University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

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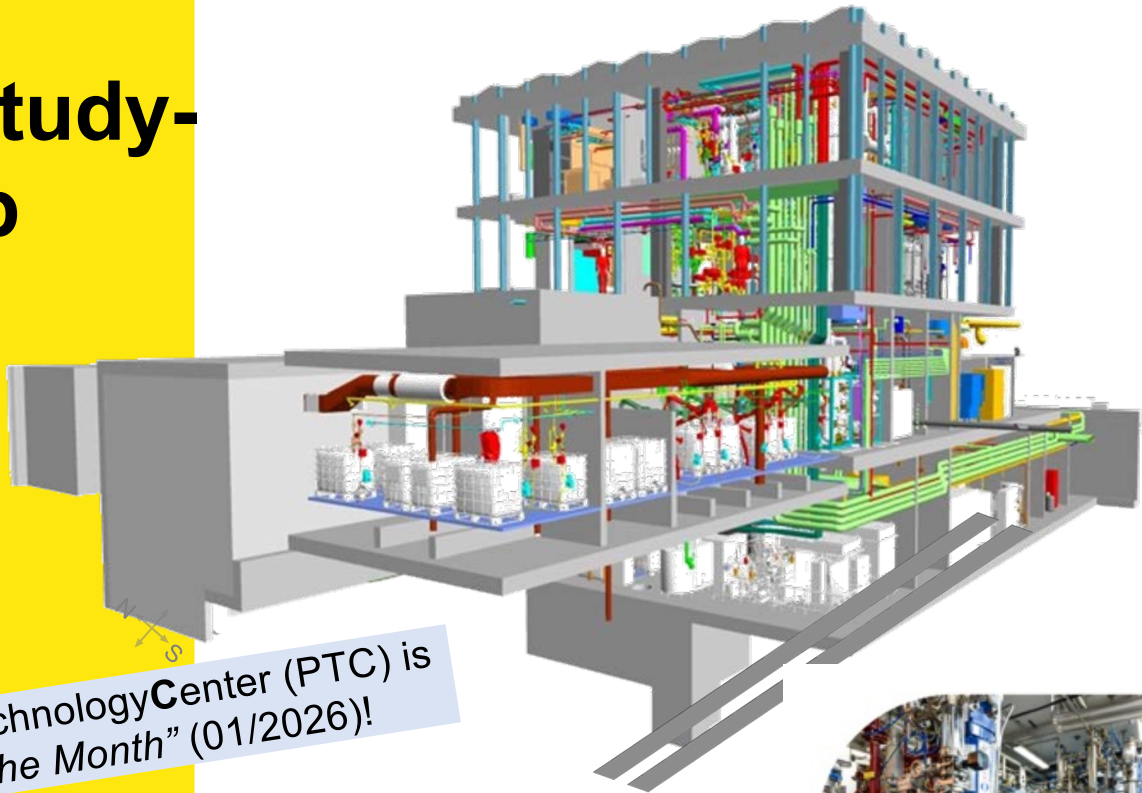
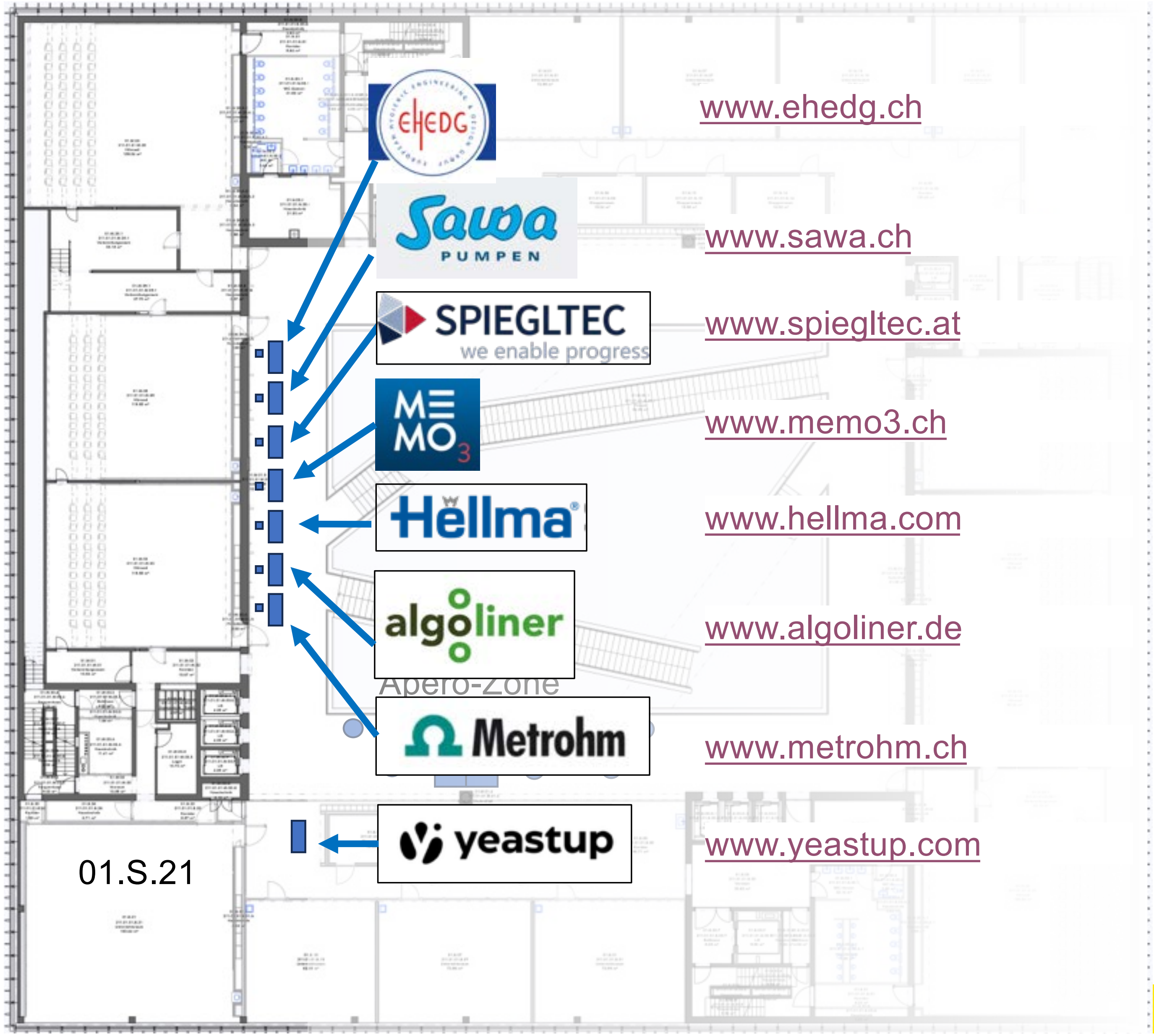
Welcome to the Study-Visit and Scale-up Workshop!

Pilots4U
powered by CoPilot
BIOECONOMY INNOVATION COMMUNITY & DATABASE



Our **P**rocess**T**echnology**C**enter (PTC) is *"Facility of the Month"* (01/2026)!

School of Life Sciences, CH-Muttenz
February 4th, 2026



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Agenda

The FHNW School of Life Sciences is organising a Study Visit and Scale-Up Workshop at FHNW Campus Muttenz (Switzerland) on February 4, 2026. The event is supported by the "PILOTS4U – powered by COPILOT" initiative, as part of its "Scale-up & Growth" and "Exchange & Connect" programmes.

We are pleased to welcome all interested researchers, engineers, innovators and investors to Muttenz!

Visit the FHNW website

9.00 – 9.30	Registration and Coffee
9.30 – 9.45	Welcome
9.45 – 10.00	Introduction to Pilots4U powered by COPILOT
10.00 – 11.00	The FHNW School of Life Sciences and its applied R&D activities
11.00 – 12.30	Scale-up session Group A // Lab tour Group B
12.30 -13.30	Lunch and Company/Project Presentation
13.30 – 15.00	Scale-up session Group B // Lab tour Group A
15.00 – 15.15	Wrap up
15.15 – 16.00	Coffee

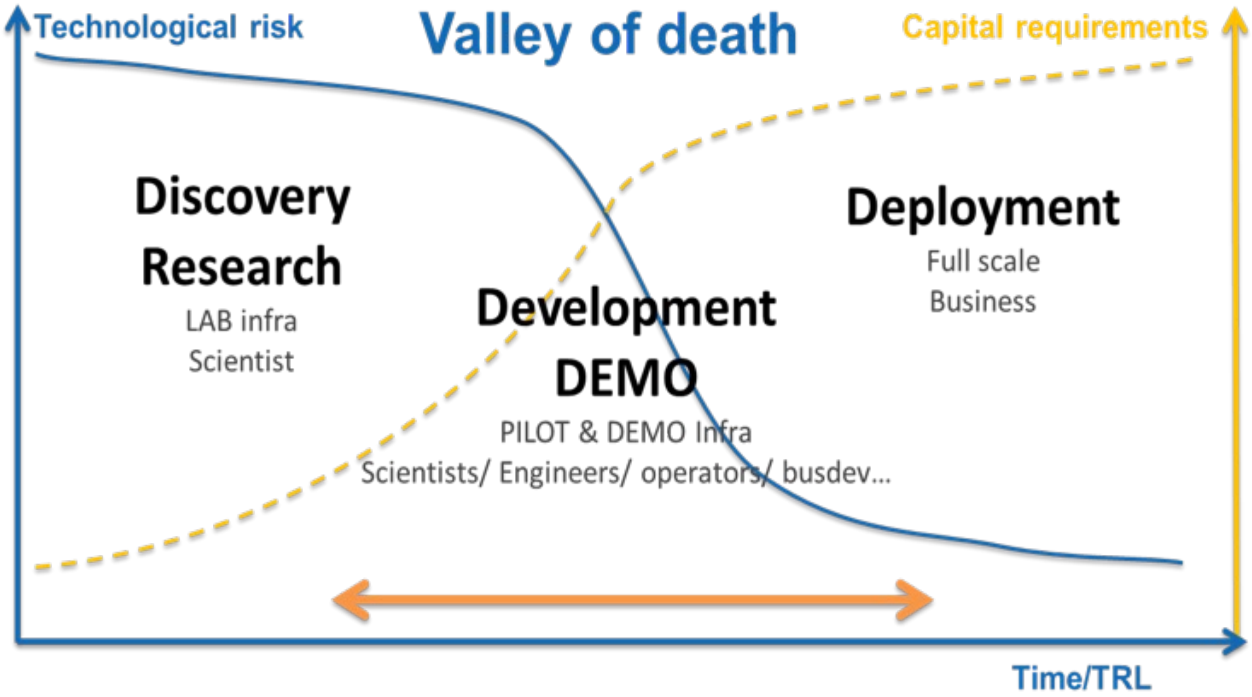
Pilots4U: Supporting the Scale-Up of the European Bioeconomy

Yang Zou, PhD

COPILOT project coordinator
Pilots4U powered by COPILOT platform manager

Co-funded by the European Union

Scaling up is a tricky phase to get through



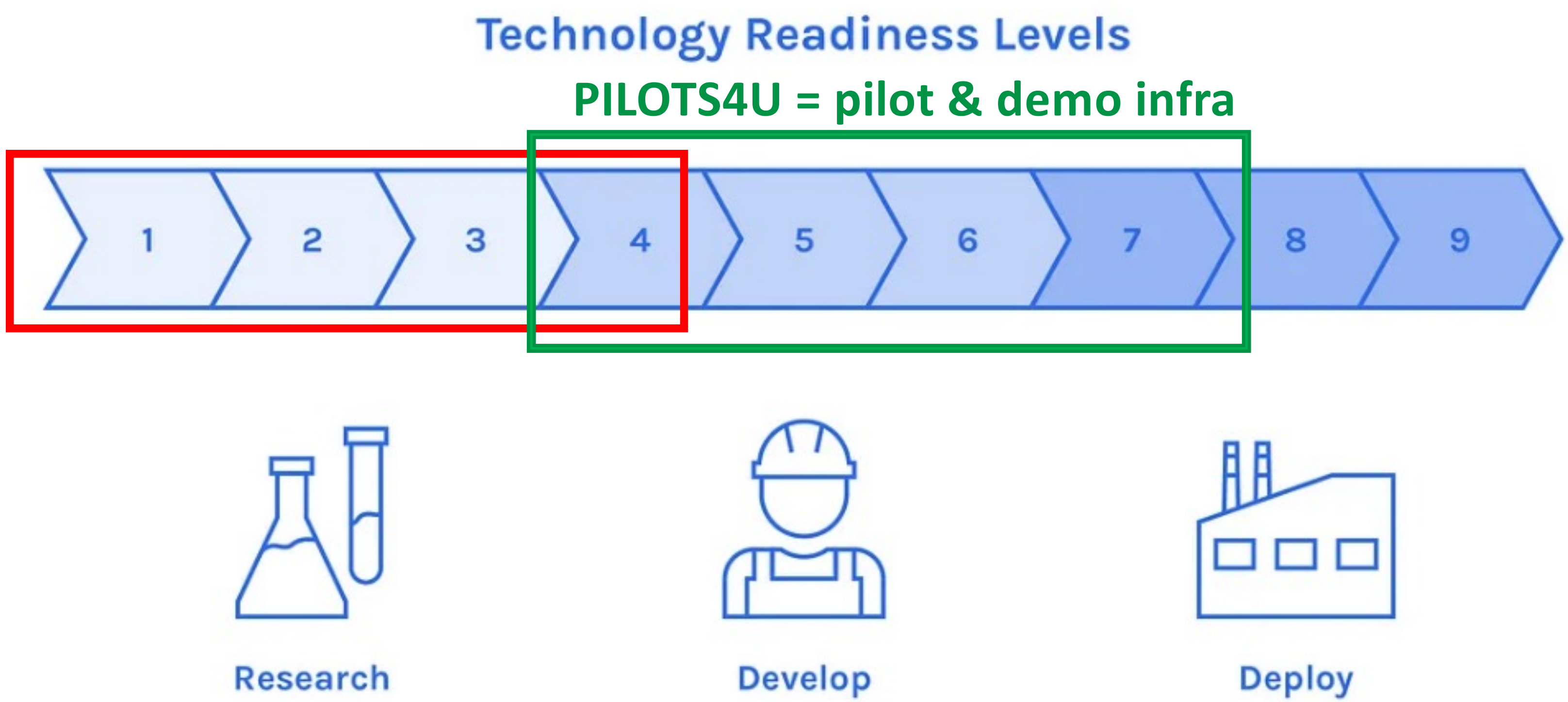
Shared Pilot Facilities

=

risk sharing & reduction

Circular Bio-based Europe Joint Undertaking
Bio-based Industries Consortium
Co-funded by the European Union

The TRL levels covered by Pilots4U



Co-funded by the European Union

Pilots4U powered by CoPilot BIOECONOMY INNOVATION COMMUNITY & DATABASE

Availability of 120+ shared pilot & demo infrastructures for the bioeconomy in Europe

Support the Pilots4U ecosystem structurally as a strong network

Put these infrastructures clearly on the map within the EU Biotech Hub

Support to keep the infrastructure state-of-the-art

Circular Bio-based Europe Joint Undertaking

Bio-based Industries Consortium

Co-funded by the European Union

Pilots4U covering a broad scope of technology areas

Pilots4U powered by CoPilot BIOECONOMY INNOVATION COMMUNITY & DATABASE

Size reduction and Homogenisation
Chipping
Extrusion
Grinding
Milling
Densification

Thermal and Pressure techniques
Steam explosion
Microwave
Cold plasma
Ultrasonication
Torrefaction
Hydrothermal

Pulping
Chemical: sulphate/sulphite, organosolv, soda
Mechanical
Hybrid: Chemi-thermo-mechanical pulping, neutral sulphite semi-chemical pulping

Thermochemical conversions
Gasification
Pyrolysis

Algae technologies
Algae cultivation in open ponds, photobioreactors and fermenters

Separation technologies
Mechanical separation
- Centrifugation
- Membrane filtration
- Particle filtering
- Particle classification and sieving

Physicochemical separation
- Chromatography
- Crystallization
- Distillation
- Drying
- Evaporation
- Crystallization and precipitation
- Field-Flow Fractionation
- Flocculation

Extraction
- Liquid-Liquid extraction
- Solid-Liquid extraction

Fermentation and Digestion
Anaerobic digestion
Biomass fermentation and precision fermentation
Solid-state fermentation
Gas fermentation
Composting

Enzymatic catalysis
Enzymatic hydrolysis and enzyme immobilization
Remediation

Chemical conversions
Acid and alkaline hydrolysis
Carbon capture utilisation
Polymerisation
Heterogeneous catalysis
Reduction

Material technologies
Coating or lamination
Textile fibre spinning
Fibre web production
Nano/micro fibre production
Biocomposite processin

Sterilisation technologies
UHT
Pasteurisation
UV

Cell cultivation
Mammalian/Insect Cells
Plant Cells

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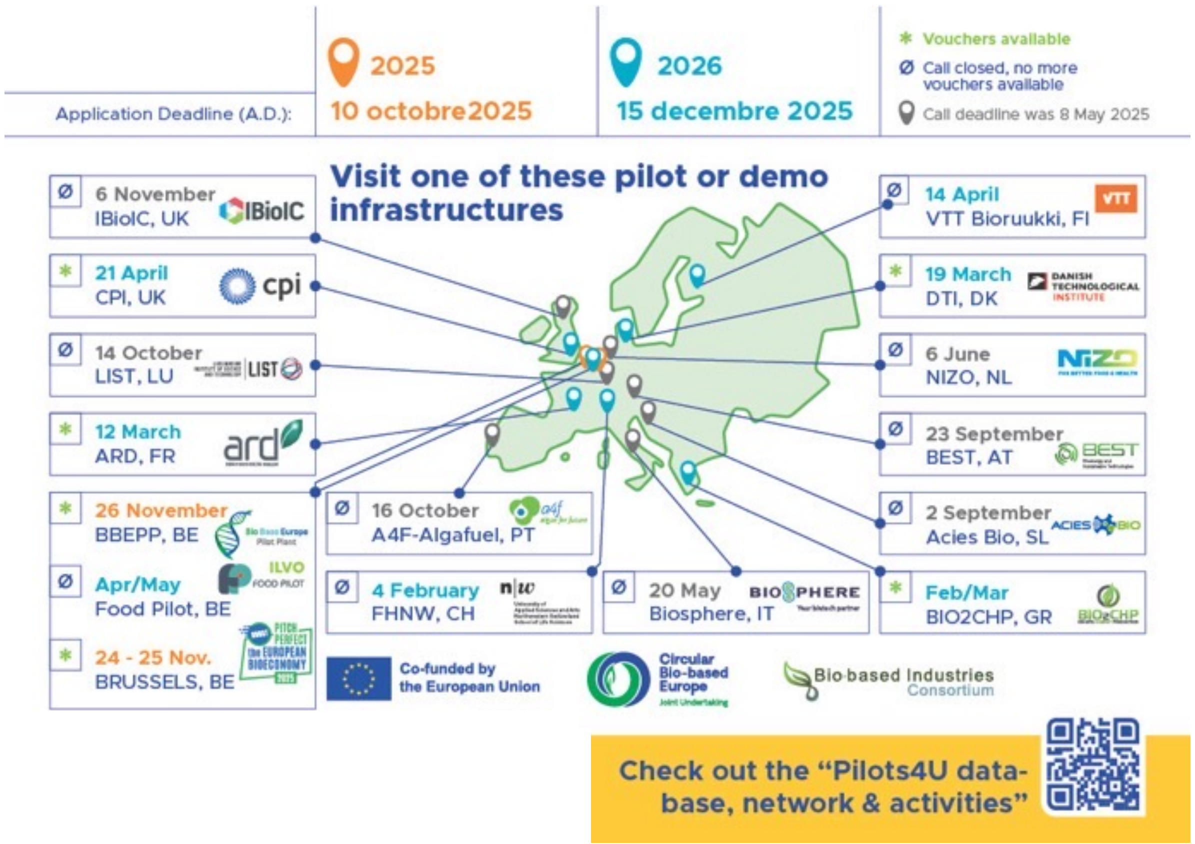
Pilots4U co-organize Open Day Visits

