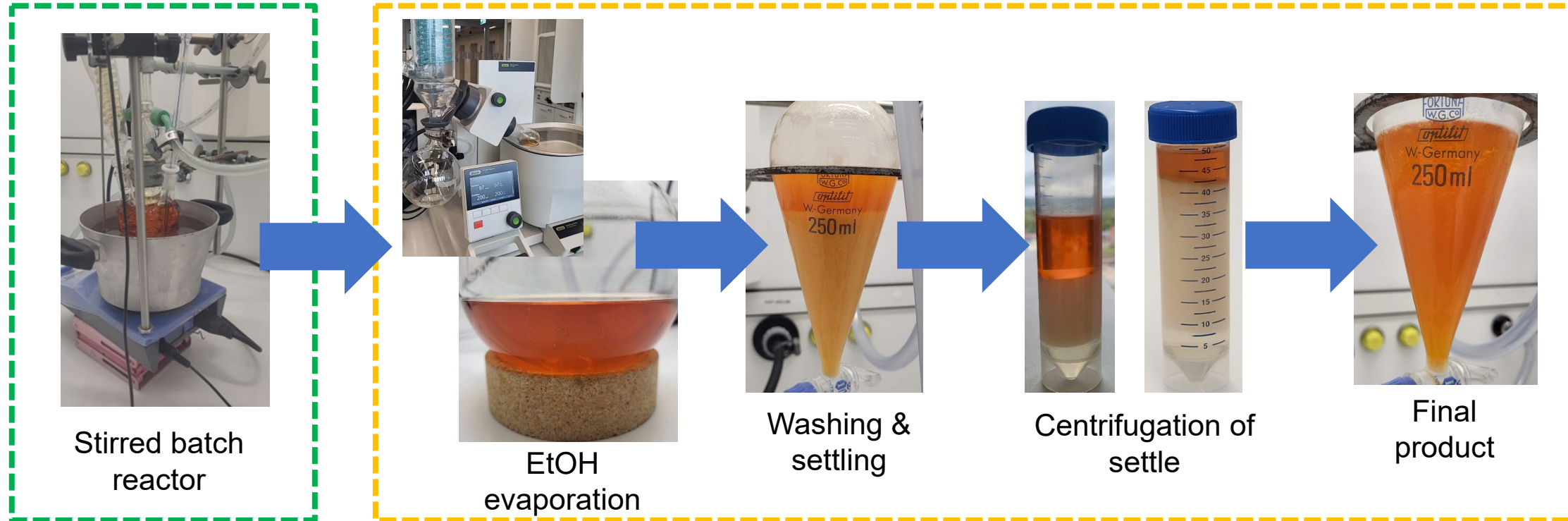
PROCESS TRANSFER

...required “mind-change”: From batch to continuous operation
(main part of this project)



