# ProMet -
# $CO_2$ to Basic Chemicals!?
## Application of $CO_2$-Electrolysis

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Dr. Katja Weichert (Covestro Deutschland AG)

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Bundesministerium für Bildung und Forschung
Projektträger Jülich Forschungszentrum Jülich

# $CO_2$-Electrolysis - Electrochemical $CO_2$-Reduction

Nachhaltig Kohlenstoff nutzen

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Reduction of the $CO_2$ footprint of Basic Chemicals by:

- Use of $CO_2$ as raw material instead of fossil resources
- Use of power from renewable energies for electrolysis process

→ $CO_2$ to Basic Chemicals !!!

**Table 1.** Half-cell reactions for the electroreduction of carbon dioxide.

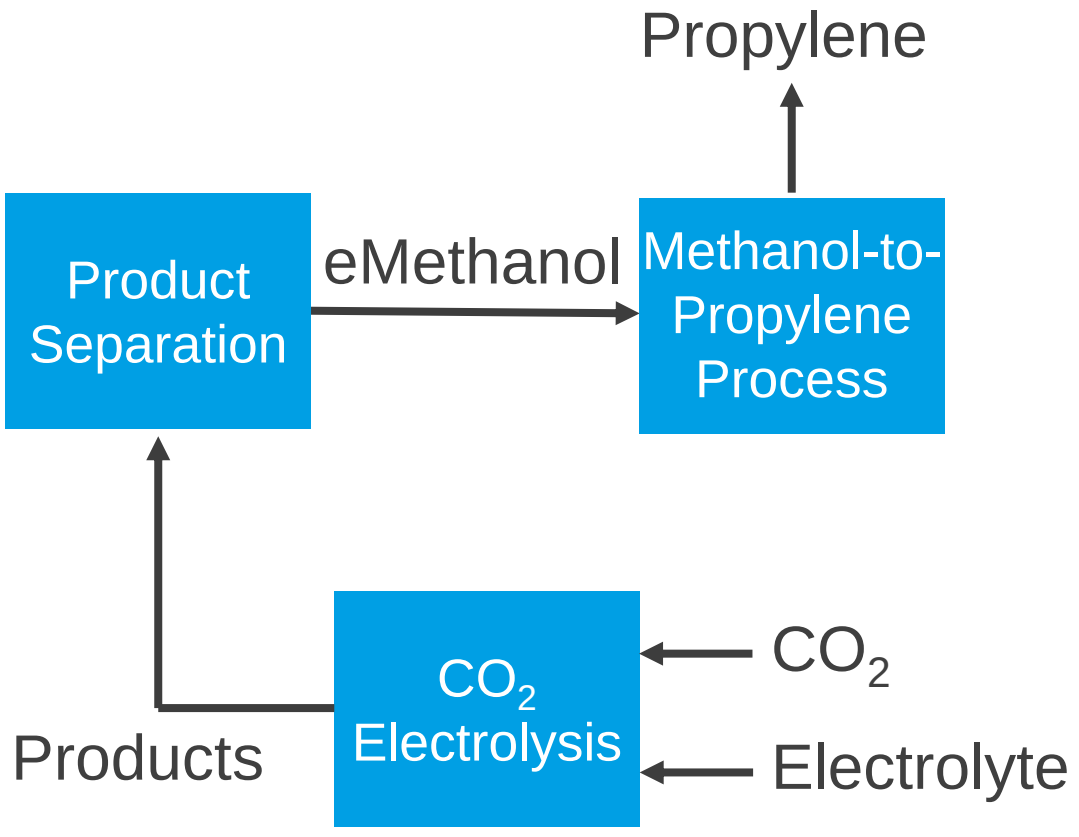
| Reaction | | $E^\circ$ [V][a] |
|---|---|---|
| a | $2CO_2 + 2H^+ + 2e^- \leftrightarrow H_2C_2O_4$ | −0.475 |
| b | $CO_2 + 2H^+ + 2e^- \leftrightarrow HCOOH$ | −0.199 |
| c | $CO_2 + 2H^+ + 2e^- \leftrightarrow CO + H_2O$ | −0.109 |
| d | $CO_2 + 4H^+ + 4e^- \leftrightarrow HCHO + H_2O$ | −0.071 |
| e | $CO_2 + 6H^+ + 6e^- \leftrightarrow CH_3OH + H_2O$ | +0.030 |
| f | $CO_2 + 8H^+ + 8e^- \leftrightarrow CH_4 + 2H_2O$ | +0.169 |

[a] $E^\circ$ versus normal hydrogen electrode (NHE) at 298 K.