Pilots4U powered by CoPilot
BIOECONOMY INNOVATION COMMUNITY & DATABASE



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Pilots4U co-organize PDI Fair

Pilots4U powered by CoPilot BIOECONOMY INNOVATION COMMUNITY & DATABASE

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Pilots4U co-organize Training Webinars

Date	Pilot Plant and Demo Infrastructures	Topic
22 May 2025	Bio2CHP	Pitch Training for Start-Ups in Biosolutions
26 May 2025	Acies Bio	Scaling innovative technologies - Different business models in scaling biosolutions
18 June 2025	LIST	Downstream from your Production Could be an Important Part of the Business Potential
25 September 2025	DTI	Choices Challenges and Collaboration in Process Scaling Up
1 October 2025	ARD	Scaling-Up Improvement, Environmental Integration Processes and Waste Characterization
10 October 2025	A4F	Biological Contaminants & Microalgae Crop Protection
20 January 2026	BEST	The Condensation of Liquids during Pyrolysis
10 February 2026	NIZO/BFF	Process and Microbial Modelling, Food Safety and Quality Aspects of Food Processing and Upscaling
26 February 2026	Biosphere	Intellectual Property and Patents for Biosolution Start-Ups
12 March 2026	Food Pilot	Integrating Novel Food Dossier Preparation into Your Product Development Process

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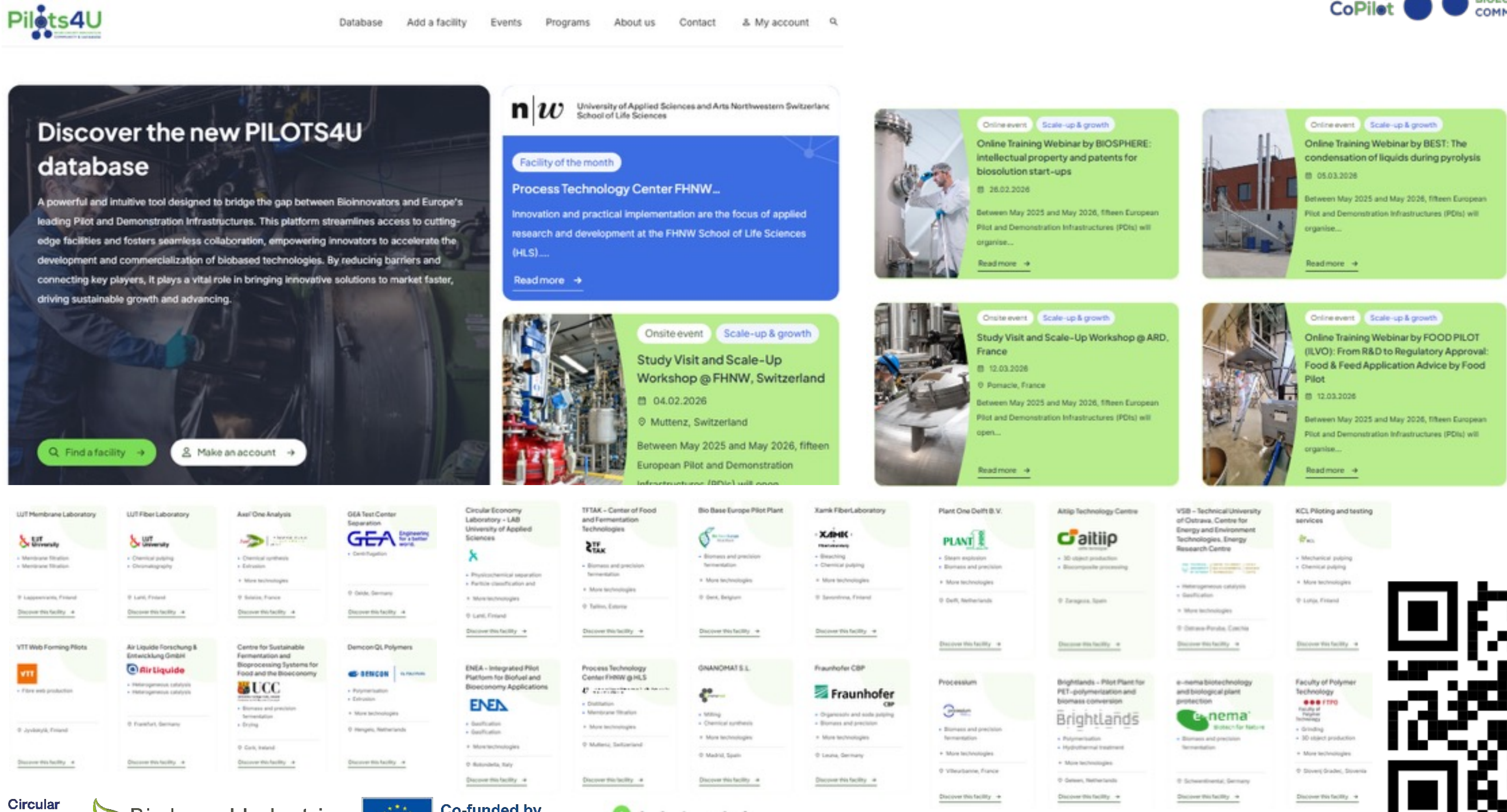
The next generation platform Pilots4U powered by COPILOT

Pilots4U powered by CoPilot BIOECONOMY INNOVATION COMMUNITY & DATABASE



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Follow Pilots4U LinkedIn Page

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Pilots4U by CoPilot
3,221 followers
3d • Edited •

REGISTER NOW: 2 upcoming FREE Pilots4U Training Webinars (Feb 2026)
Looking to strengthen your scale-up journey, from process understanding to protecting your innovation? Join our next two online training sessions, ...more

Stef Denayer and 75 others · 6 comments · 16 reposts

Pilots4U by CoPilot
3,221 followers
1mo • Edited •

Pilots4U powered by COPILOT is officially launched! https://biopilots4u.eu/
A proud moment: we unveiled the brand-new Pilots4U platform during Pitch Perfect and Boost the European Bioeconomy 2025! This is a true milestone in our ...more

You and 156 others · 9 comments · 20 re

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Bio-based Industries Consortium
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Why are we doing scale-up @ School of Life Sciences / FHNW CH-Muttenz

1) From an academic / engineering point of view:

- Minimum requirement: In order to see, which effects occur when the process is operated in x10-x100 lager scale then in the (controlled) lab environment (and describe/quantify them, if possible)
- Advanced: In order to see, to witch extend your simulations / (rigorous?) mass/heat transfer models do work in larger scale, too (or which adoptions are required to do so)

2) From an economic / industrial point of view:

- Especially Start-ups simply need some “Kilogram” to show to their (future) customer
- As a confidence-building measure for investors: “Look, we have a process in place!” Theranos failed to do so!
- Show, if and to what extend there is an “economy of scale” (=the larger, the cheaper)
- Further reasons: See “academic/engineering point of view” above!

Why are we doing scale-up?

1) From an academic / engineering point of view:

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- ➢ Advanced: In order to see, to witch extend your simulations / (rigorous?) mass/heat transfer models do work in larger scale, too (or which adoptions are required to do so)

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- ➢ As a confidence building measure for investors: "Look, we have a process in place!" Theranos failed to do so!
- ➢ Show, if and to what extend there is an "economy of scale" (=the larger, the cheaper)
- ➢ Further reasons: See "academic/engineering point of view" above!

Why with us?
(a University of Applied Sciences)

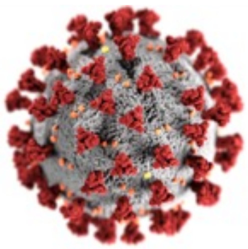
Do you agree?

- ➢ The "speed" of Universities ≠ (required) speed of industrial projects (3 years for ph.D. vs 3 month for concept phase)
- ➢ Universities are not equipped good enough ("Only Experts in specialised fields / technologies")
- ➢ Switzerland == expensive

AT THIS PLACE…..

Why with us?

HeiQ Viroblock

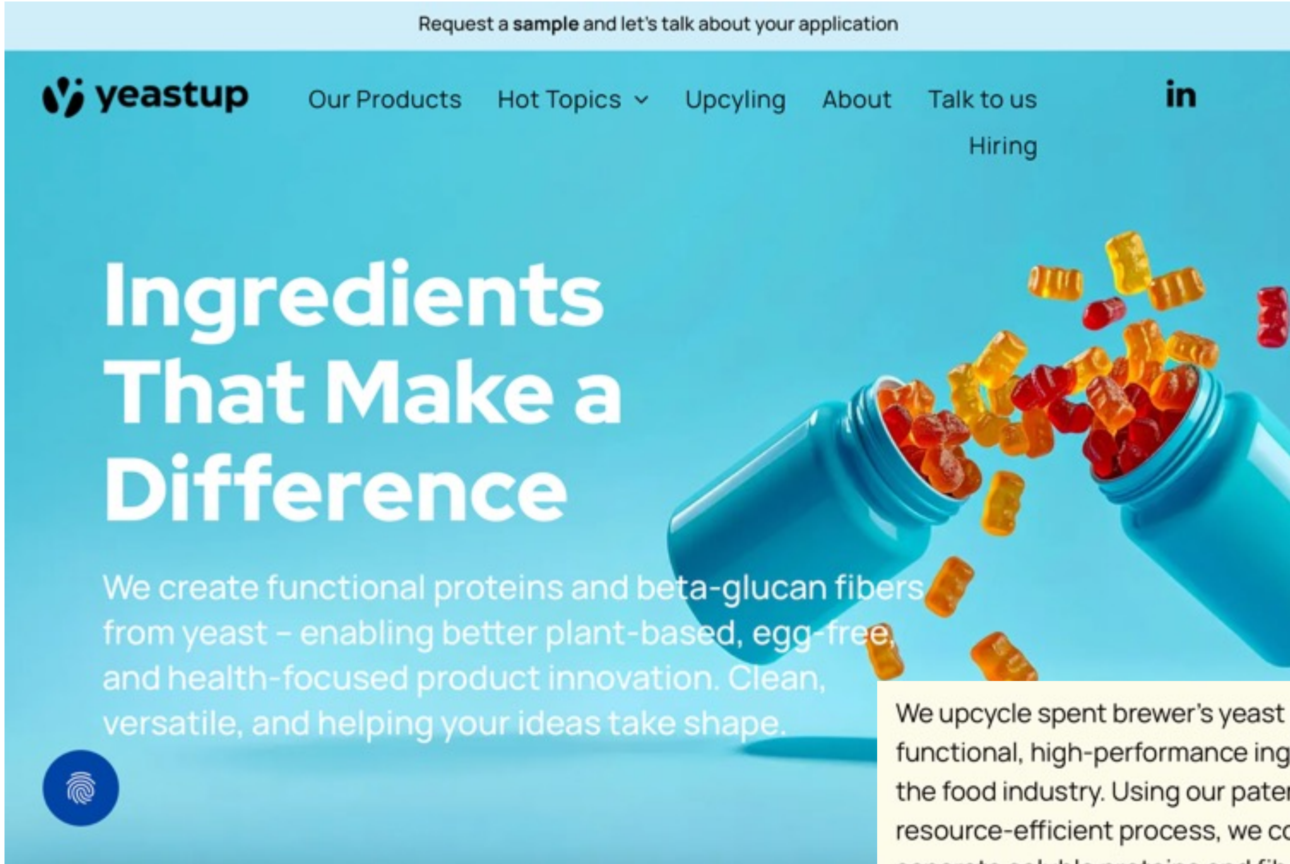


…During Easter 2020, around **5,000 kg of 'Viroblock'** chemicals for coronavirus protective masks were produced **in just 2 weeks**. To achieve this, the FHNW team transferred the HeiQ laboratory process to pilot scale, and **it still serves as the recipe for global production** today.

"Speed", "Costs"?!

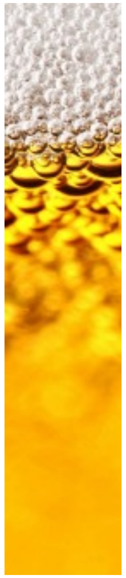
yeastup

- process development (including patent application)
- Technical support during scale-up and Pilot installation



We upcycle spent brewer's yeast into functional, high-performance ingredients for the food industry. Using our patented, resource-efficient process, we continuously separate soluble proteins and fibers from spent brewer's yeast – without harsh chemicals or unnecessary waste.

De-alcoholisation of Beer (and Wine) with ***membrane technology***



KLEINBRAUEREIEN

Basler Tüftler revolutionieren den Markt - mit einer Anlage für alkoholfreies Bier

von Samuel Hufschmid — bz Basel • 22.3.2016 um 07:41 Uhr

Professor Wolfgang Riedi präsentiert den Prototyp einer Entalkoholisierungsanlage für Kleinbrauer.

BrauBeviale,
D-Nürnberg, 2011

- ➢ Development of an easy-to-operate stand-alone Membrane skid for the de-alcoholisation with Nanofiltration
- ➢ Now more then 5 references in Switzerland, Germany, Austria and abroad

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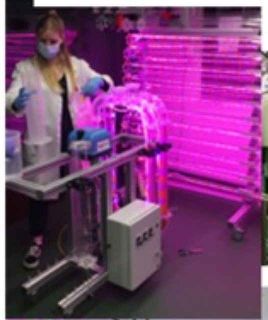
ADALBERT RAPS STIFTUNG

Algae reactor with membrane contactor	Solid/liquid separation	Extraction	Drying







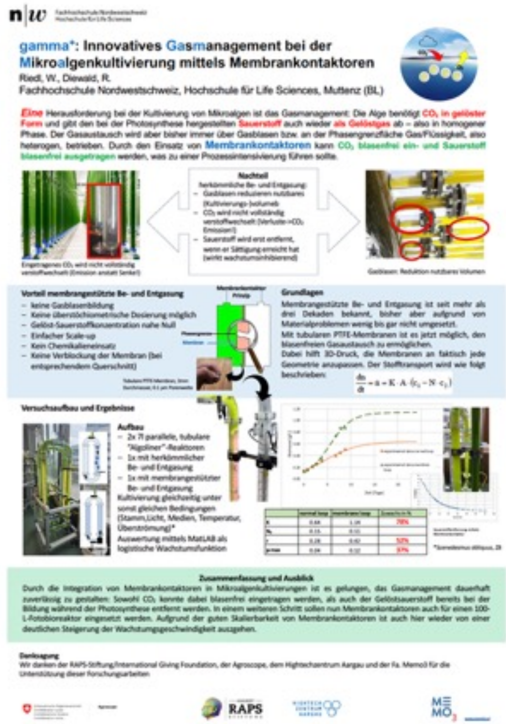




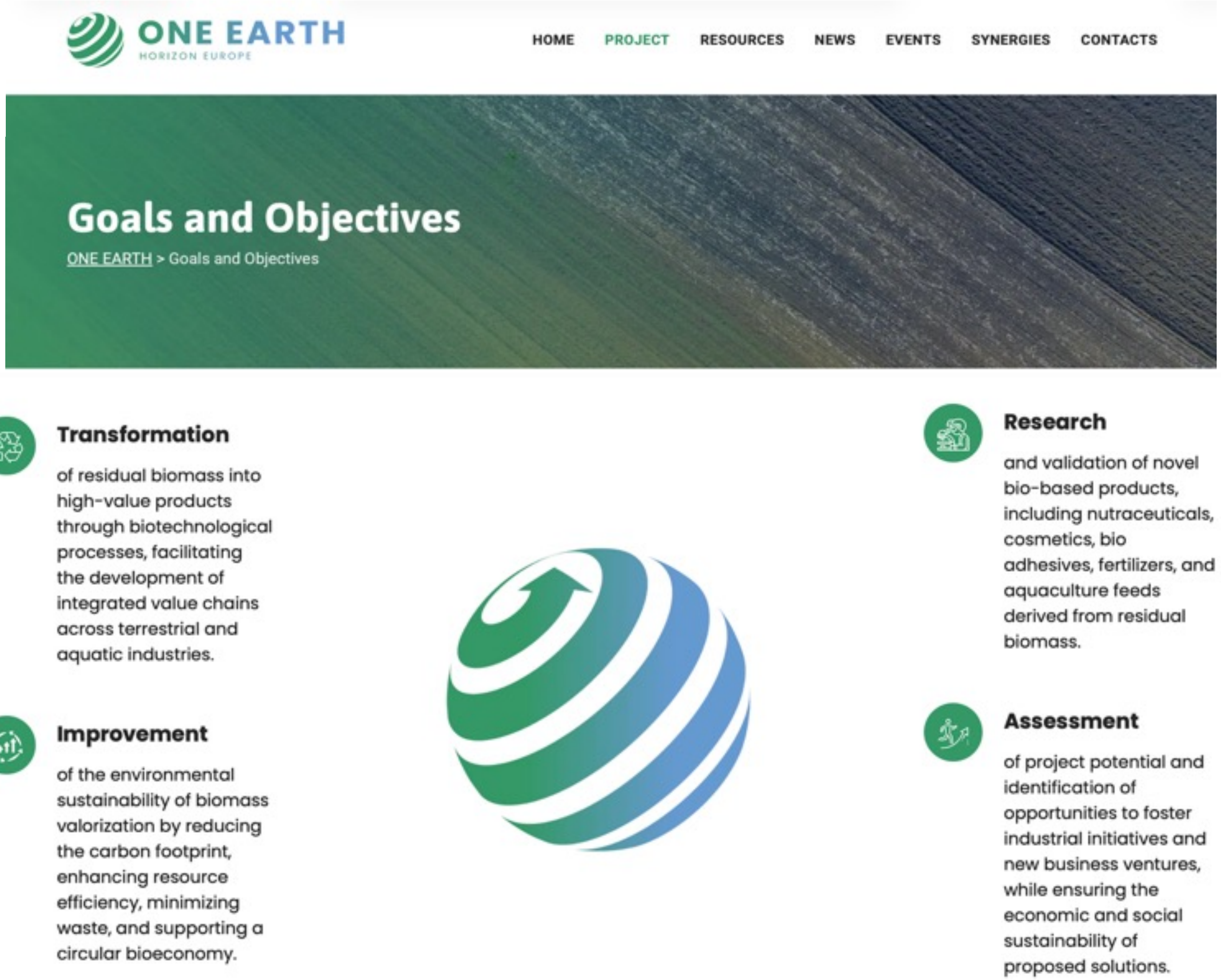


DSP Equipment: see our webpage
(FHNW Process Technology Center-PTC: https://www.fhnw.ch/de/die-fhnw/hochschulen/lifesciences/process-technology-center-ptc

Fachhochschule Nordwestschweiz
Hochschule für Life Sciences



gerne!


ONE EARTH
HORIZON EUROPE

HOME PROJECT RESOURCES NEWS EVENTS SYNERGIES CONTACTS

Goals and Objectives

ONE EARTH > Goals and Objectives

Transformation

of residual biomass into high-value products through biotechnological processes, facilitating the development of integrated value chains across terrestrial and aquatic industries.

Improvement

of the environmental sustainability of biomass valorization by reducing the carbon footprint, enhancing resource efficiency, minimizing waste, and supporting a circular bioeconomy.

Research

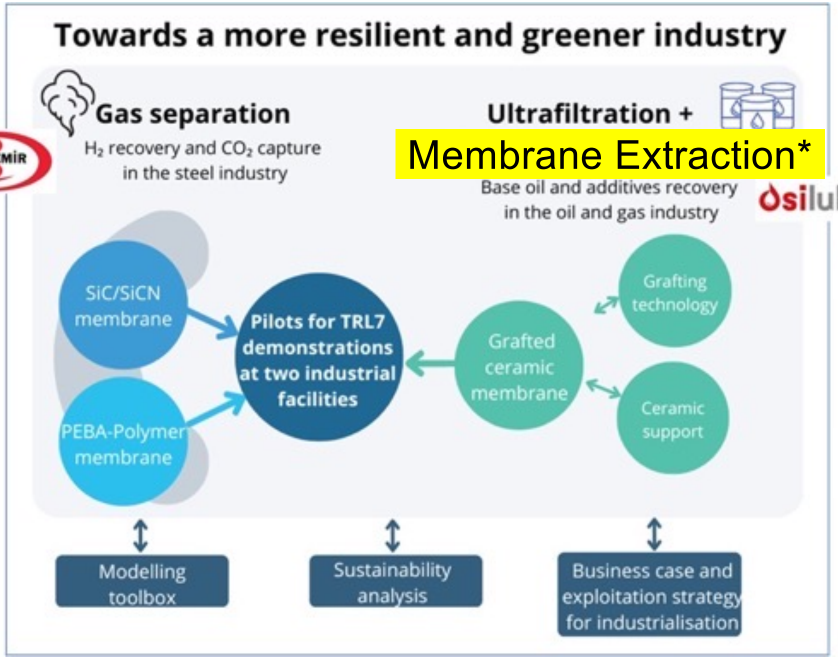
and validation of novel bio-based products, including nutraceuticals, cosmetics, bio adhesives, fertilizers, and aquaculture feeds derived from residual biomass.

