GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
ptJ Projektträger Jülich Forschungszentrum Jülich

THM TECHNISCHE HOCHSCHULE MITTELHESSEN

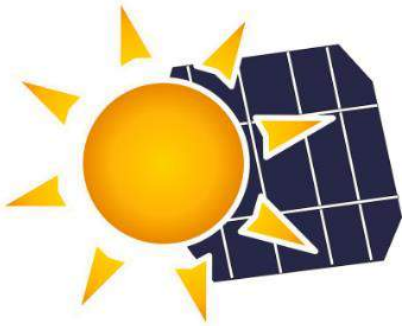
DECHEMA FORSCHUNGSINSTITUT

Mit Strom und CO_2 zum Biokunststoff

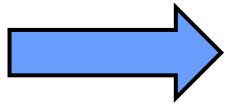
Kombination von CO_2 Elektrolyse und biotechnologischer Wertstoffsynthese

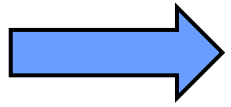
Markus Stöckl
markus.stoeckl@dechema.de

Renewable energy sources and CO_2

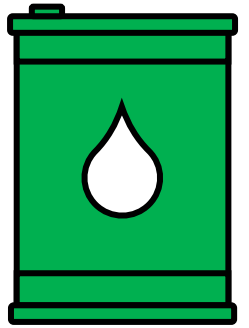


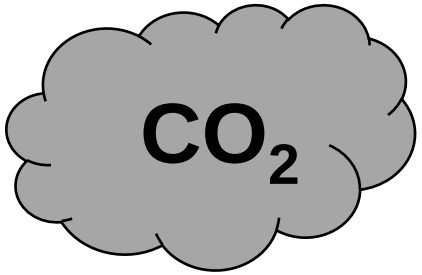
- Renewable Energy
- Daily and seasonal fluctuations
- Electrical power





Carbon based
- **fuels and**
- **chemicals**

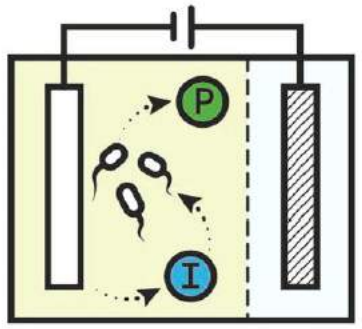




- Ubiquitous Resource
- Replacement of fossil feedstocks

CO_2 to biobased products - approaches

MET

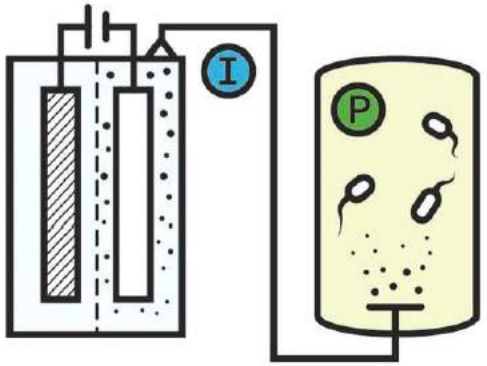


Example: H_2[24] *or formate* [21, 23]

+ no downstream
+ one step process / all in one
+ *in-situ* conversion of the EC intermediate

– scale-up
– compromise of individual process steps
– non-ideal EC reaction conditions

Current to gas

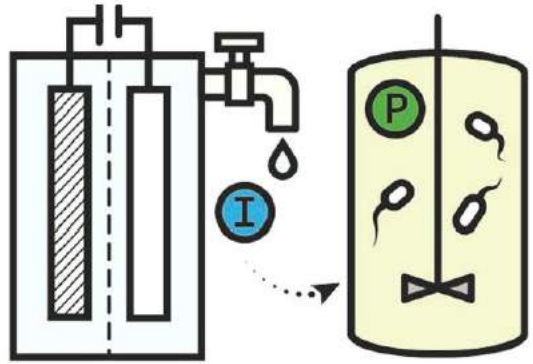


Example: H_2[25] *or Syngas* [10]