C. Oloman. H. Li. ChemSusChem. **2008**;1(5):385-91

# ProMet: $CO_2$ to Propylene via eMethanol

- Development of the whole process (starting from $CO_2$ electrolysis)
- Catalyst screening and gas diffusion electrode manufacturing for $CO_2$ electrolysis
- Evaluation of the economic feasibiltiy as well as of the sustainability of the process





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# ProMet: $CO_2$ to Propylen via eMethanol

- Extensive catalyst screening, but no success
- Techno-economic analysis showed Methanol cost of about 1000€/t, which is four to five times more expensive than conventional (fossil) Methanol
- Simulation of the whole process shows a high energy demand to separate and purify the product mixture after $CO_2$ electrolysis

Flow cell for electrochemical characterization (1 $cm^2$ electrode area)

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# ProMet: $CO_2$ to Ethylene

- New catalyst: Copper (Cu) doped with Boron (B)[1]
- Several catalysts prepared, using different conditions (temperature, time, concentration)
- Screening of catalyst activity and preparation scale up



[1]Y. Song et al., *Angew. Chem. Int. Ed.* 2021, *60*, 9135. https://doi.org/10.1002/ange.202016898

# ProMet: $CO_2$ zu Ethylen

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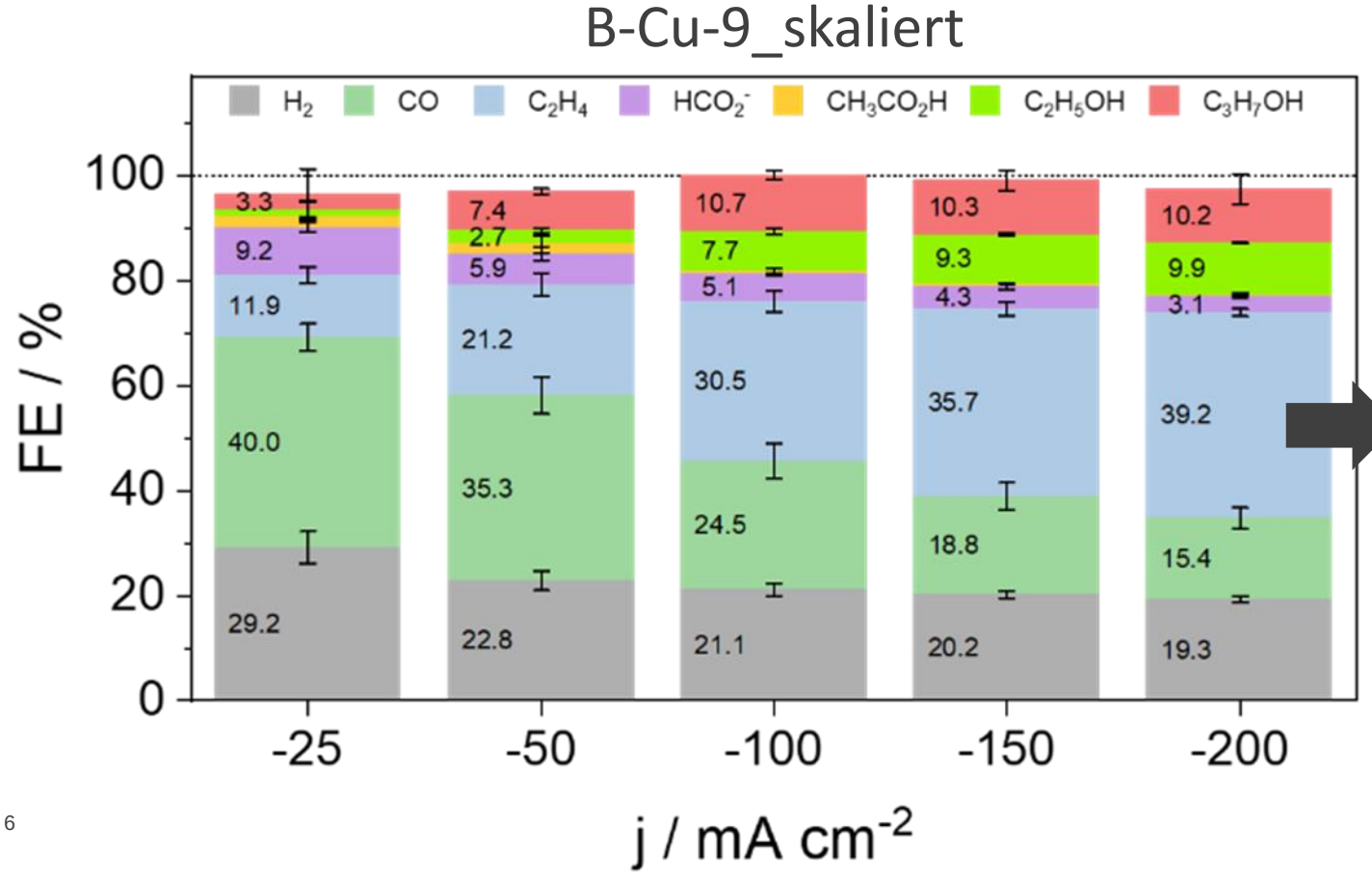
Faraday Efficiency (FE) versus Current Density j