Assessment

of project potential and identification of opportunities to foster industrial initiatives and new business ventures, while ensuring the economic and social sustainability of proposed solutions.

Funded by the European Union

This project has received funding from the European Union's HORIZON EUROPE research and innovation programme, under grant agreement No. 101135559.

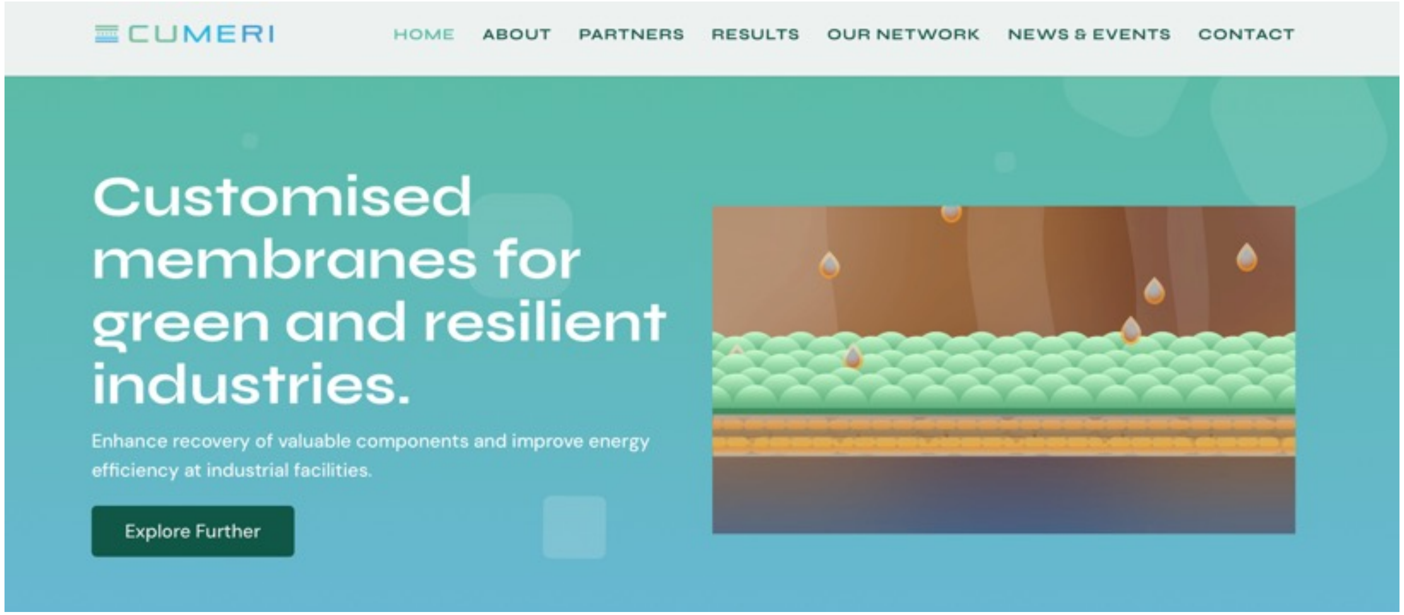


vito
Fraunhofer IKTS
Rauschert
a-membranes
Fachhochschule Nordwestschweiz
osilub

*UF + ME shall replace 2 distillation steps (at 260°C and 360°C)

CUMERI

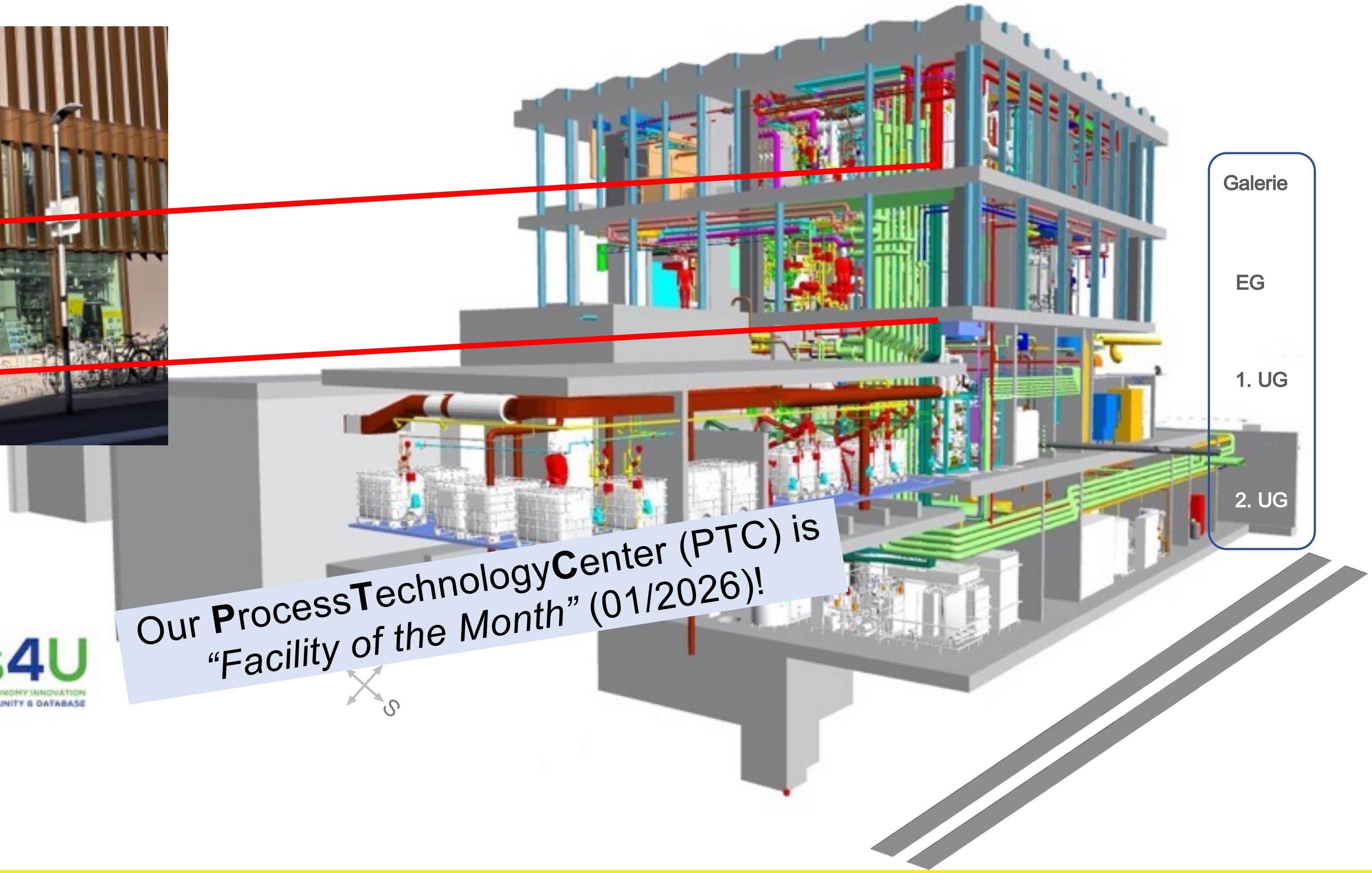
This project has received funding from the European Union's Horizon Europe Research and Innovation programme under Grant Agreement No. 101091812.



https://cumeri.eu

This project has received funding from the European Union's Horizon Europe Research and Innovation programme under Grant Agreement No. 101091812. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Health and Digital Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

Process **T**echnology **C**enter



Our **P**rocess**T**echnology**C**enter (PTC) is *“Facility of the Month”* (01/2026)!

Pilots4U

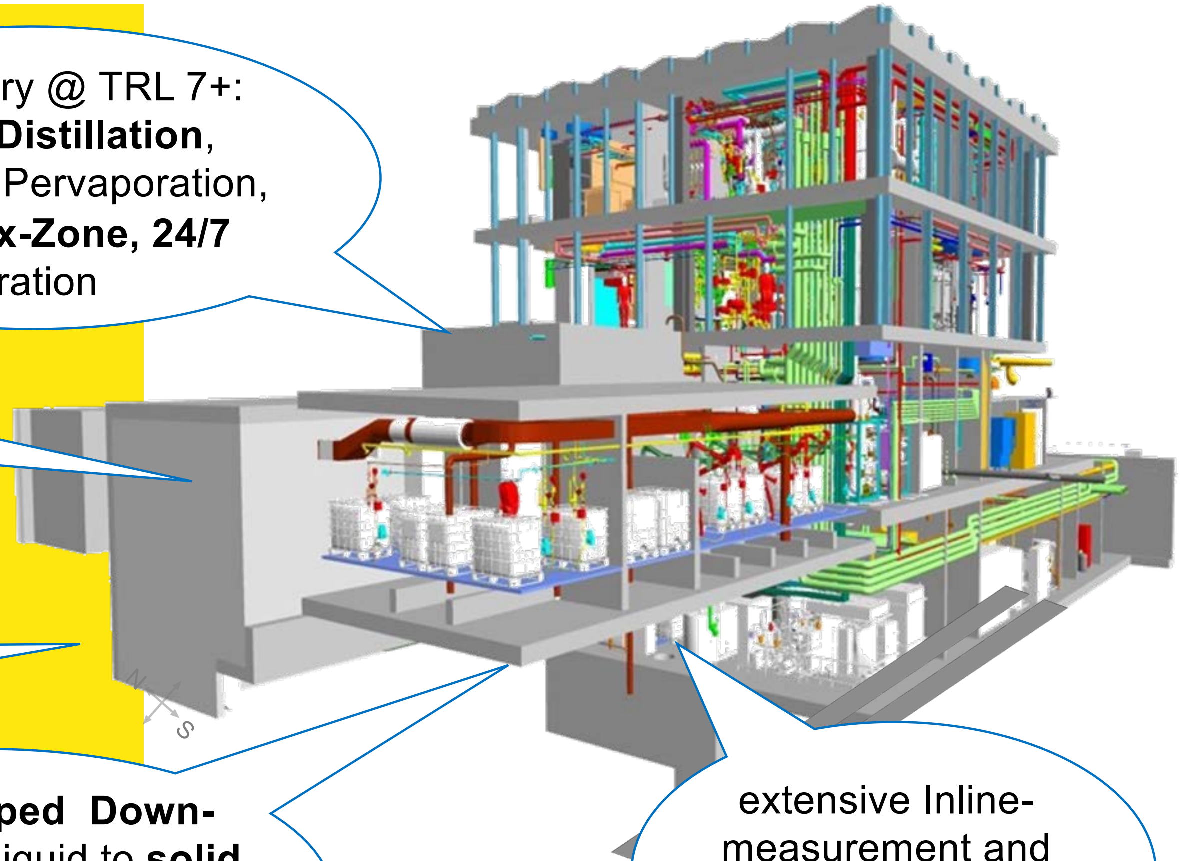
Hands-on education and process development @ our Process Technology Center (PTC)

1100 m^2 @ 16 rooms, 4 floors

(Bio-)Refinery @ TRL 7+: Reaction, **Distillation**, Rectification, Pervaporation, Drying in **Ex-Zone, 24/7** operation

Reaction Technology (**100 l**), Scale-up and scale-down reactors, **flow chemistry**
Reaction safety (Ex-Zone)

Natural Products / **Green Chemistry Lab** incl. 100 l **Microalgae reactor**, Solid-liquid extraction, Drying and final fill



Fully equipped Down-Stream from liquid to **solid products (10 kg)** for Biotech, Green Chemistry and Natural Products

extensive Inline-measurement and Process control (Siemens PCS neo)

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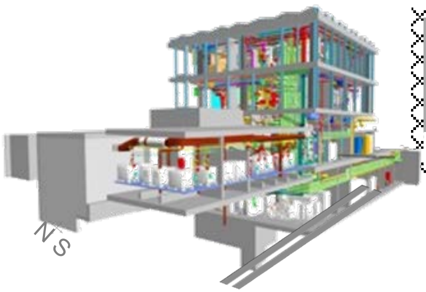
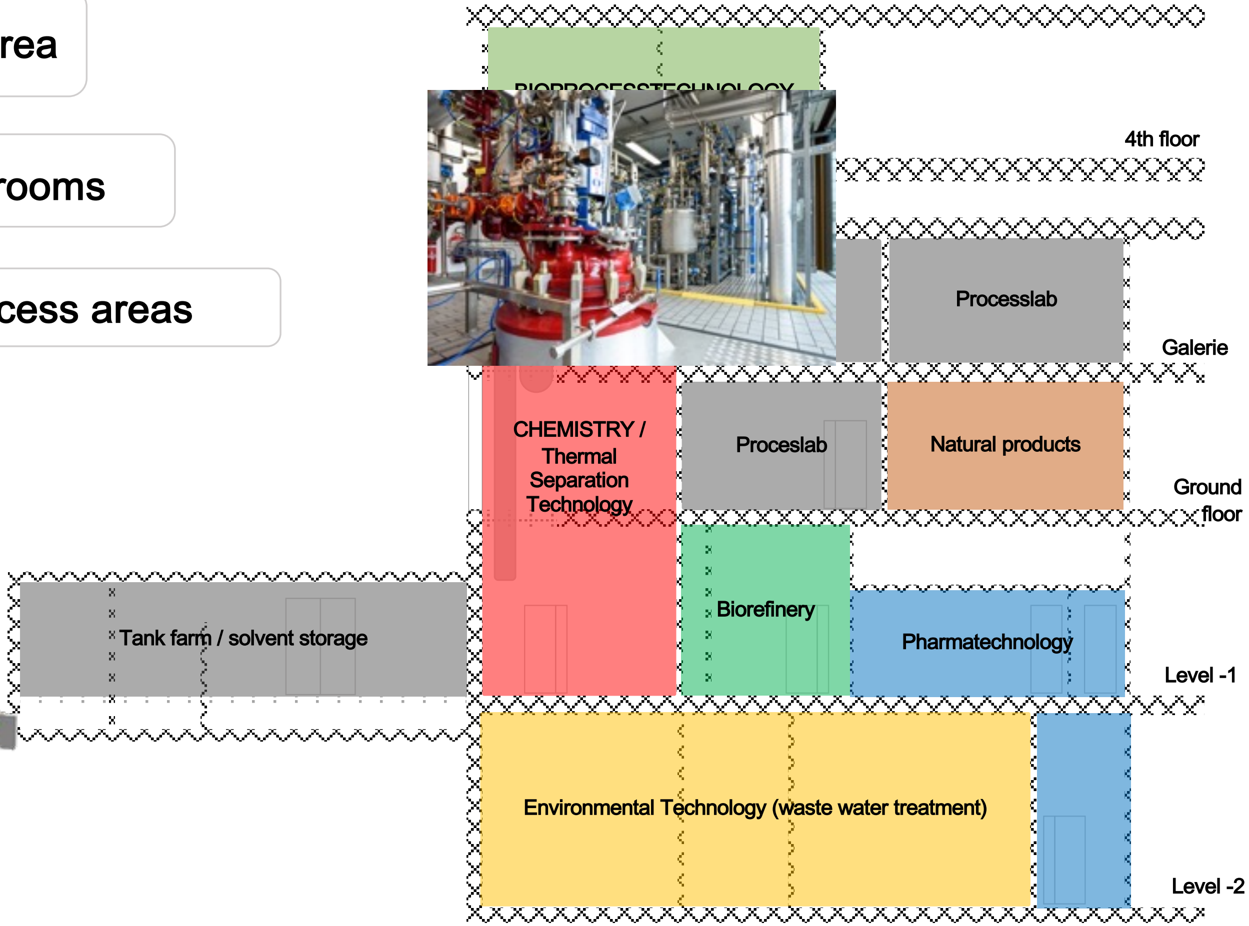
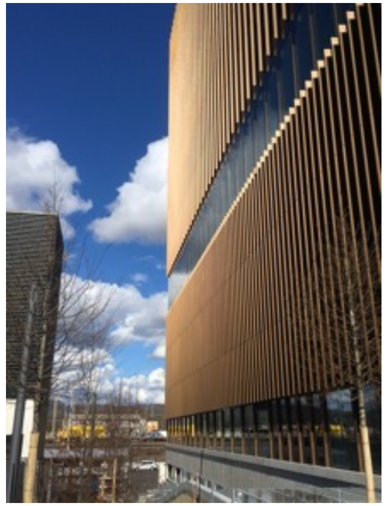
1’100 m^2 process area

16 process rooms

6 process areas







How to explain scale-up best?

1:1

1:87

…coming soon to the "Miniatur Wunderland" in Hamburg! (world largest indoor model train world)

Impressions from Students education

How we do projects

- **Direct financed aR&D- or third party financed projects (Innosuisse, Horizon Europe/CBE JU, Foundations, starting from >1 kCH …. 1000 kCHF**
- **Services / contract research**

- Supported by or via Bachelor-, Master-, ph.D. thesis (ph.D. in cooperation with Universities)
- (only) during internship time (2x per year for 2 weeks), reduced priority for projects
- Start of projects normally very soon after signing a contract (aimed for 1-2 weeks)
- Governance: Not all kind of projects are accepted

- **Clear and transparent IP approach: What you bring in, belongs to you, what we developed together is shared IP (exploration via agreement/licences)**

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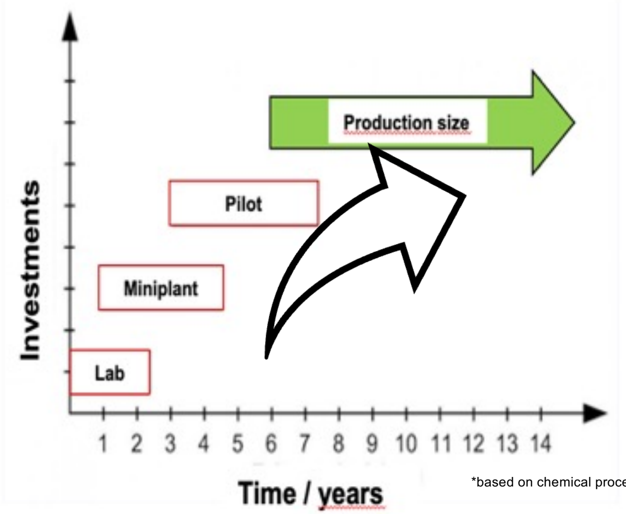
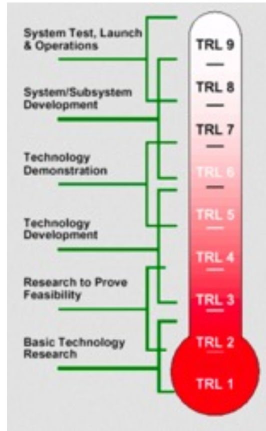
0.1 l labscale



*based on chemical process development

TRL = „technology readiness level“



100 l pilot/production scale

Are we courageous enough to skip steps?

Process transfer & scale-up

- The current challenges require fast action! (e.g. „climate neutrality before 2050“)
- Many (disruptive) processes are described in literature, however only a view are now in operation (or at least in „pilot phase“)


swissinfo.ch

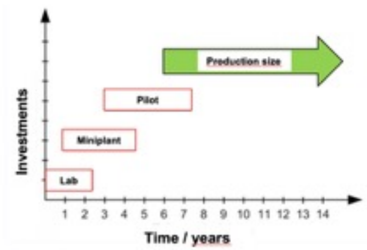
Using Swiss technology to store CO2 in Iceland

The Swiss company Climeworks has just opened in Iceland the world's largest plant for the capture and permanent storage of carbon dioxide from the air. This technology is deemed essential for combating global warming, yet it raises some questions.