Batch process

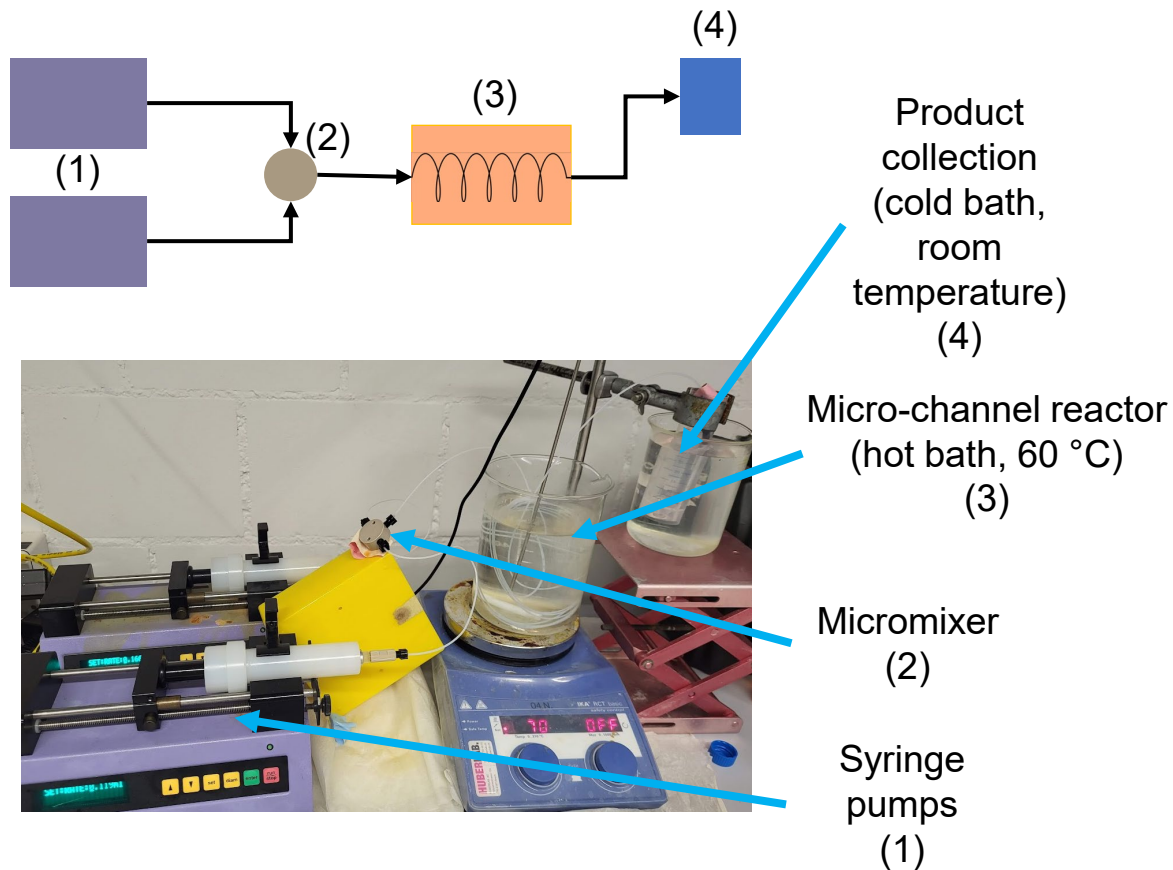
RESULTS



- Reaction time: 60 minutes
- Reaction temperature: 60 °C
- EtOH:oil ratio: 40:1 v/v

Downstream steps

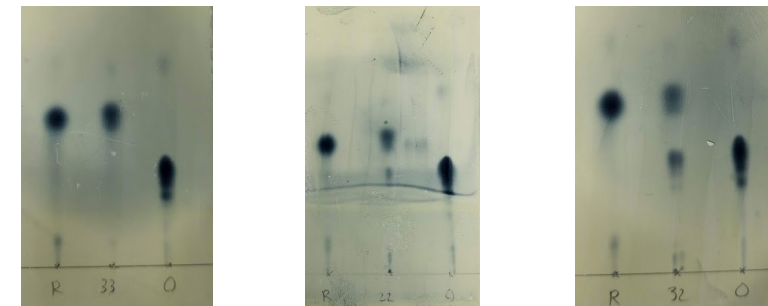
Microreactor system



Evaluated parameters

- Ethanol/oil molar ratio (5 – 18)
- Residence time (100 – 3600 s)
- Reactor length (1 – 2 m)