+ no downstream
+ scale-up
+ TRL up to 8 – 9
+ use of established bio-infrastructure

– storage of gaseous, explosive and toxic intermediates

Drop-in electrolysis



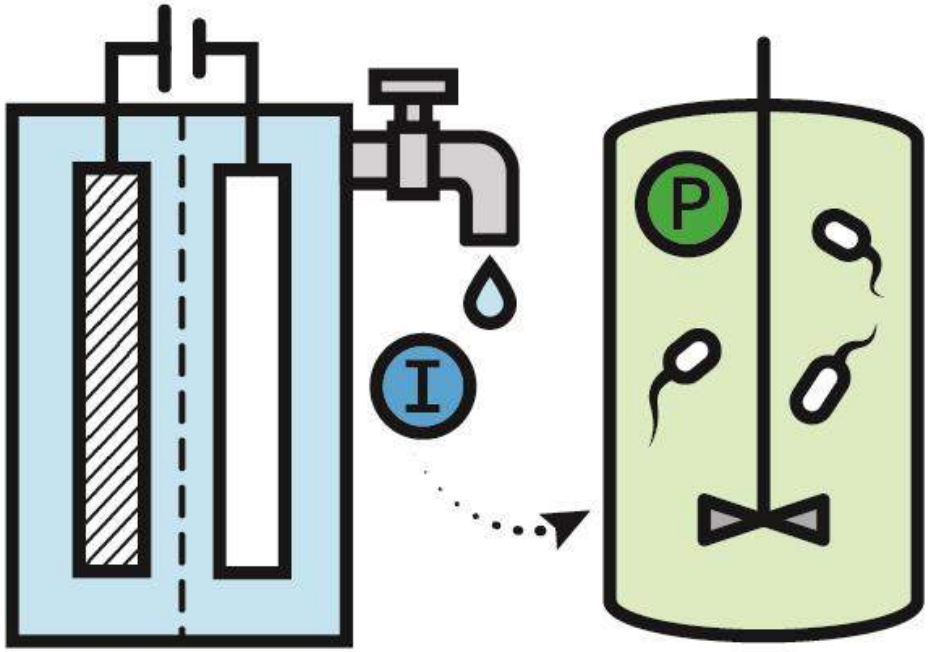
Example: formate [26, this study]

+ no downstream
+ scale-up
+ storage of uncritical intermediates
+ use of established bio-infrastructure

– electrolysis with lower salinity

Development of a scalable „drop-in electrolysis“

→ **Spatial separation** of EC synthesis and PHB production

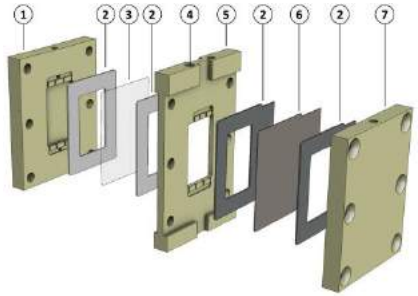


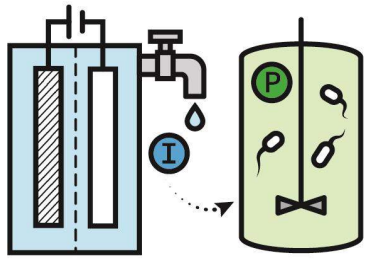
- Improved conditions for CO_2 conversion
- High formate production rates
- Optimized biotechnological conditions
- Individually scalable processes
- **Closer to Industrial application**

From CO_2 to bioproducts

Development of drop-in electrolysis

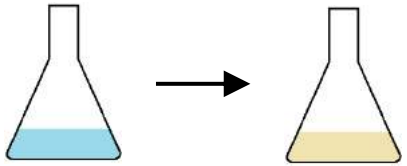
Reactor design and formate production rates