September 10, 2021 · 09:00

From business point of view (only):

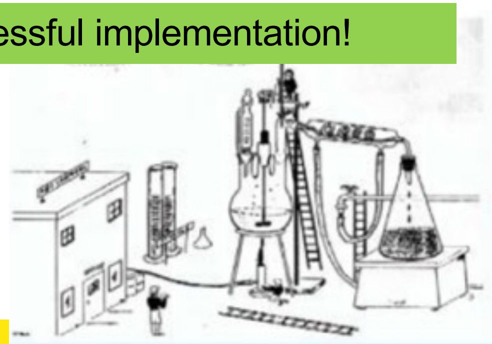
Disruptive/innovative ideas (processes) needs to be „transferred“ into (large-scale) production in very short time („time-to-market“!)



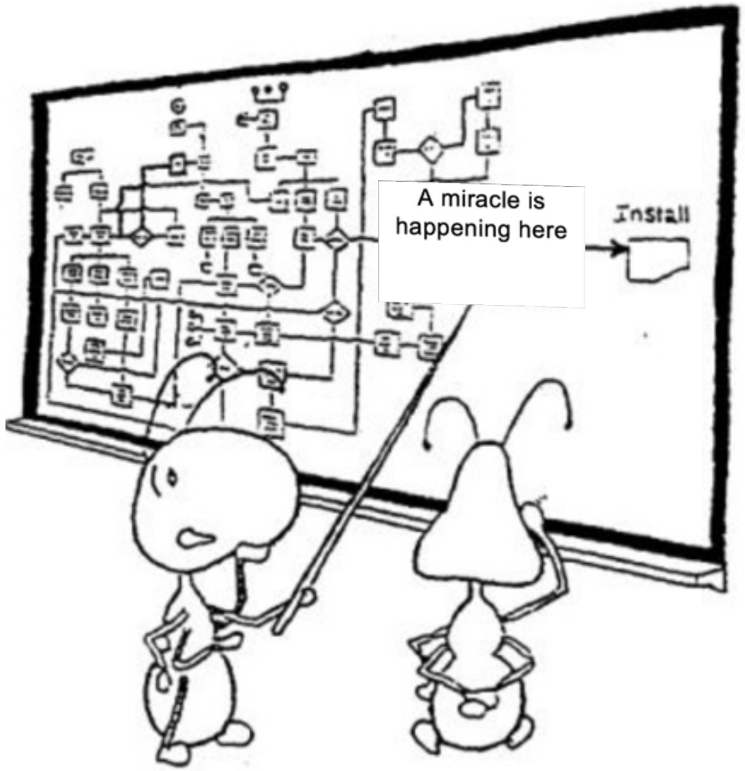
*based on chemical process development

„Process understanding“ is the key for successful implementation!

However: From Research to production (scale) there are a lot of Pitfalls!
(is there really a “technology readiness“?/ Do we have a robust process idea?)



Challenges and pitfalls at scale-up: Focus on the “right” things…



versus

(Bio-)Process
Development - and Scale-up Challenges

Engineering Skills
(GEP)

Even if this warlike image is perhaps not ideal in these times, it does impressively demonstrate how important it is to involve engineering early on in projects.
If you nevertheless take offence at this example, **we apologise.**

The outside-view on engineers….

Common understanding of an engineer…

Engineers are Scientists, too!

They might not be experts in Biotech, Chemistry or Pharmaceutics, but:

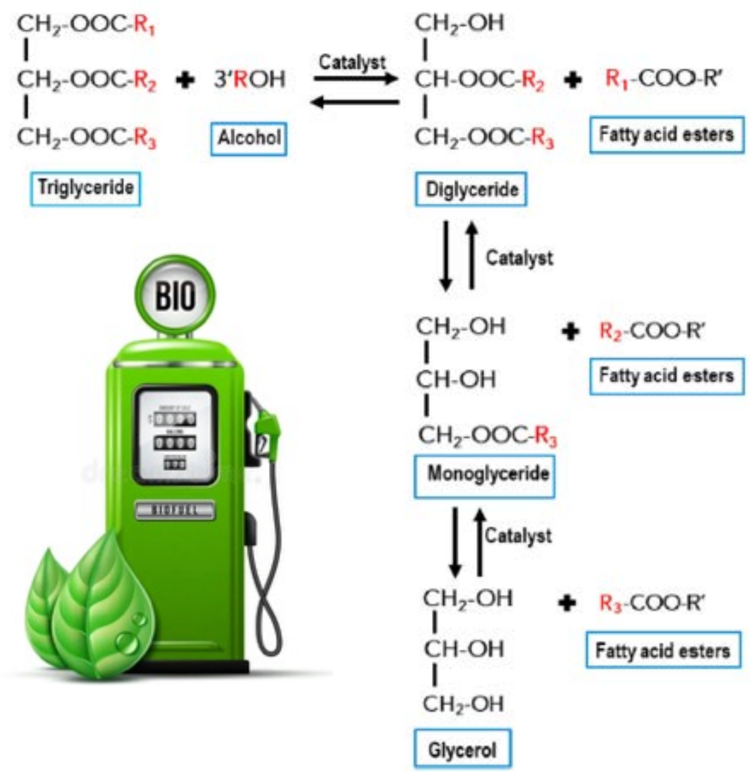
Engineers look for the levers that can improve the process best – and then offer a technical solution that can be used to apply these levers in a reliable manner

The key to successful process development / improvement and scale-up is:

**Process understanding!
What does the process really need?**

Biodiesel – a renewable fuel and potential starting material for sustainable aviation fuel

Stoichiometry tells you:



However, Chemists apply the following ratio

Molar ratio oil / alcohol	Yield / %
1:40	94.5[3)]
1:40	0.6[4)]
1:40	94.1
1:20	87.7
1:10	89.7

Here`s why:

➢ **If you improve mixing, you`ll improve performance!**

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- Use of “Micromixers” (=Microreactors) help to intensify mixing and thus reduce the excess alcohol
- Same yield with 1:10 oil:alcohol ratio (Micromixer) instead of 1:40 (conventional mixing)
- **By focusing on the key challenges, (disruptive) process optimization takes place!**
- Scale-up in this case is a different story…

Reduction of excess alcohol during transesterification of various native oil sources

Prof. Dr.-Ing. W. Riedl; Dipl.-Ing. (FH) D. Mollet; F. Ippolito, BSc
School of Life Sciences, Institute for Chemistry and Bioanalytics
Gründenstrasse 40, CH-4132 Muttenz www.fhnw.ch/lifesciences

Abstract

The generation of fuels out of regenerative sources is one of the key technologies to overcome climate change and limited resources of crude oil. Such biofuels however have to fulfil the same strict quality standards as are valid for conventional fuels in order to guarantee a full compatibility with the state-of-the-art fuel engines. To achieve such qualities, a common (chemical) process technology as transesterification can be applied. Due to the very poor miscibility of the native oils with the reactants, excess alcohol is required.
This poster shows how the use of micro mixing and –reaction technology leads to a better mixing of both the native oil and the alcohol and thus a considerable reduction of the excess alcohol (-80%) with comparable yield and quality.

Transesterification

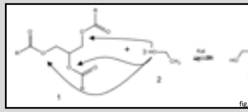


fig. 1: chemistry of transesterification

During the transesterification of native oils (1) (e.g. rapeseed or algae oil), glycerol esters will be split into crude glycerol (3) and fatty acid esters (4) which can be used as biofuels. Various catalysts and reaction conditions are described for the transesterification [1].
Most of the natural oils are immiscible with lower alcohols (e.g. methanol / ethanol). Thus, excess alcohol is required for starting a reaction between oil and the reactants (up to 15 times molar excess alcohol for 1 mol of

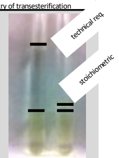


fig. 2: Required volume of alcohol for stoichiometric as well as technical trans-esterifcation

Micromixing and –reaction technology

Microreaction technology can be used for extensive mixing and reaction purposes in µ-liter scale. Due to the very small equipment dimensions only a small amount of product will be generated. Thus, even very exothermal processes can be tested. In addition, macroscopic effects (turbulence etc.) can be avoided allowing to study intensively the microscopic mass- and heat transfer effects.

used micromixers and –reactors:
T-mixer, LTF-mixer, ICIQ mixer, Ehrfeld-mixer, micro stirrer

fig. 3: test set-up for transesterification of several native oils using microreactors

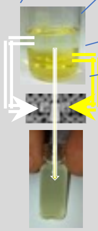
test set-up:
Using syringe or gearpumps different native oils will be contacted with different alcohols by using micro-reactors followed by a reaction tube (up to 25 m length). At the end of the pipe, samples were taken to determine both quality and yield.

Results and discussion

applied parameters[1]:

alcohols	Methanol, Ethanol
catalysts	H_2SO_4, TBD[2], KOH
Flow rate ratio oil/alcohol	0.5…6
Molare ratio oil/alcohol	1/3….1/40

1) based on rapeseed oil, 65°C reaction temperature, 60 minutes residence time
2) TBD: 1,5,7-triazabicyclo[4.4.0]dec-5-ene



- different types of microreactors were tested
- high throughput does not necessarily lead to better mixing / higher yield (depending of typ of microreactor)
- Mixtures are stable for 5-7 minutes, afterwards, repeated mixing is required to maintain good mixtures
- **Mixtures can be formed with considerable reduced molare ratios**

Molar ratio oil / alcohol	Yield / %
1:40	**94.5[3)]**
1:40	**0.6[4)]**
1:40	**94.1**
1:20	**87.7**
1:10	**89.7**

tab.1:
Comparison of biodiesel yield at different molar ratios
(TBD 1mol%, Methanol, temperature 65°C, Ehrfeldmixer)

3) from literature [1], confirmed by own trials / with methanol
4) with ethanol

Results:
Compared to results described in literature the continuous micromixing and –reaction leads to comparable yield but requires considerable lower oil/alcohol ratios of about 1:10 (lit.:1:40).
Poor yield with „green" ethanol, described in literature, were found in microreaction tests, too [3].
Unfortunately a expected further reduction of reaction time for the continuous microreaction compared to conventional lab scale reaction could not be found unfortunately.

Conclusions / Outlook

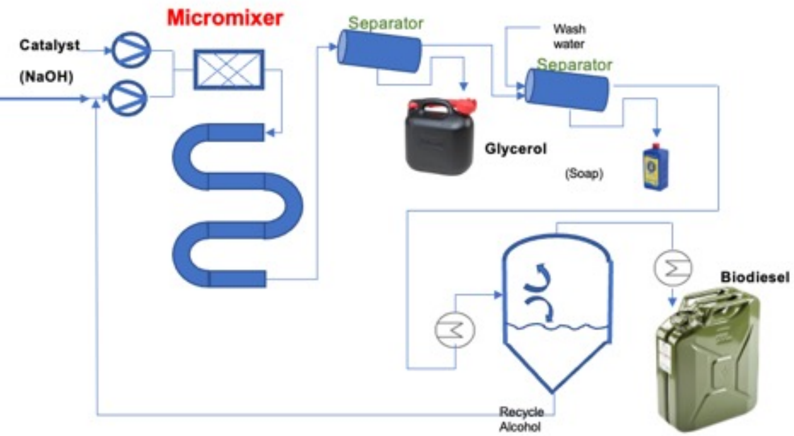
It could be shown that the use of microreactors for the transesterification of native oils help to overcome the problem of the poor miscibility of both the native oil and the reactant alcohols. Thus, the excess alcohol used in conventional transesterification for a better miscibility can be reduced in a considerable amount (up to -80%).
With a running actual project the scale-up ability of the microreaction process as well as alternative mixing and reaction technologies for pilot scale will be investigated.

[1] **A. Demirbras**: Progress and recent trends in biodiesel fuels; Energy Conversion and Management 50, 2009
[2] **U. Schuchardt**: Transesterification of vegetable oils: a review; J Brazil Chem Soc, 1998
[3] **D. Henke, J. Hagen**: Katalysatorscreening bei der Umesterung von Fetten und Ölen mit Ethanol, Chemie Ingenieur Technik, 81 (9), 2009

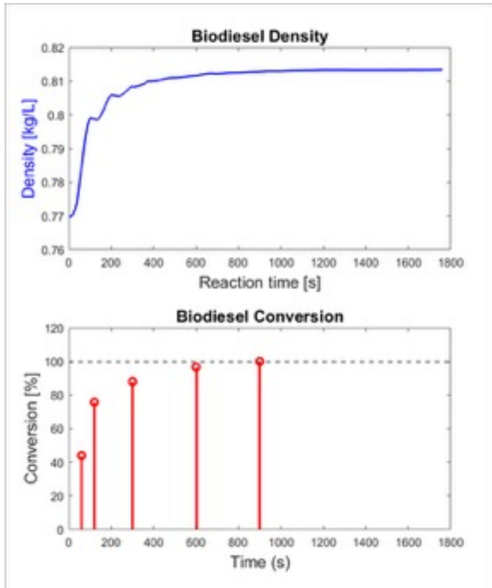
Oil/Alcohol don`t mix!

Excess Alcohol is required or: different way of mixing!

Biodiesel-Production via Transesterification in Microreactor



Endress+Hauser



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Energie

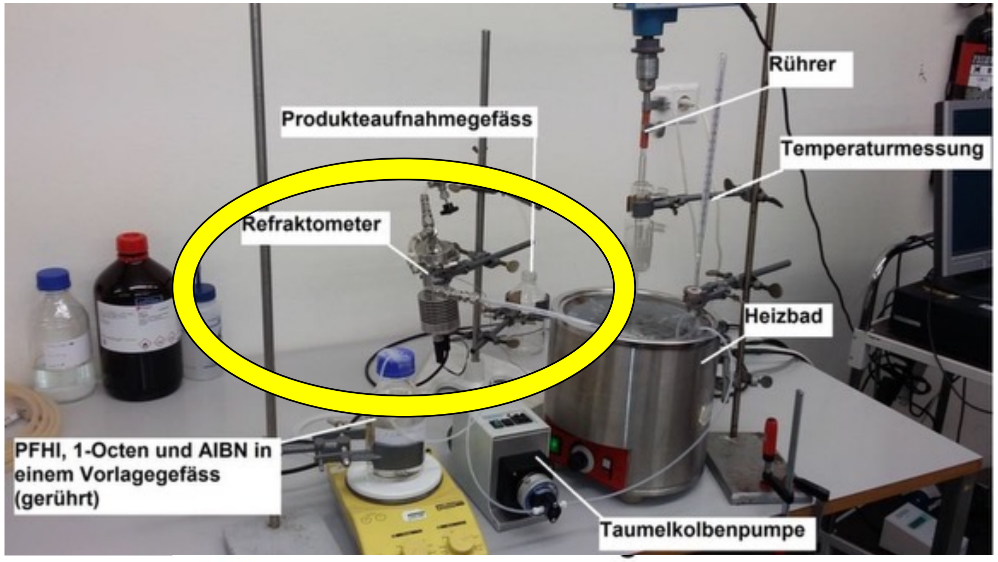
Forschungsstelle	BFE (Bioenergie, F+E)
Projektnummer	SI/502131
Projekttitel	Dezentrale Herstellung von grünem Treibstoff aus Überschussalgenöl

Grunddaten | Texte | Beteiligte | Kategorien

Projektstatus	Abgeschlossen
Startdatum	02.11.2020
Endedatum	30.09.2023
Gesamtkosten bewilligt	141'300.00 CHF
Bereich	Bioenergie
Forschungsart	Angewandte Forschung und Entwicklung
NABS-Klassifikation	Erzeugung, Verteilung und rationelle Nutzung der Energie

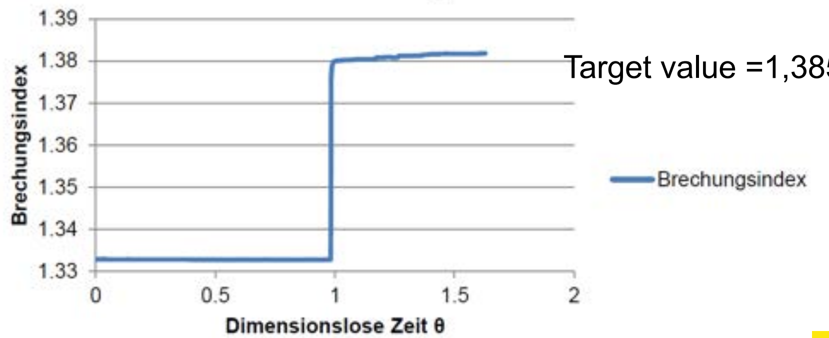
- In-Process Control and Product Quality Measurement via **Density** (Coriolis-Flow-Meter)
- Reduction of reaction time **from 60 min (batch) to 5-15 min (cont.)**

Another way of Inprocess-Control: Refractometric Index



From batch to conti:

- ✓ Adjustable tube length (residence time!)
- ✓ Adjustable flux
- ✓ Adjustable Temperature
- ✓ Measure the refractometric index at the end of the reaction!



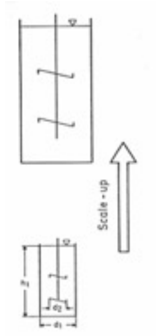
Target value =1,3850

Scale-up of Mixing / Homogenisation (following Penny`s rationals):

Assuming, that….