Thin Layer Chromatography (TLC) analysis

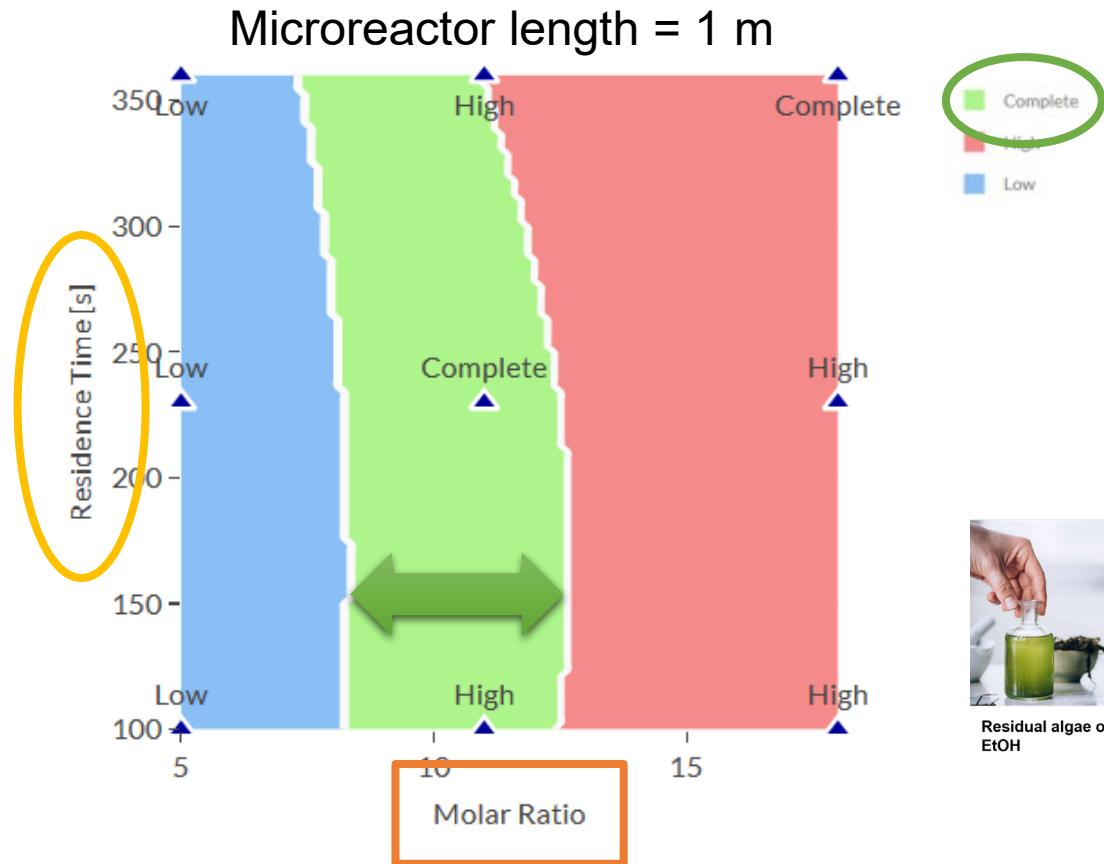


Conversion: Complete

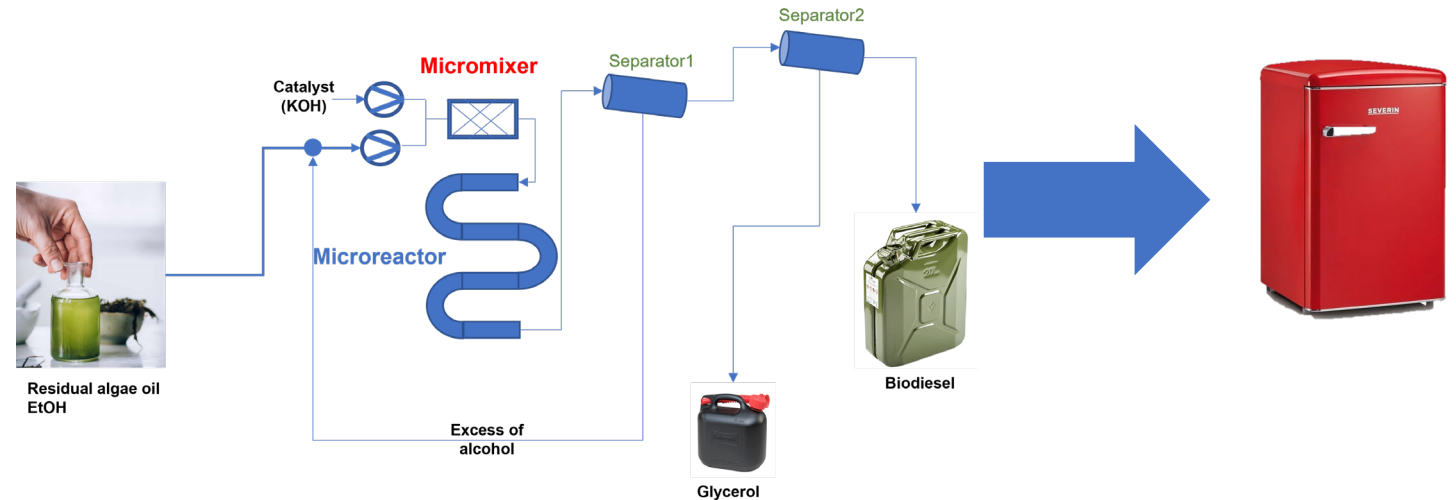
High

Low

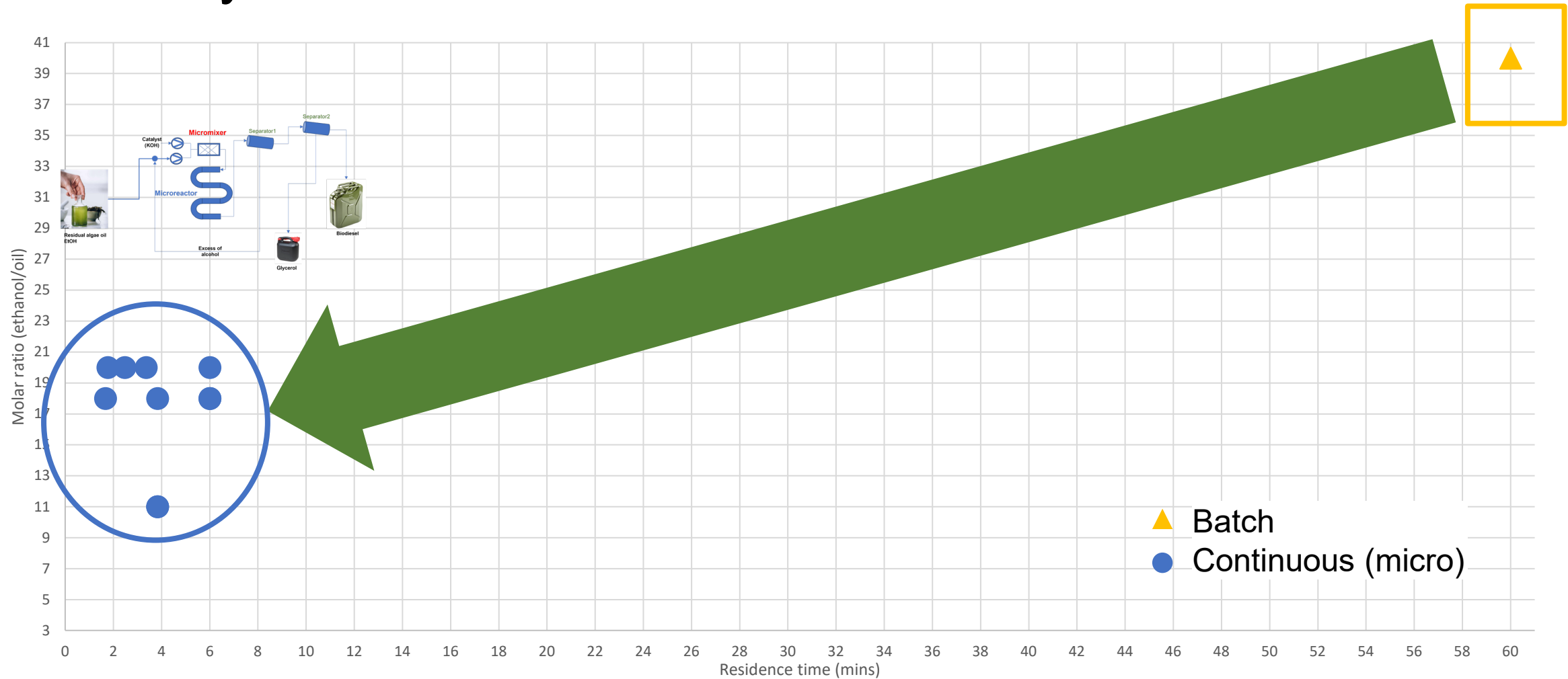
DoE (Stavex, 3-Level Full Factorial Design 3^3)



Minimum residence time = 1.6 minutes
Maximum residence time = 5.4 minutes



Summary of results



CONCLUSIONS

It could be shown that surplus algal oil/ethanol solutions from PUFA extraction out of microalgae can be successfully transferred into biodiesel, glycerol (and in some cases soap, too) by “transesterification”

This chemical process could be successfully transferred into a continuous operation using microreactors due to a tremendous reduction of required reaction time (from 60 minutes to 1.6 - 6 minutes max.)

Based on these results, a compact reactor-concept („fridge size approach“) could be provided as “plug-an-play” approach for terminal use side streams from high-value product (PUFA) capturing from microalgae cultivation and its conversion into **storable energy** (=biodiesel)

As an **outlook**, we hope this solution to a classical side-stream problem helps to increase the number of installed micro-algae cultivations (e.g., at Swiss farms) and thus through economy of scales „auto-catalysis“ further new installations.

ACKNOWLEDGMENTS

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Process engineering and technology team