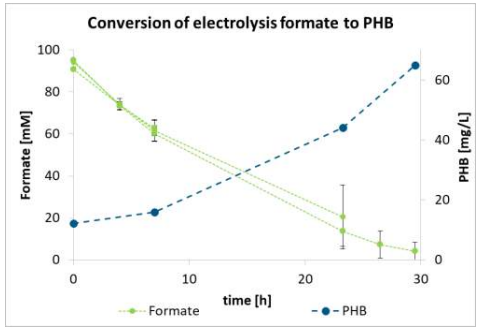




Biological conversion

Formate consumption and PHB production

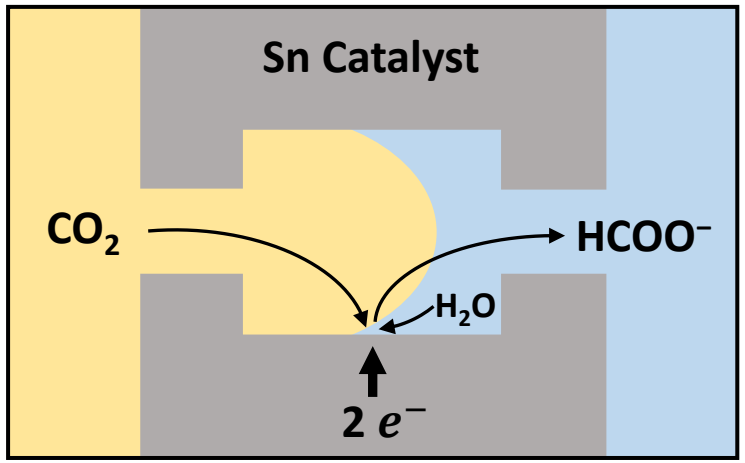


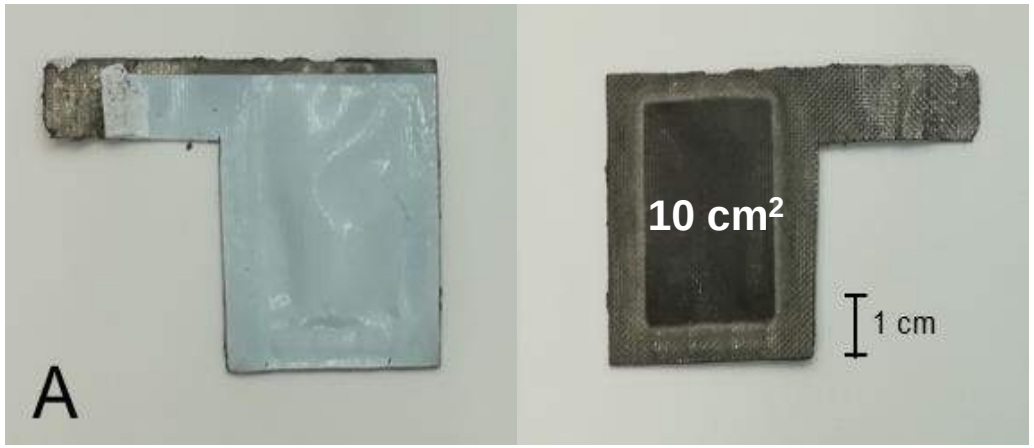


CO_2 Reduktion an Gasdiffusionselektroden

$$\boldsymbol{CO_2(g)} + H_2O + \boldsymbol{2\,e^-} \leftrightharpoons \boldsymbol{HCOO^-(aq)} + OH^-$$