…Educts remain the same…

…Degree of mixing reamins the same



„production scale" =H

„lab scale" =Model = M
=geometric similarity

for (P/V)=const., then:

$$\frac{t_H}{t_M} = \left[\frac{d_{1,H}}{d_{1,M}}\right]^{2/3} = \left[\frac{V_H}{V_M}\right]^{2/9}$$

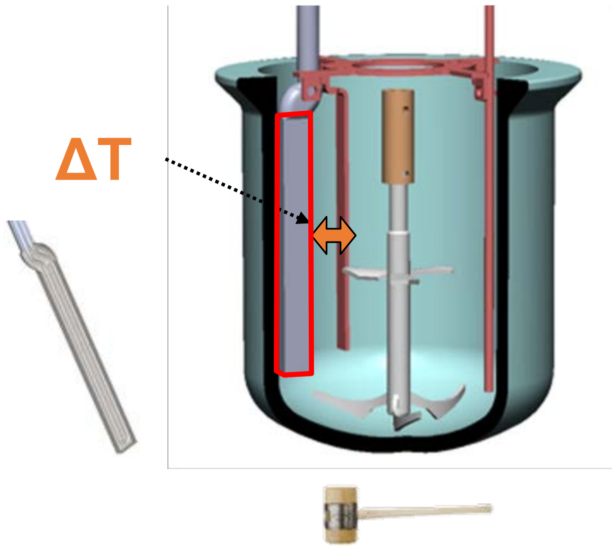
for t_{mix} = const., then:

$$\frac{P_{sp,H}}{P_{sp,M}} = \left[\frac{(P/V)_H}{(P/V)_M}\right] = \left[\frac{d_{1,H}}{d_{1,M}}\right]^2 = \left[\frac{V_H}{V_M}\right]^{2/3}$$

- A typical approach to calculate the expected time in scaling-up of processes and/or required power intake

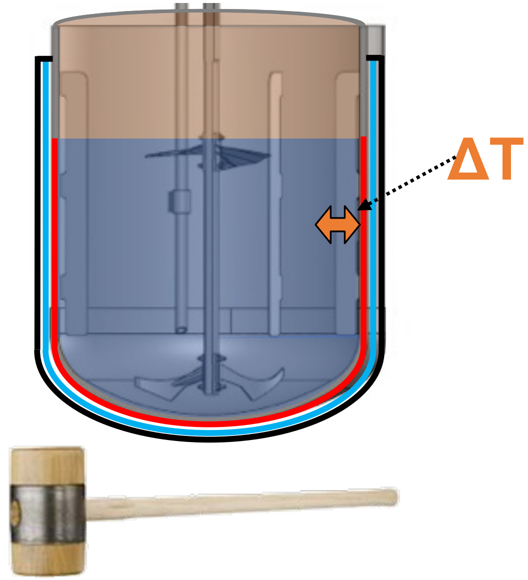
New approach for the scale-up of the heat transfer

Scale-Down-Reactor: 1 l
Heat exchange via H/C-Finger



Direct Scale-Up

Production: 4‘000 l
heat exchange via jacket



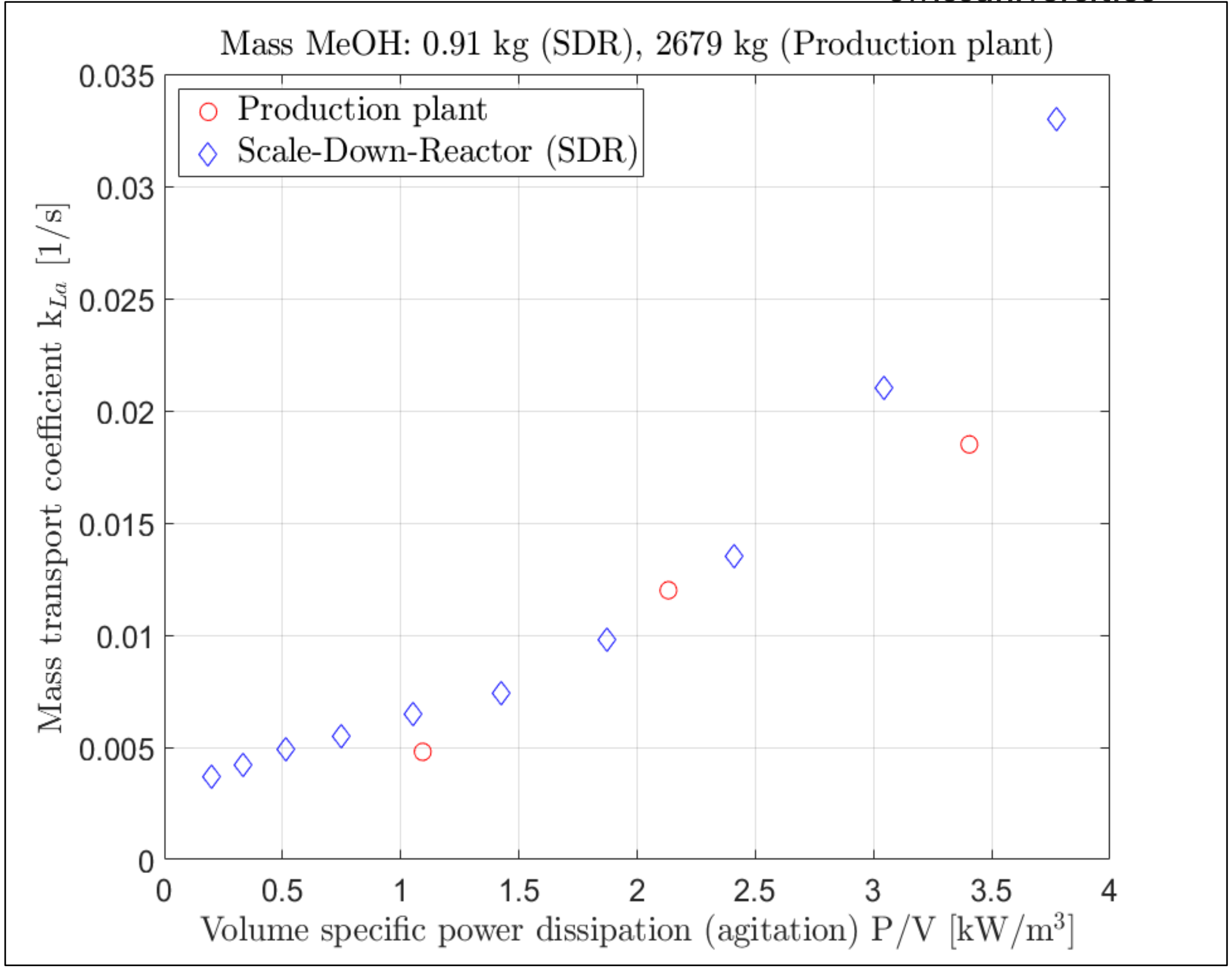
$\frac{Heat\ transfer\ area}{Volume}$: 2.8 m^2/m^3 — 2.8 m^2/m^3

ΔT : **12** K — **12** K

- Reduce “over-performance” in labscale equipment for better fit to large scale equipment

Scale-down experiments

Mass transport

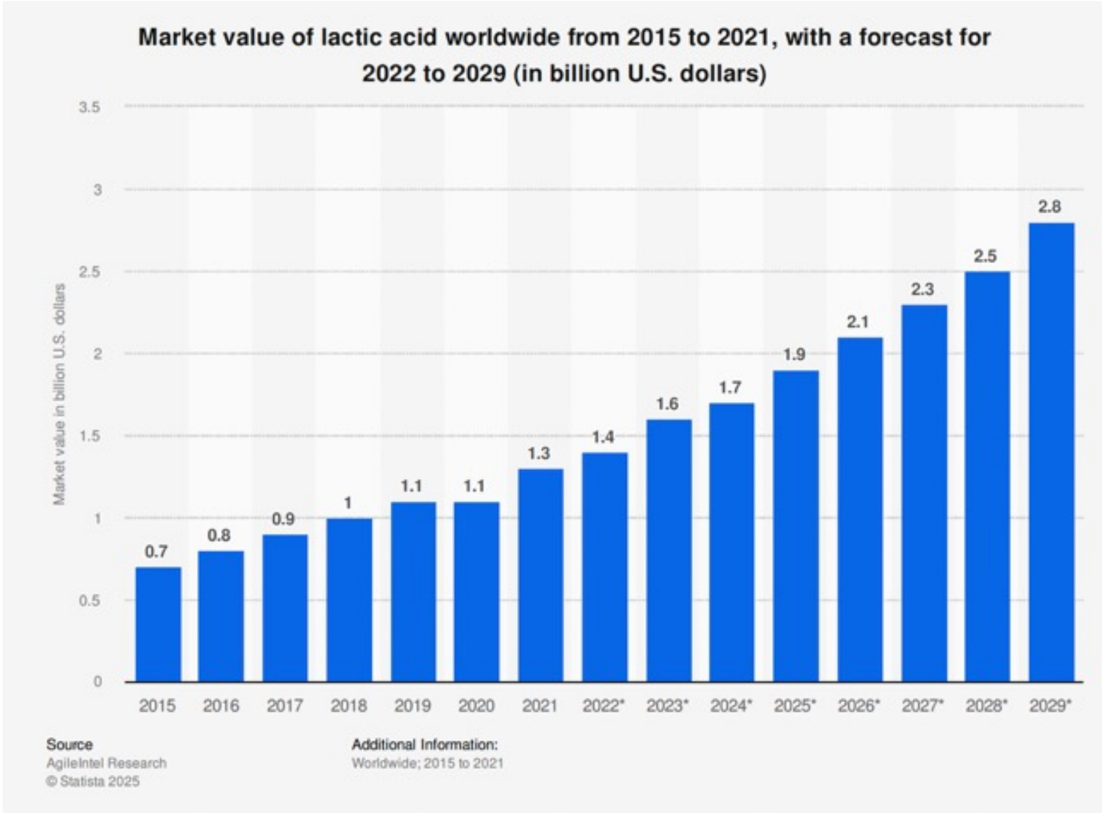


Scale-up in Green Chemistry and Biotechnology – (P)LA as example

Polylactic acid (PLA) is a **biodegradable**, thermoplastic polyester **derived from renewable resources** like corn starch or sugarcane. It is widely used in 3D printing, packaging, and medical applications due to its eco-friendly, biocompatible, and non-toxic properties.

Fun fact:

White beer provided in PLA plastic cups show a nice foam stability - from non-PLA plastic cups not!



LA production by fermentation

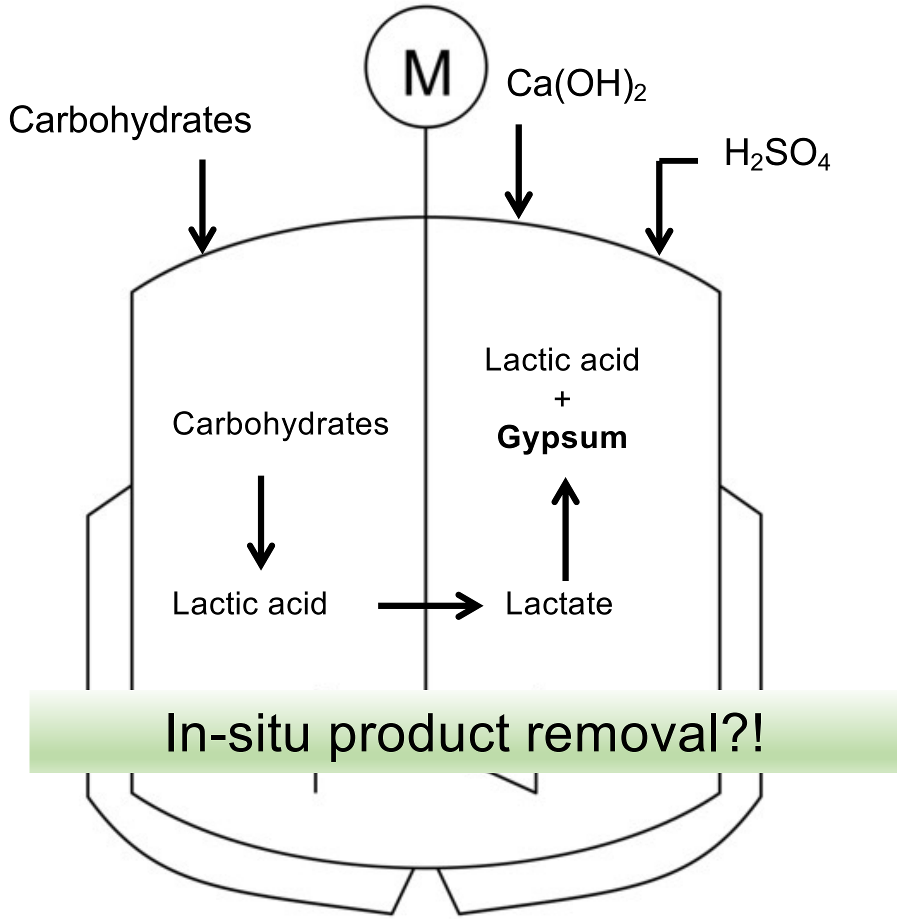
A variety of carboxylic acids are produced by fermentation [1]

Challenges:

- Product inhibition by pH decrease

  To avoid this: addition of chemicals:
  $Ca(OH)_2$ - Lactate precipitates
  H_2SO_4 - sets lactic acid free

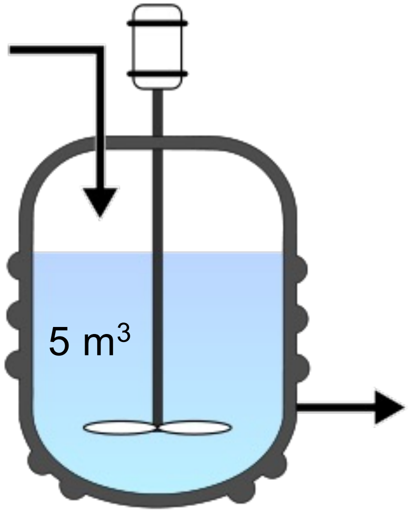
- Stoichiometric gypsum production!



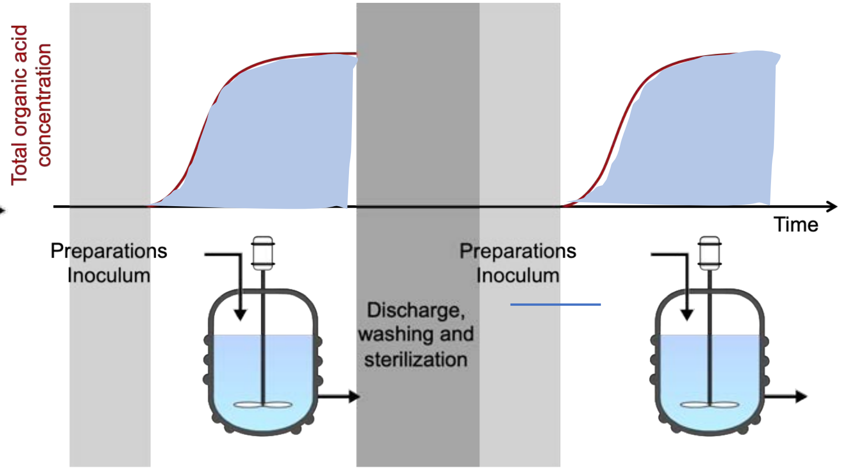
In-situ product removal?!

[1] H.-J. Endres, A. Siebert-Raths, Technische Biopolymere, Hanser-Verlag, München **2009**, 103

The beginning: A typical batch approach..



- 0.33 g/L/h
- 1650 g/h

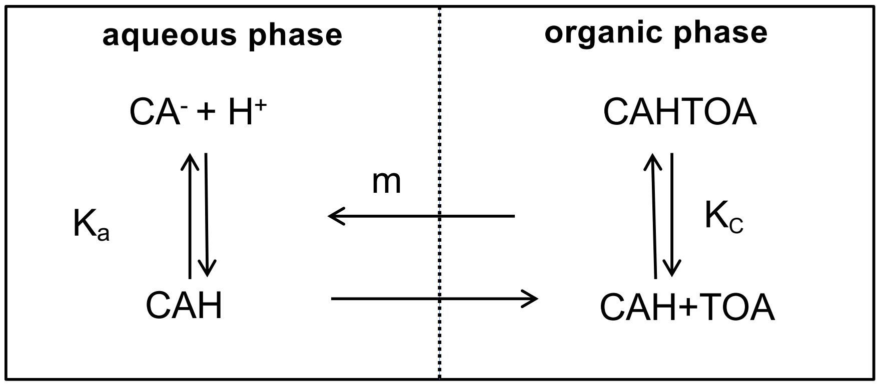


…with a clear and reproducible protocol – and “batch release” through (final) control (or inline with e.g. Raman…)

Direct capturing of LA from fermentation broth:

Techniques such as reactive distillation, stripping, adsorption and membrane-processes have been investigated to avoid continuous broth neutralization

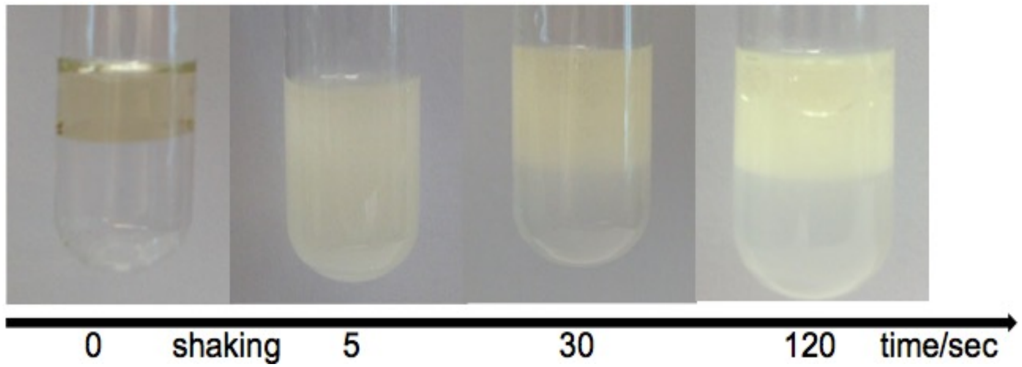
➡ **Reactive liquid-liquid extraction** has shown to be an interesting technology for (carboxylic) acid capturing



CA = deprotonated carboxylic acid
CAH = carboxylic acid
TOA** = tri-n-octylamine
m = distribution coefficient $= \frac{C^*_{LA,org}}{C^*_{LA,aq}}$

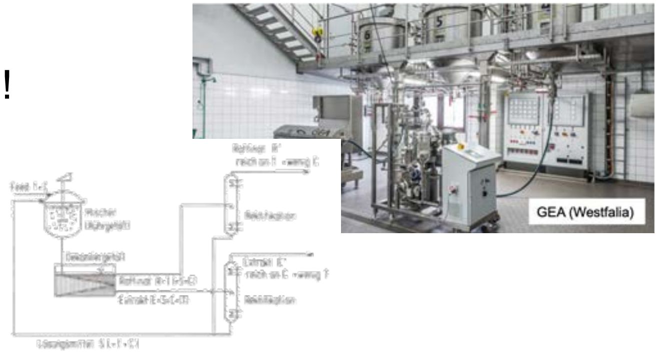
however….

Systems form stable Emulsions!



- Normally, this is the end of any further investigation in Liquid-Liquid Extraction!

  (since to "brake" stable emulsions, additional technologies and/or long(er) times are required for e.g. large settler devices, centrifugues, salt/chemicals and/or temperature (cooling)

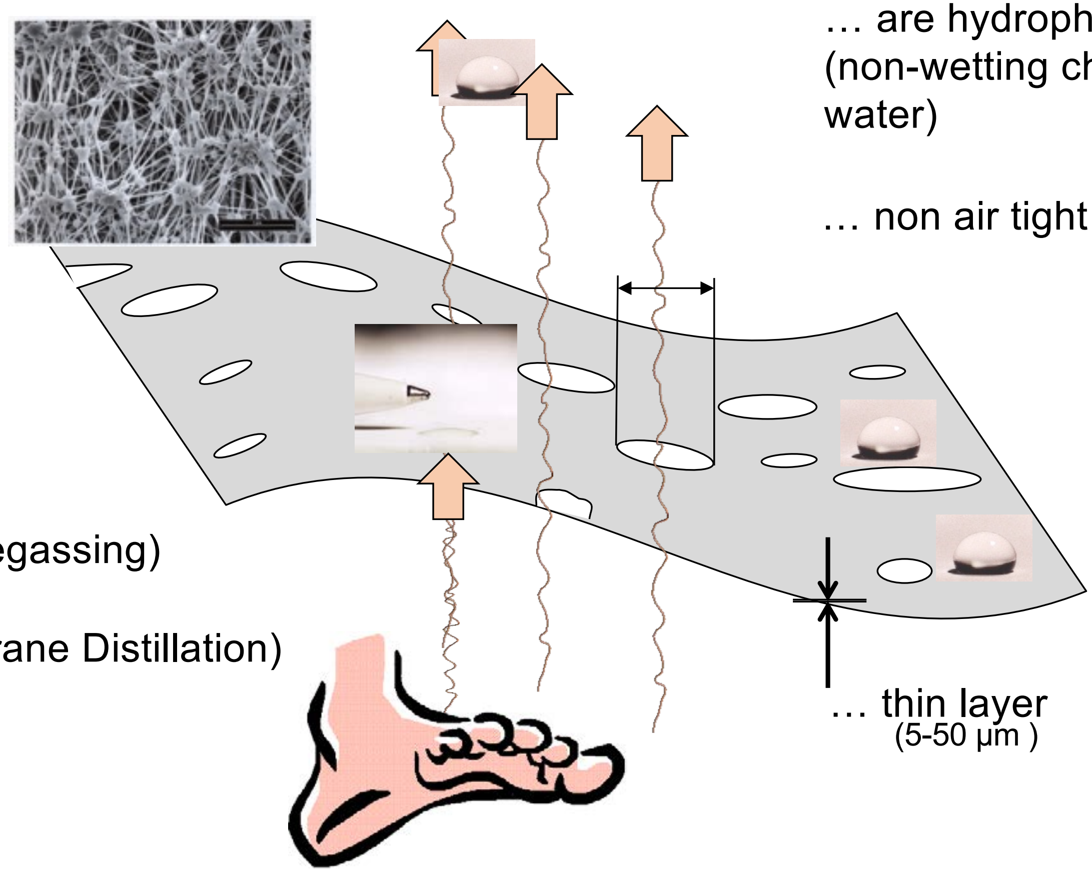


- No further process development nor scale-up activites!

  …although there is an effective separation technology available!

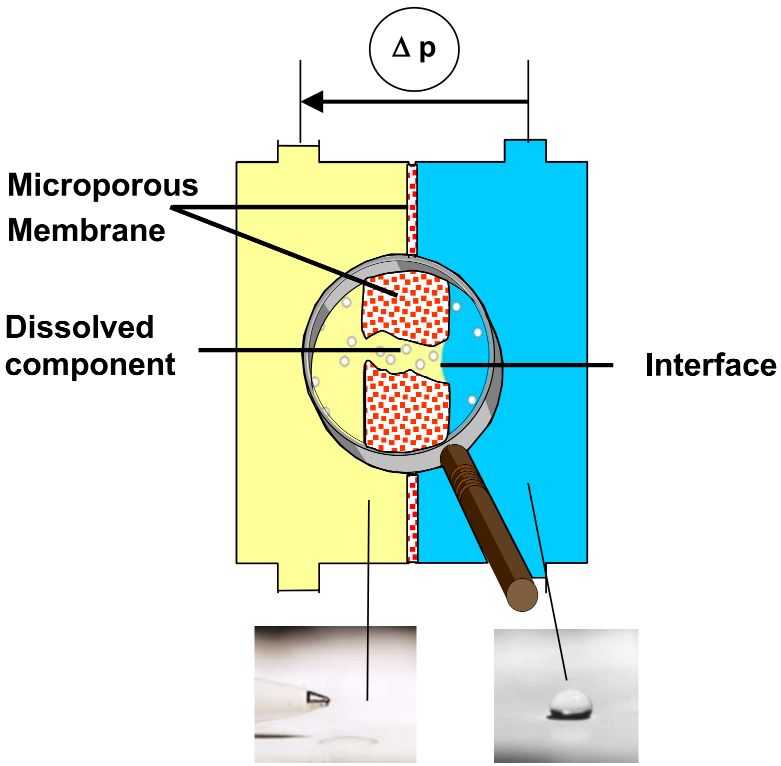
- **We (engineers) do have the simple and effective technology to continue!**

Microporous membranes for fluid-fluid contact



Suited for:
-gas/liquid (Aeration / Degassing)
-liquid/liquid (Extraction)
-liquid/gas/liquid (Membrane Distillation)

Membrane assisted fluid-fluid contact: Liquid-liquid Extraction



<u>Advantages:</u>

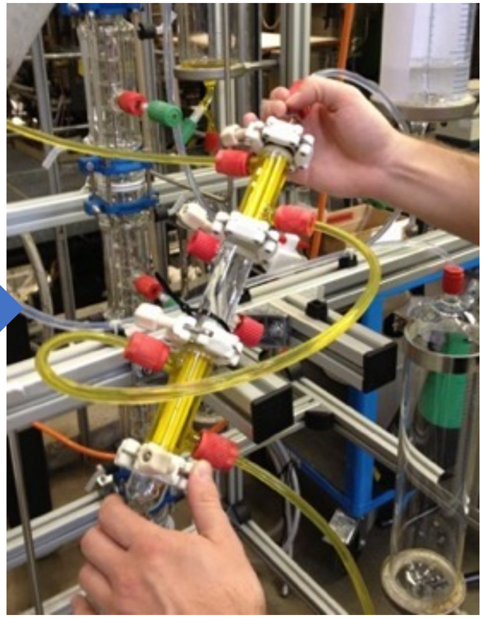
- no phase dispersion required
- no density difference required
- Phase ration can be choosen in a broad range (>> 1:100)
- **no emulsion formation**
- Operation irrespective of position
- Compact & modular design

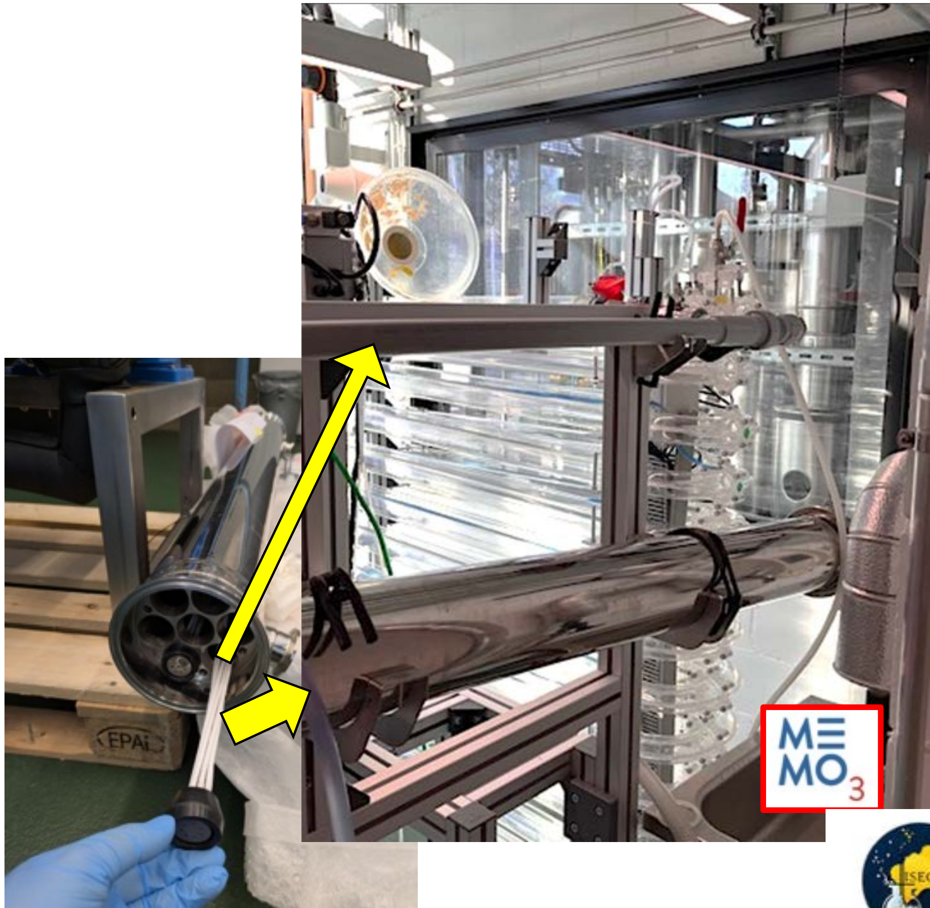
<u>Disadvanteges:</u>

- Additional mass transfer resistance
- ~~Limitations caused by membrane design and stability~~ no longer!!

From the Keynote at " ISEC " – international Solvent Extraction Conference / October 2025 / Melbourne

Membrane assisted fluid-fluid contact: Liquid-liquid Extraction





From the Keynote at " ISEC " – international Solvent Extraction Conference / October 2025 / Melbourne

Wiley Online Library

ChemBioEng Reviews

Membrane-Supported Liquid-Liquid Extraction – Where Do We Stand Today?

Wolfgang Riedl[1],*

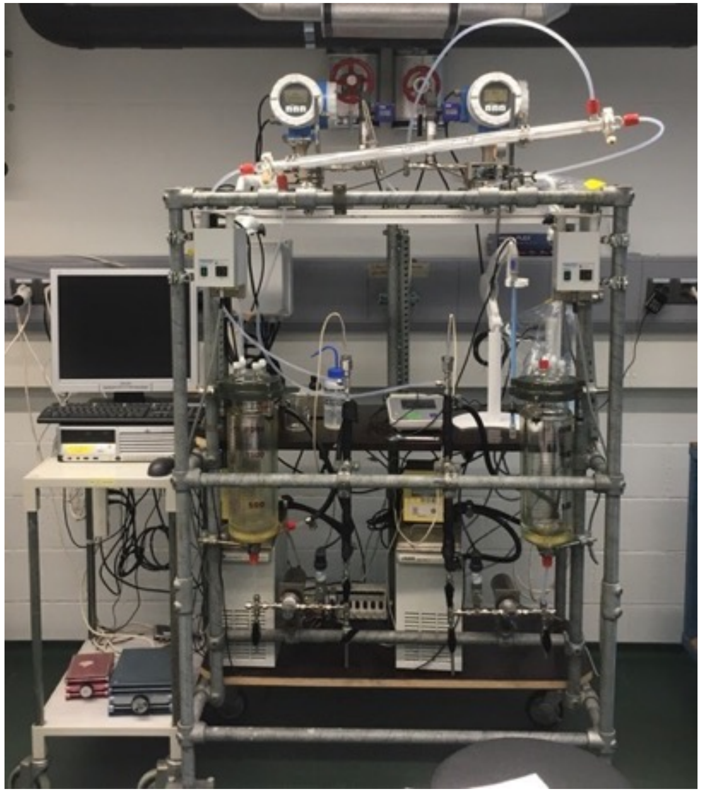
Abstract

Thanks to advances in materials science and manufacturing technology, membranes are now available for stable liquid-liquid extraction processes. Rigorous calculation models can be used to calculate the membrane areas required for a specific separation task as well as to optimize the module design. Rapid tests can determine the basic suitability and kinetic parameters. Thus, the general requirements for exploiting the specific advantages of this separation technology in technical applications are fulfilled.

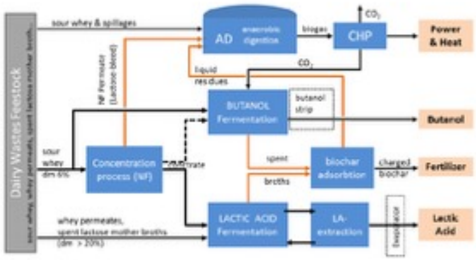
Keywords: Mass transfer model, Membrane-assisted liquid-liquid extraction, Membrane contactors

Received: October 25, 2020; *accepted:* January 13, 2021

DOI: 10.1002/cben.202000032

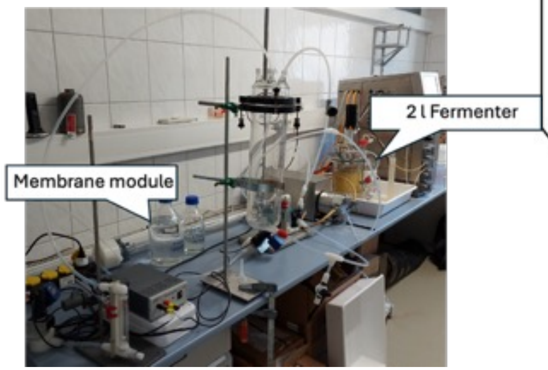


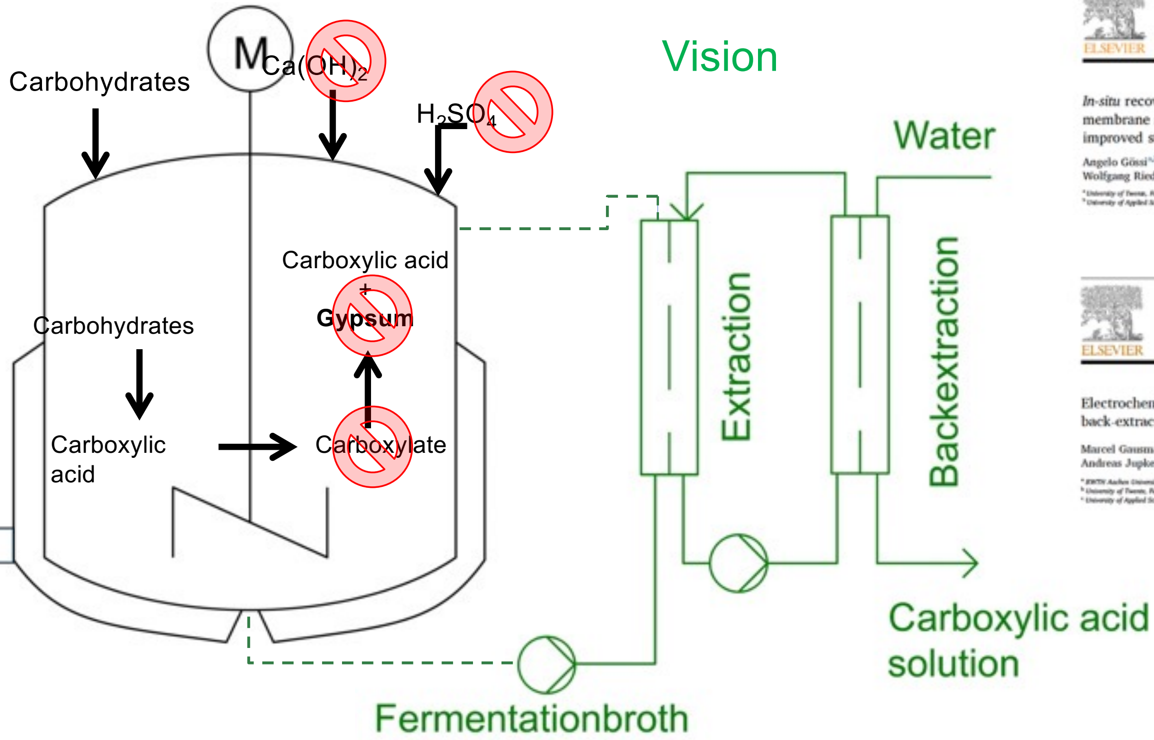
In-situ extraction of carboxylic acids



ERA-NET Bioenergy

European Commission






Separation and Purification Technology 241 (2020) 116694

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Separation and Purification Technology

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In-situ recovery of carboxylic acids from fermentation broths through membrane supported reactive extraction using membrane modules with improved stability

Angelo Gössi[a,b], Florian Burgener[b], David Kohler[b], Alessandro Urso[b], Boris A. Kolvenbach[b], Wolfgang Riedl[b], Boelo Schuur[a,*]


Contents lists available at ScienceDirect

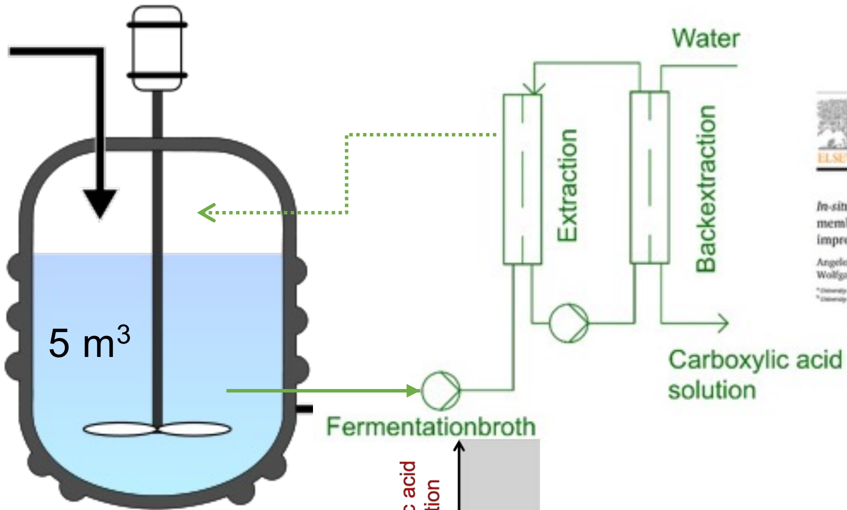
Separation and Purification Technology

journal homepage: www.elsevier.com/locate/seppur

Electrochemical membrane-assisted pH-swing extraction and back-extraction of lactic acid

Marcel Gausmann[a,1], Angelo Gössi[b,c,1], Franziska Bertram[a], Wolfgang Riedl[c], Boelo Schuur[b], Andreas Jupke[a,*]

From Batch to Conti: Adoption of the Measurement required?

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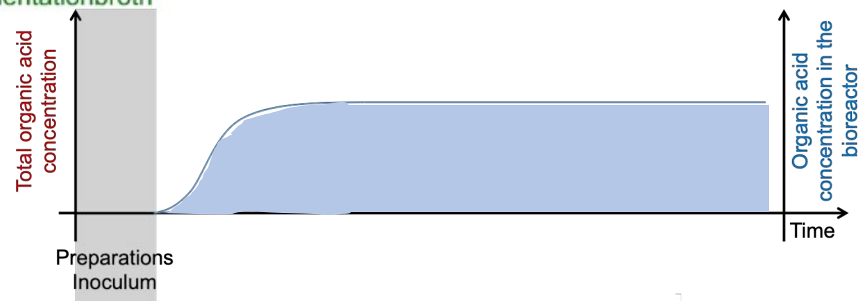
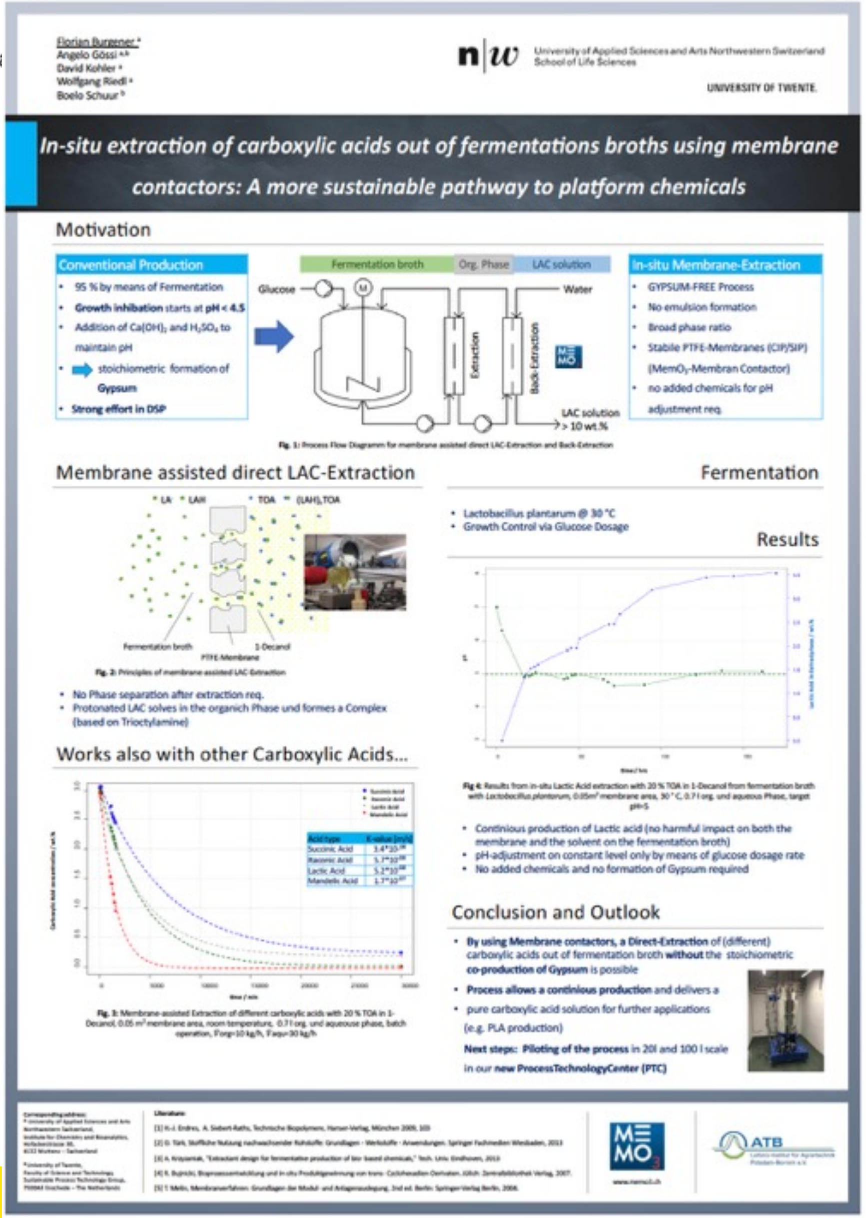
- 0.33 g/L/h
- 1650 g/h



- **Best Poster Award** @ Dechema Fachsektion Extraktion
  annual Meeting hold here in Muttenz,
  Feb. 2019

- **Also works for:**

- Succinic Acid
- Itaconic Acid
- Mandelic Acid and
- **Acetic Acid / Acetate**
  -> THE most interesting feedstock for Fermentations generating high value end products