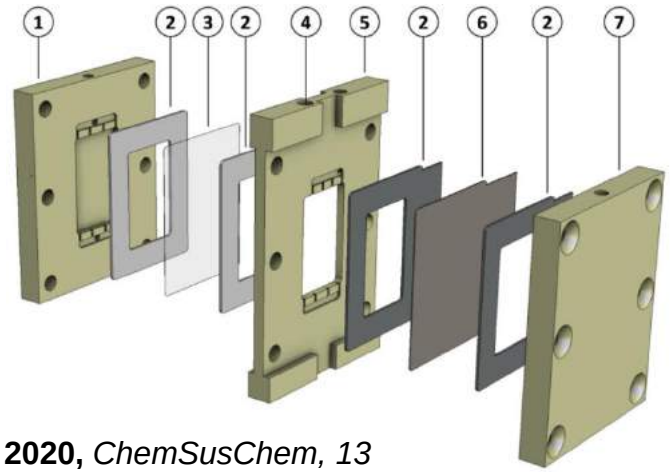
$$E^0(vs.SHE) = -0.43\,V$$





gaskatel

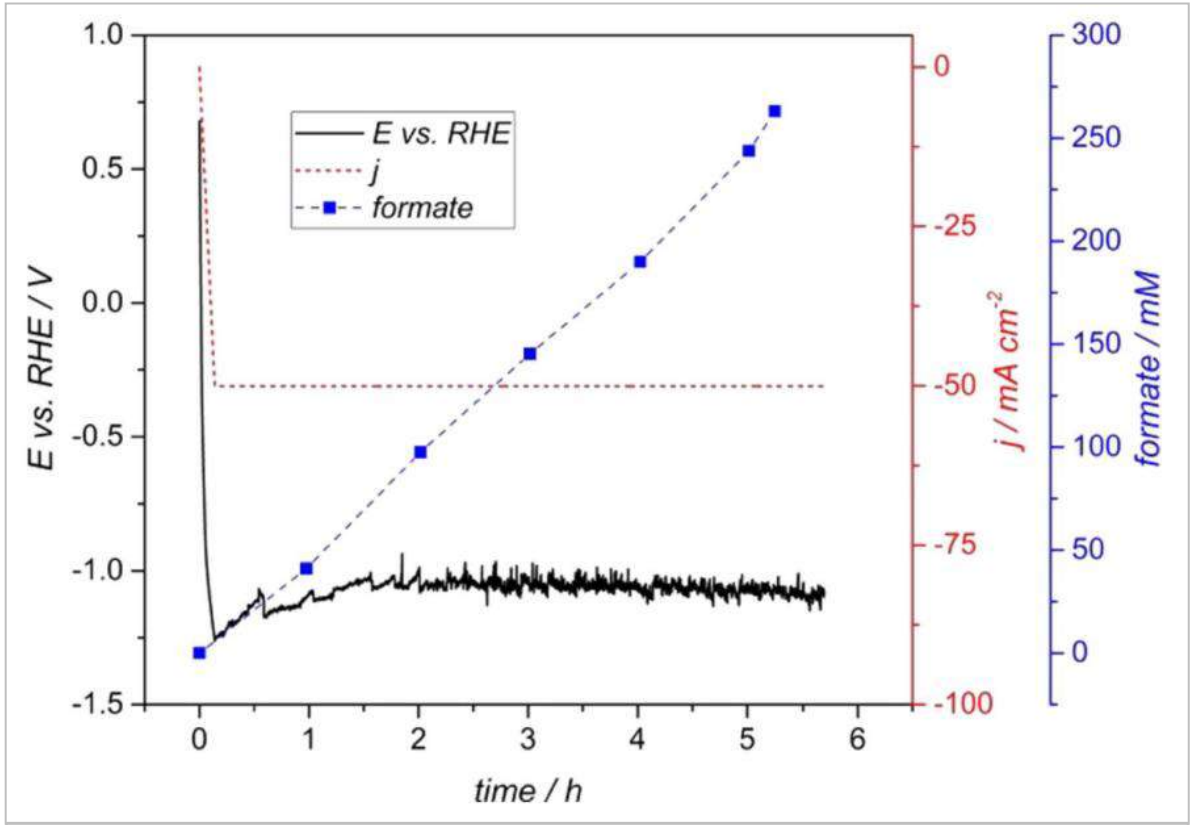
Synthesis @ technical current densities



Scheme modified from: Jörissen et al. **2011,** *Chemie in Unserer Zeit 45*

Stöckl et al. **2020,** *ChemSusChem, 13*

Continuous formate synthesis



E vs. RHE: no iR-drop correction; 0.2 M phosphate buffer, 80 mL min^{-1}; 10 mbar CO_2 overpressure, -50 mA cm^{-2}; n = 1