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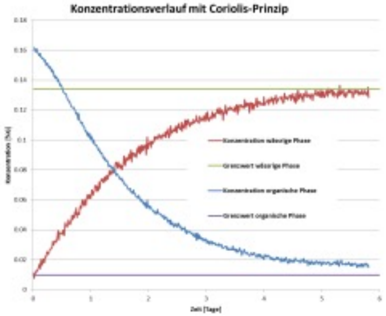
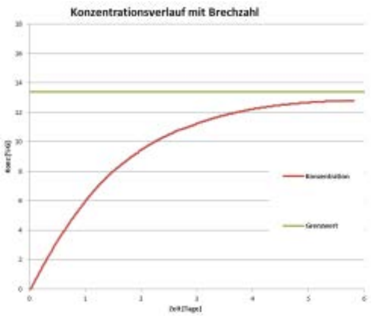
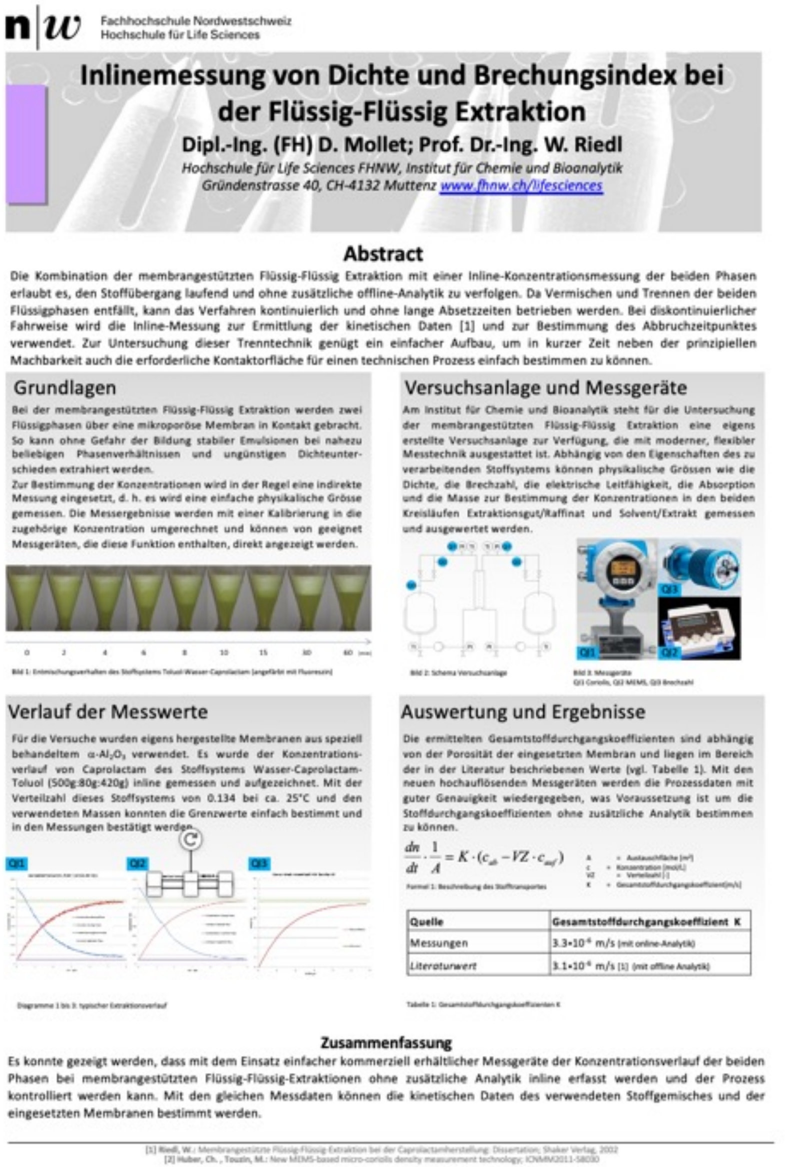
School of Life Sciences

Scale-up requires in-process control!







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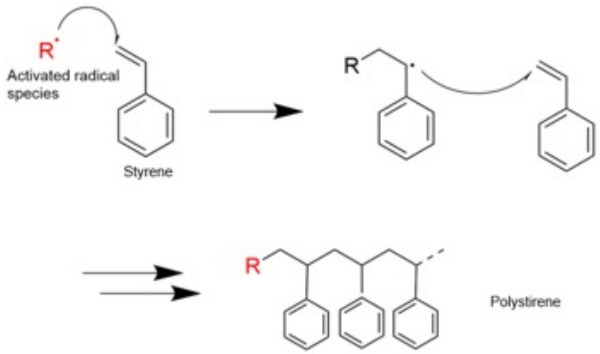

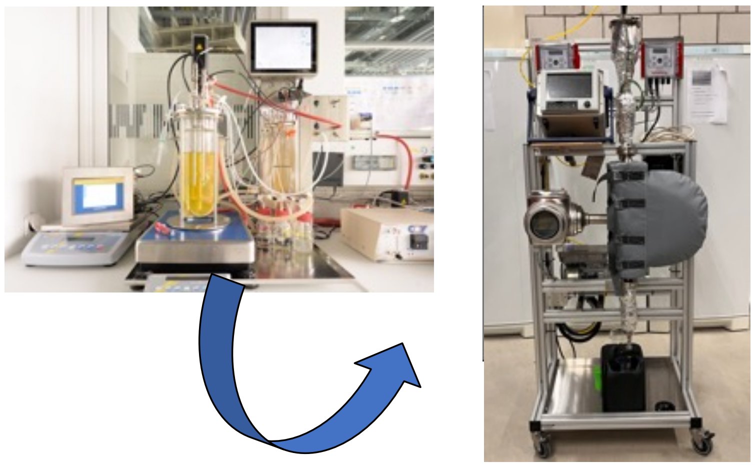

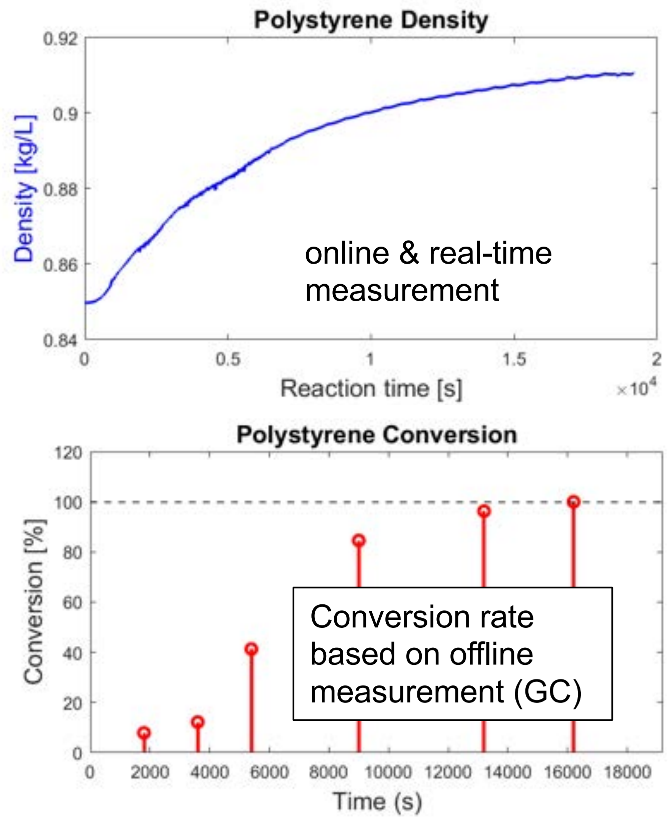

Endress+Hauser

ECCE – Lisbon/ 09/2025

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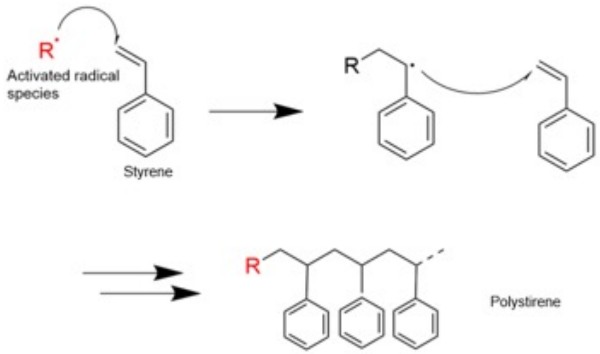

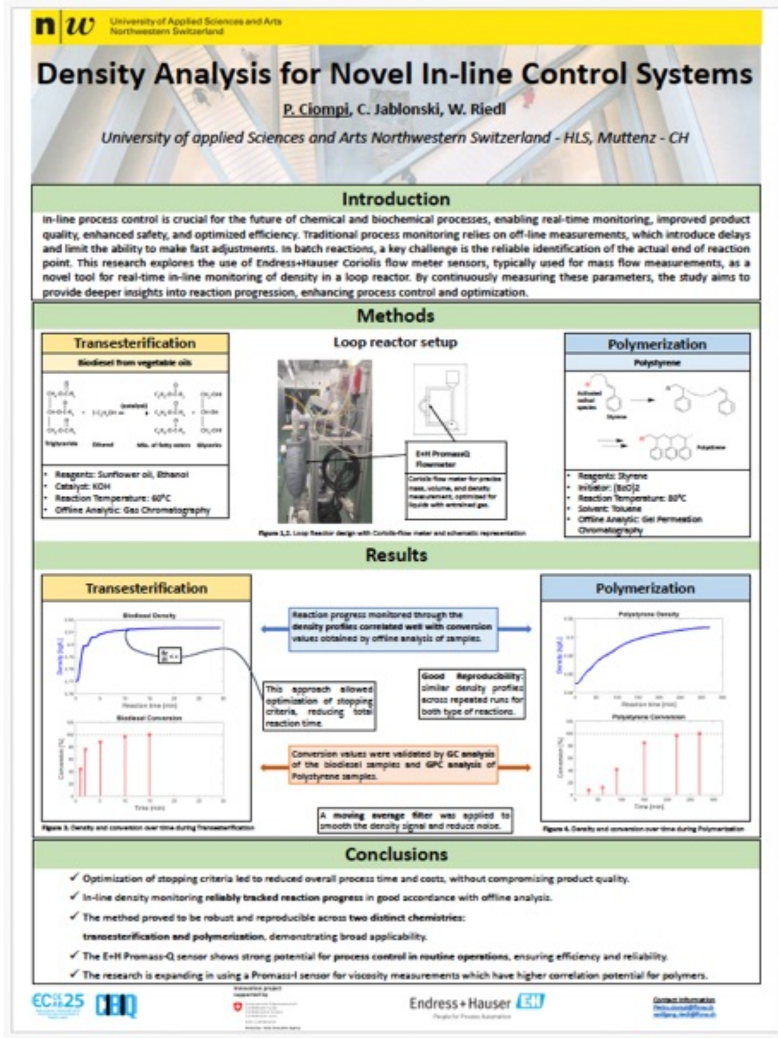
University of Applied Sciences and Arts Northwestern Switzerland

Density Analysis for Novel In-line Control Systems

P. Ciompi, C. Jablonski, W. Riedl
University of applied Sciences and Arts Northwestern Switzerland - HLS, Muttenz - CH

Introduction

In-line process control is crucial for the future of chemical and biochemical processes, enabling real-time monitoring, improved product quality, enhanced safety, and optimized efficiency. Traditional process monitoring relies on off-line measurements, which introduce delays and limit the ability to make fast adjustments. In batch reactions, a key challenge is the reliable identification of the actual end of reaction point. This research explores the use of Endress+Hauser Coriolis flow meter sensors, typically used for mass flow measurements, as a novel tool for real-time in-line monitoring of density in a loop reactor. By continuously measuring these parameters, the study aims to provide deeper insights into reaction progression, enhancing process control and optimization.

Methods

Transesterification

Biodiesel from vegetable oils

- Reagents: Sunflower oil, Ethanol
- Catalyst: KOH
- Reaction Temperature: 60°C
- Offline Analytic: Gas Chromatography

Loop reactor setup

E+H PromassQ Flowmeter

Coriolis flow meter for precise mass, volume, and density measurement, optimized for liquids with entrained gas.

Figure 1,2. Loop Reactor design with Coriolis-flow meter and schematic representation

Polymerization

Polystyrene

- Reagents: Styrene
- Initiator: (BzO)2
- Reaction Temperature: 80°C
- Solvent: Toluene
- Offline Analytic: Gel Permeation Chromatography

Results

Transesterification

Biodiesel Density

Biodiesel Conversion

Figure 3. Density and conversion over time during Transesterification

Reaction progress monitored through the **density profiles correlated well with conversion** values obtained by offline analysis of samples.

This approach allowed optimization of stopping criteria, reducing total reaction time.

Good Reproducibility: similar density profiles across repeated runs for both type of reactions.

Conversion values were validated by **GC analysis** of the biodiesel samples and **GPC analysis** of Polystyrene samples.

A **moving average filter** was applied to smooth the density signal and reduce noise.

Polymerization

Polystyrene Density

Polystyrene Conversion

Figure 4. Density and conversion over time during Polymerization

Conclusions

- ✓ Optimization of stopping criteria led to reduced overall process time and costs, without compromising product quality.
- ✓ In-line density monitoring **reliably tracked reaction progress** in good accordance with offline analysis.
- ✓ The method proved to be robust and reproducible across **two distinct chemistries: transesterification and polymerization**, demonstrating broad applicability.
- ✓ The E+H Promass-Q sensor shows strong potential for **process control in routine operations**, ensuring efficiency and reliability.
- ✓ The research is expanding in using a Promass-I sensor for viscosity measurements which have higher correlation potential for polymers.

Endress+Hauser

Contact information

Endress+Hauser

ECCE – Lisbon/ 09/2025

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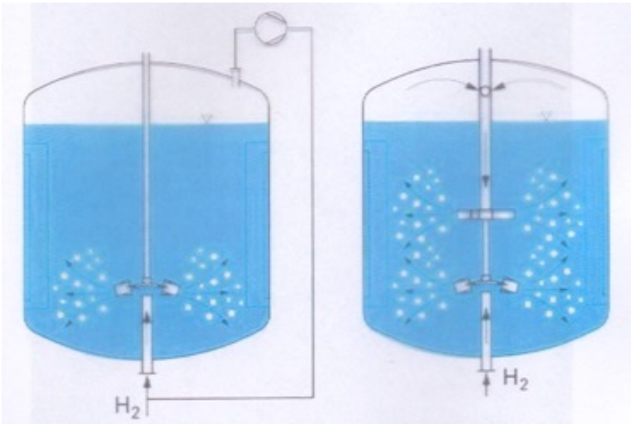
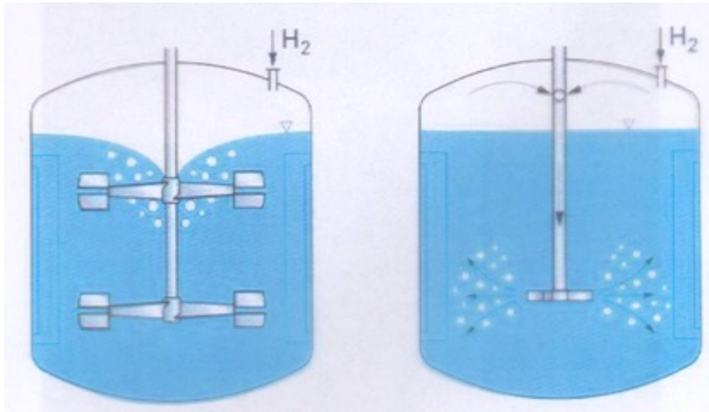
latest Plant design

SCHMIDT HAENSCH

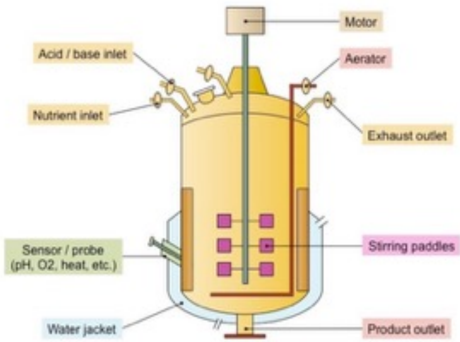
- Technology for the membrane-assisted de-alcoholisation of Beer, Wine
  and
- In-Process Control for the measurement of acutal alcohol concentration and membrane performance
  was developed together with School of Life Sciences

Aeration / Degassing as a key process in reaction technology and (Gas-)Fermentation





Challenges in scaling-up with
- P/V (Energy consumption, agitator design and construction)
- Foaming
- Residence time for gases (yield!)

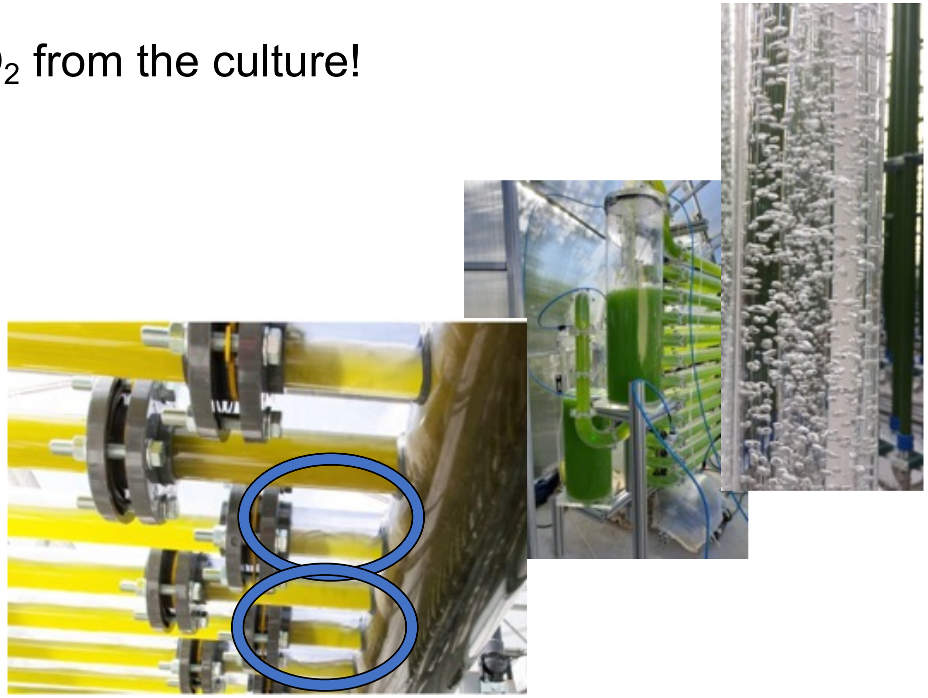


- Aeration, however, can be carried out bubble-free, too!

Gas Management @ microalgae cultivation:

Transfer of CO_2 into and O_2 from the culture!

- Bubbles reducing active reactor volume
- Oxygen content in gas bubbles reduces growth
- Gas exchange every 70-200 m required



- ANY gas volume occurance reduces available cultivation volume (and needs compensation via additional installation (-> cost!)

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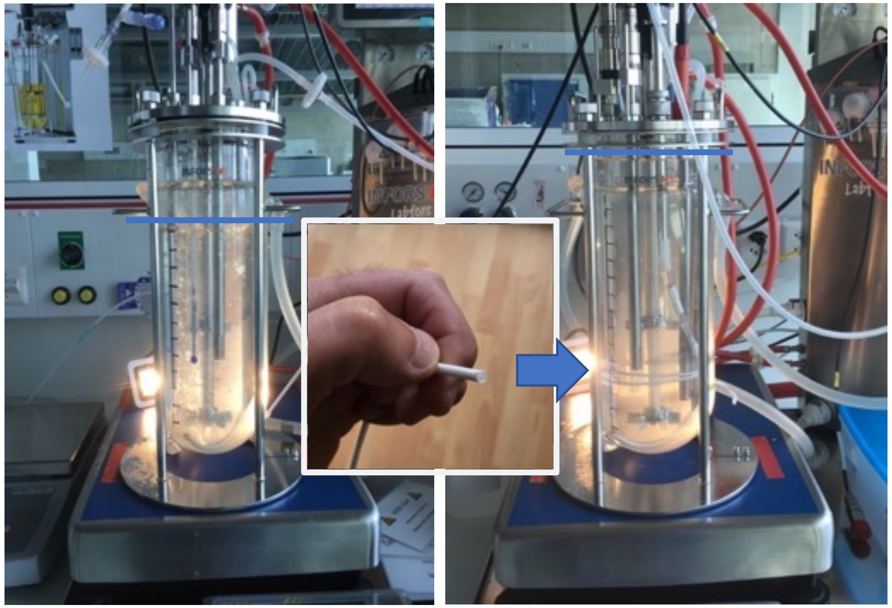
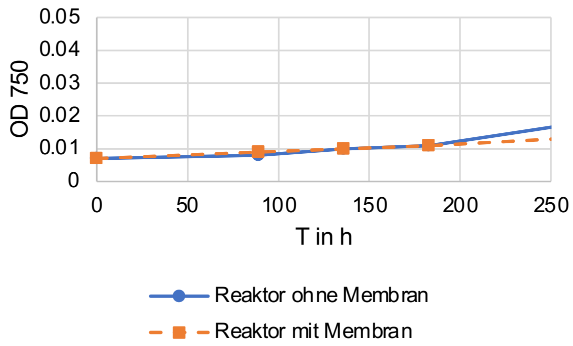
Aeration / Degassing with our
Membrane contactor platform technology



www.memo3.ch



- Using microporous membranes for bubble-free gas transfer (CO_2 into culture)
- **+30%** more effective cultivation volume (increase in room-time-yield) and
- NO negative effect on algae growth!
- NO foam formation

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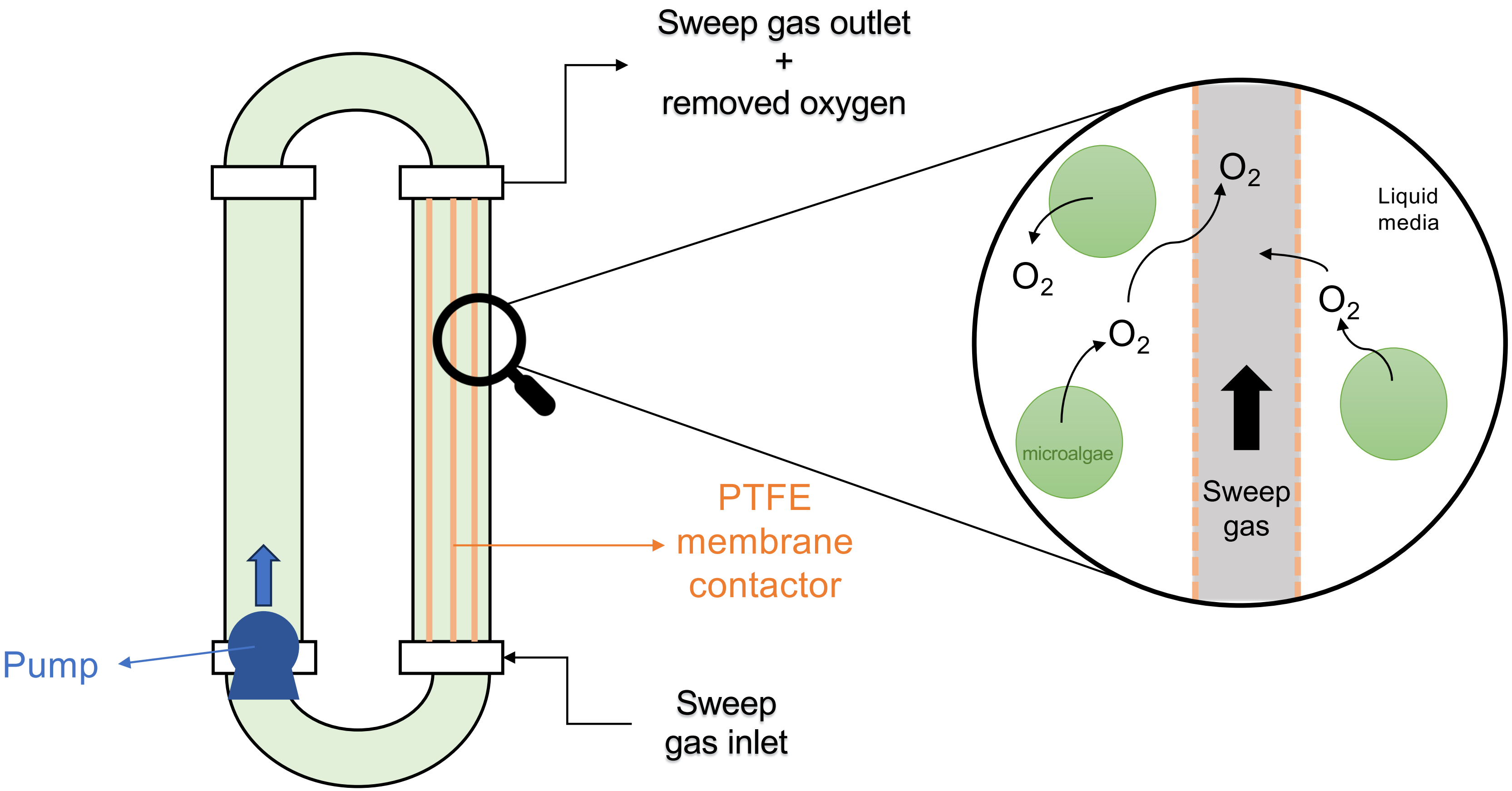
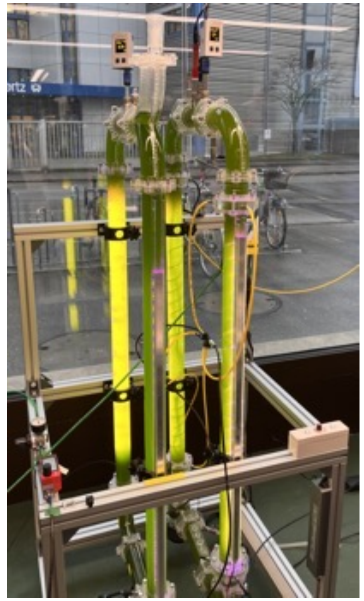
In situ oxygen removal from microalgae cultivation media by means membrane contactor



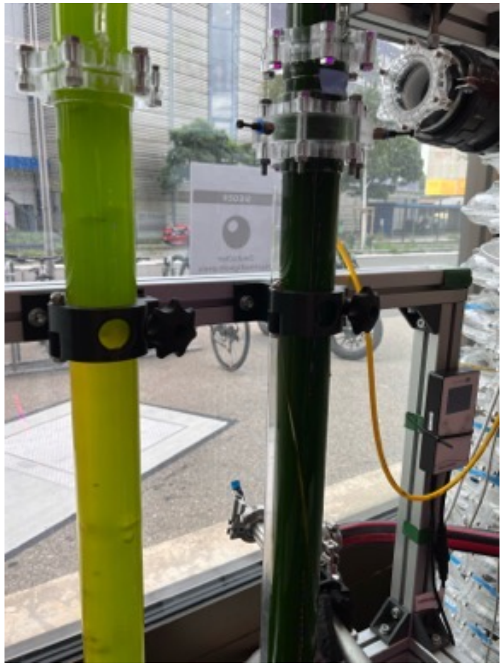
7.2 L loop photo-bioreactor



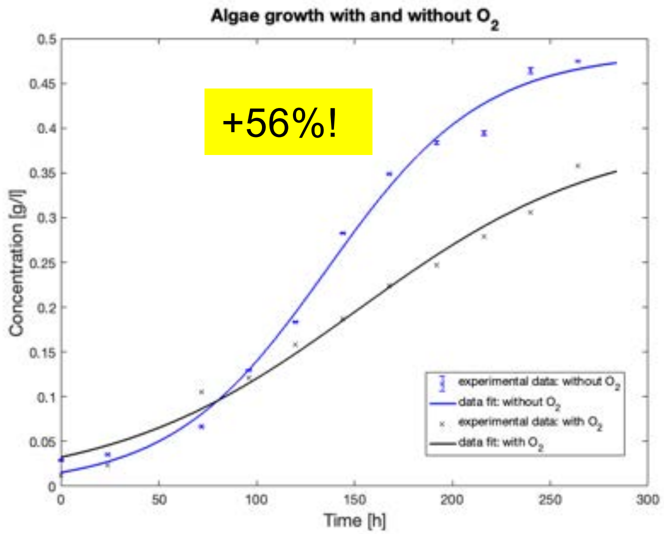
And the Microalgae?

- Say “Thanks” and grow faster!

River water after (right) and after ozonation:
decolourization takes place…



	with O_2	without O_2
Growth rate r	0.0159	0.0251



- Bubble-free Aeration and Degassing was tested already for other gases, eg. H_2, CO_2, O_3, NH_3…

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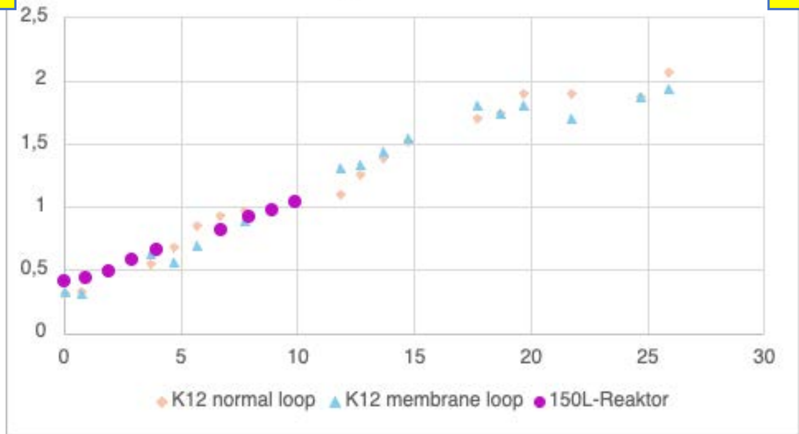
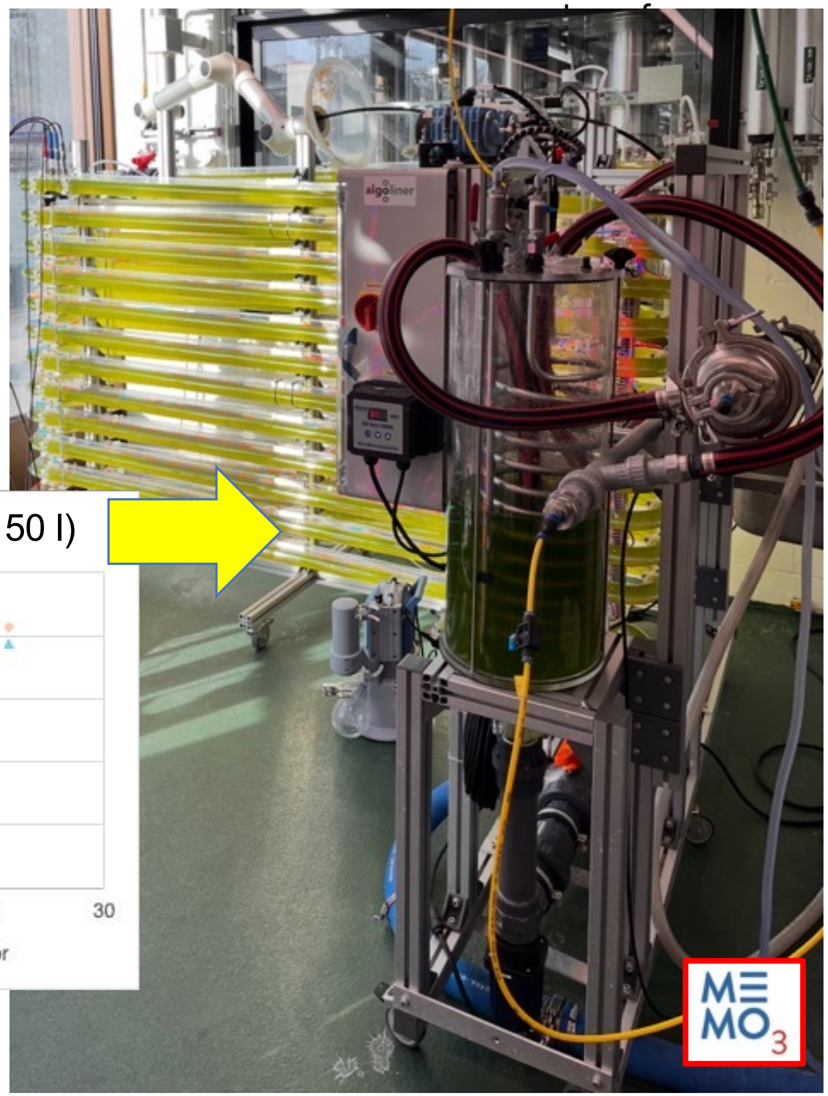
Actual Scale-up experiments (7 l vs. 150 l)





ONE EARTH
HORIZON EUROPE

Funded by the European Union

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Up- and Down-Stream, starting with 160 l Photobioreactor (with membrane aeration) and complete Downstream

Algae reactor with membrane contactor

algoliner

Solid/liquid separation

Extraction

Drying

Final product

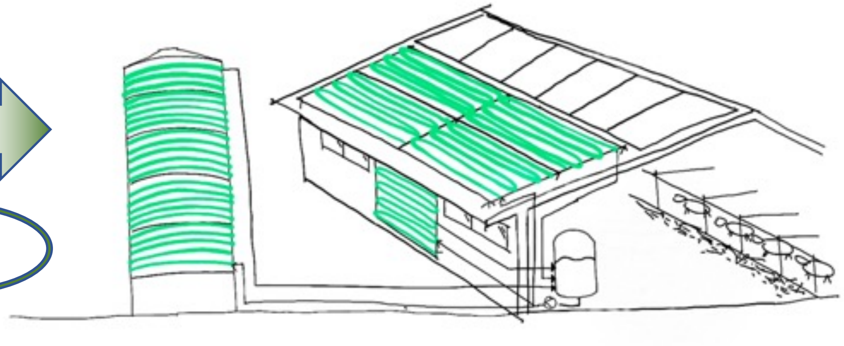
DSP Equipment: see our webpage (FHNW Process Technology Center-PTC: www.fhnw.ch) x2000

x20

x100

150 l
Photo-
bioreactor

x700



„Standard“ Pig barn:

200 pigs, min. 25% feed with Microalgae-Protein -> 50 pigs / 400 g Protein/d
-> <60 m^3 Photobioactor required

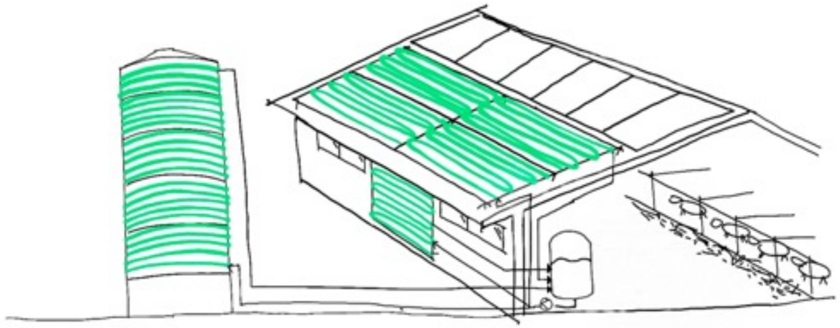
Disruptive Membrane technology for combined gas- and heat transfer

Building integration at the new Agroscope campus

- 50m^3 Bioreactor

Abbildung 2: Draufsicht Gebäude inkl. Algenanlage

"30 by 30"



Agroscope

Dr. Fabian Wahl, Agroscope

Installation of Microalgae-Reactors at Farmer`s site for the production of (liquid) animal feed

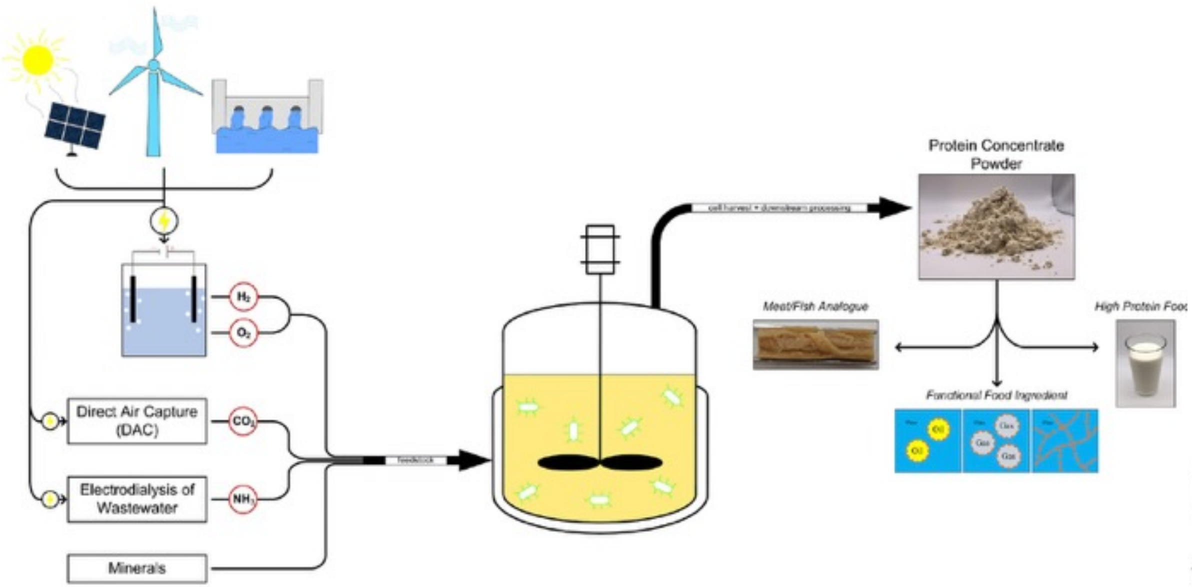
("Algae smoothy")

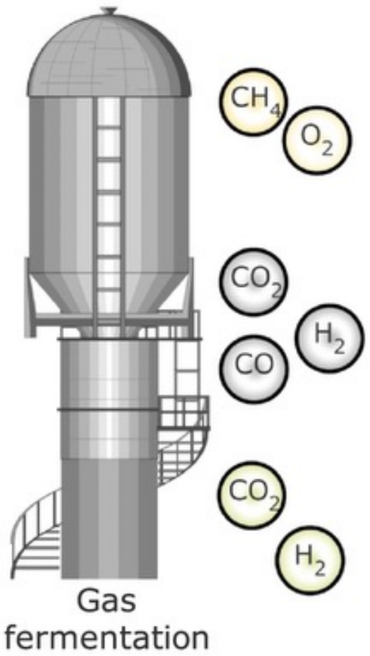
Endress+Hauser

Robust PAT required for
- Easy "plug&play" operation

…and potential Remote Control

Gasfermentation for the production of Ethanol & Acetat as feedstock for further Fermentation processes (e.g. for Single Cell Proteins)





LanzaTech / ArcelorMittal / Gent-Site (BE)

from www.corporate.arcelormittal.com, accessed on 2026-01-31

From: Carlos Woern, Lutz Grossmann, Biotechnology Advances 69 (2023) 108240

THE PROTEINNCLUB www.theproteinnclub.eu

Thank you for visiting us!

Wolfgang Riedl FHNW / HLS

See you (soon?) in Muttenz @ HLS!

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For further information please visit our website:

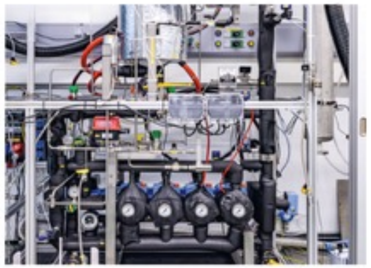
https://www.fhnw.ch/en/about-fhnw/schools/lifesciences/process-technology-center-ptc

Natural materials technology
Many natural materials contain health-promoting compounds and other beneficial substances. The Natural Materials Technology lab extracts valuable ingredients from plants, and processes and packages them professionally.

Thermal separation processes and (bio)refinery
The (bio)refinery produces fuel and recovers solvents. The starting mixture is separated as energy-efficiently as possible based on different boiling points; bioethanol is produced in this way for example.

Bioprocessing
One goal of modern medicine is to provide patients with individually tailored therapies, but complex processes are required to produce the biological agents necessary. Bioprocess technology ensures that these processes run at higher yields and always deliver a high quality product.

Chemical Process Development and Process Safety
At the PTC we can measure chemical reactions precisely, make them more efficient with catalysts or test their explosion safety. In this way, processes can be established and optimized on a pilot scale.



Environmental plant – wastewater management of the future
New wastewater treatment methods are analysed in the environmental plant; filtration and purification steps are tested and combined to ensure the best possible purification.

Pharmaceutical process technology
Correct composition and production of medicines are crucial to their efficacy. A wide variety of drug forms are developed, manufactured and tested in the pharmaceutical process technology lab.

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