- Final c($HCOO^-$) = 263 mM
- Faradaic efficiency = 54 %
- Linear production rate: **50 mM / h**

→ **pH_{END} = 6.68**

→ **<u>Suitable for biological conversion</u>**

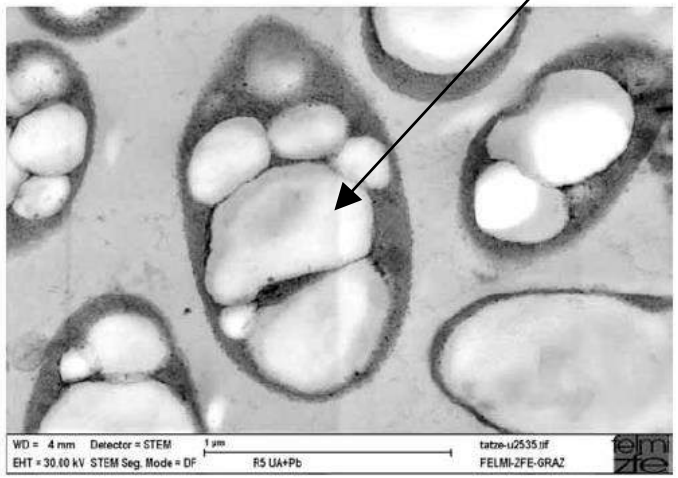
Stöckl et al. 2020, *ChemSusChem, 13*

„Drop-in“ electrolysis and PHB production

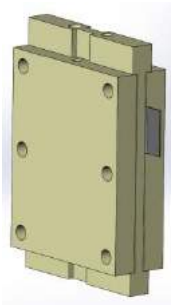
Cupriavidus necator

„Knallgasbakterium“

- Model organism
- Substrates: H_2, **formate**, acetate, fructose, etc.
- Energy conservation: **PHB**

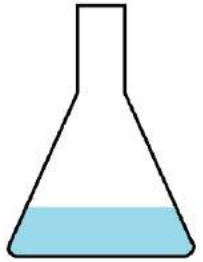


Koller et al. **2010**, *Food Technol. Biotechnol. 48 (3)*

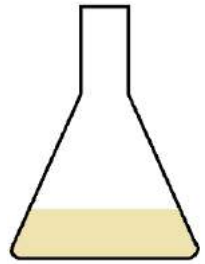


Electrolysis of
100 mM formate

Preculture on
100 mM formate

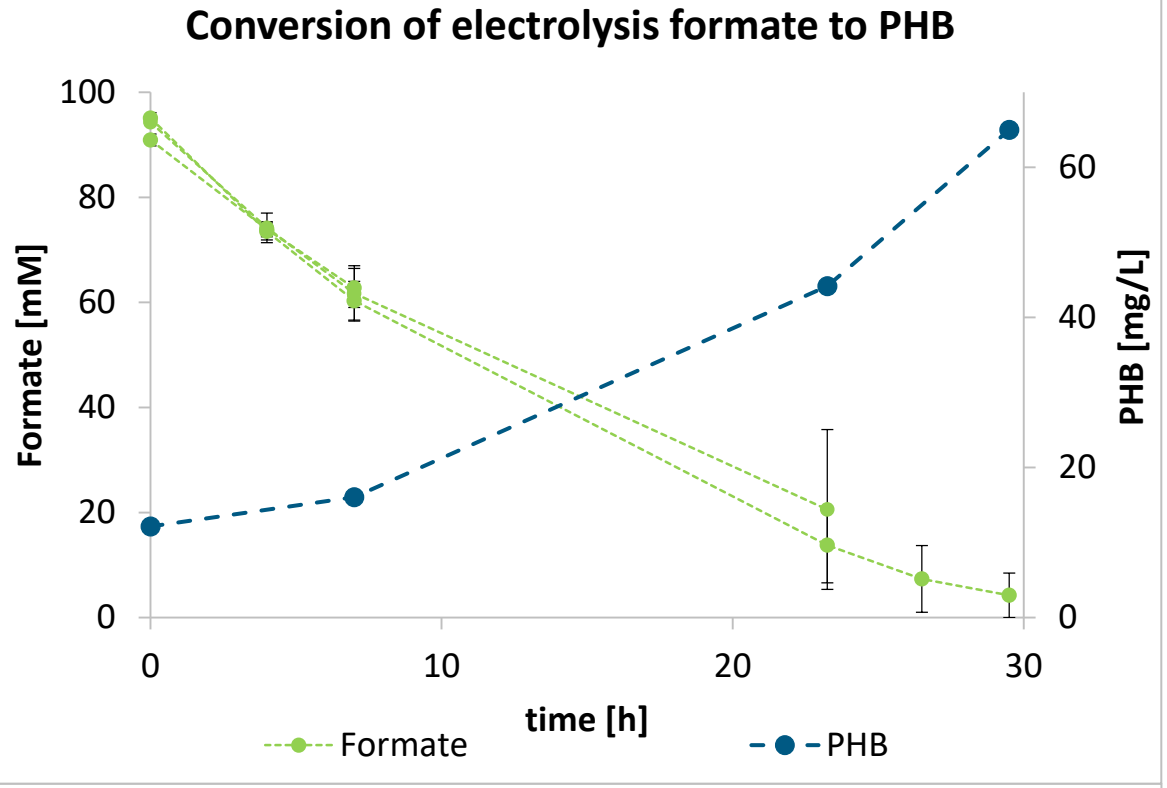


100 mM Formate
200 mM PO_4^{2-}
Buffer



Resting cells
100 mM formate

PHB production on electrolyzed formate



90 – 100 mM formate from electrolysis; NH_4^+ limitation, n = 3
Wildtype Strain; manual pH control around pH = 7

- Slightly increasing OD; final OD_{600} = 1.0
- Nearly complete substrate consumption
- Final pH = 6.82

- Increasing PHB concentration

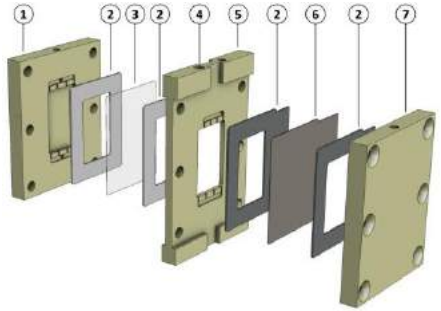
→ **PHB_{final} = 66 mg/L** (10 mg/L from preculture)

→ **$Efficiency_{overall}$ = 4 %**

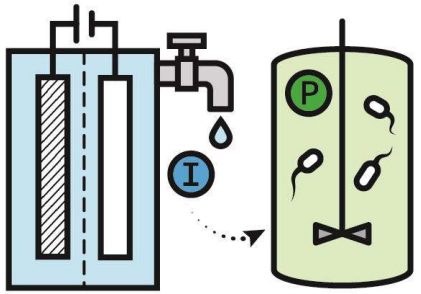
Stöckl et al. 2020, *ChemSusChem, 13*

CO_2 to bioproducts: conclusions and outlook

- Biological substrate synthesis from CO_2 and electric current
- **Drop in electrolysis concept → 50 mM formate/h with 54 % FE**



- Conversion of electrolysis formate to PHB → **56 mg PHB/L**
- **(Faradaic) efficiency of the overall process → 4 %**



- **Increasing of faradaic efficiency for CO_2 reduction**
- **Improvement biological formate conversion**