Faraday Efficiency (FE):

Ethylene: 39.2 %
Ethanol: 9.9 %
Propanol: 10.2 %

# ProMet: $CO_2$ zu Ethylen

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**Successful Business Case and more sustainable chemical production if…**

- …High product selectivity and high current densities are achieved in electrochemical process
- …Gas diffusion electrodes can be assembled, in which catalyst activity is preserved, with long-time stability
- …Renewable energies are used

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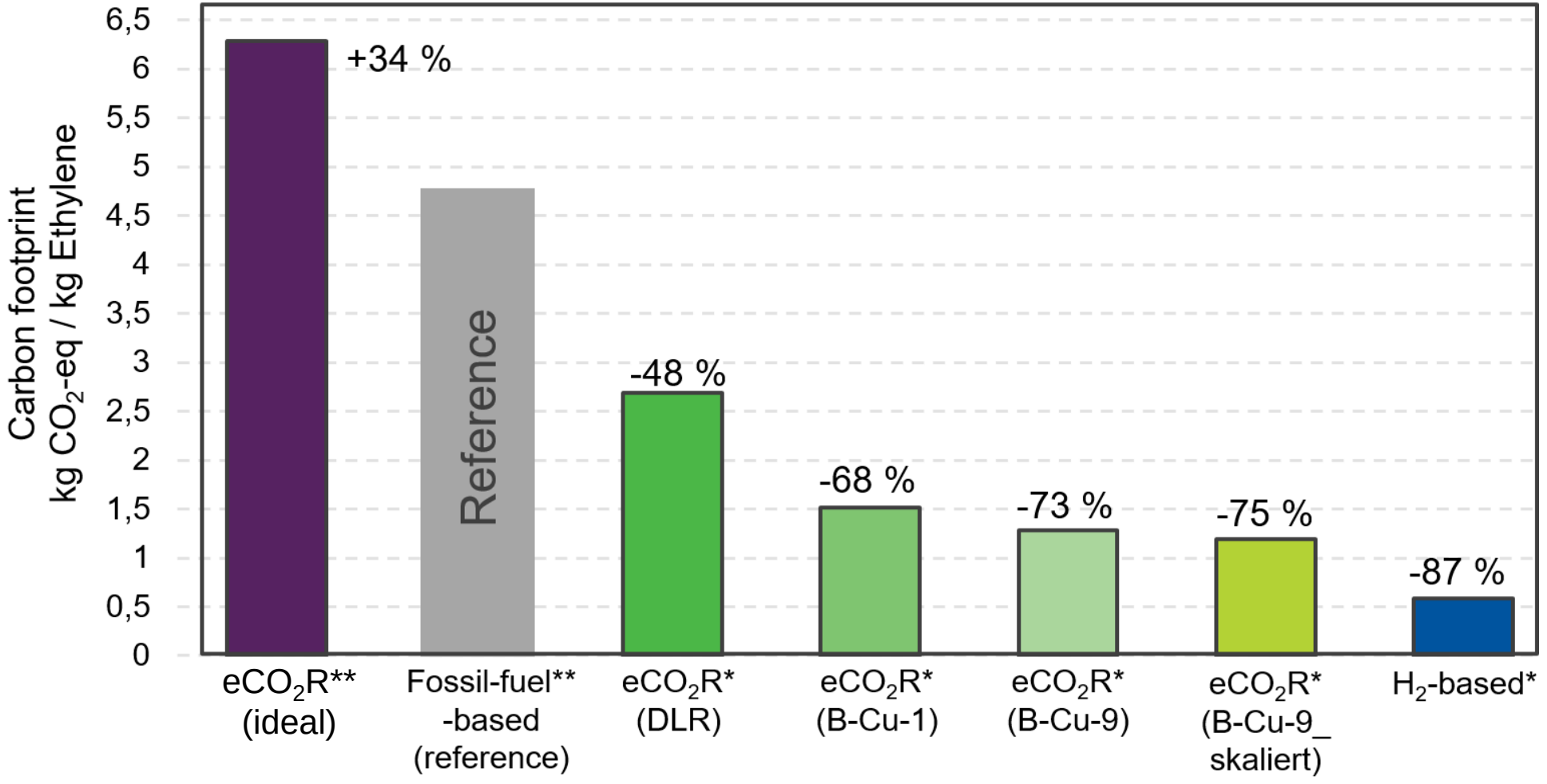
[1]Y. Song et al., *Angew. Chem. Int. Ed.* 2021, *60*, 9135. https://doi.org/10.1002/ange.202016898

# Life Cycle Assesment: $CO_2$ footprint of Ethylene




* : using electricity from wind energy.
** : using electricity from current EU-28 grid mix



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# Summary

- The use of $CO_2$ as a raw material in combination with electrolysis technology using electricity from renewable energies is a promising concept for reducing greenhouse gas emissions in chemical production.
  Basic chemicals using $CO_2$ electrolysis!

- To produce basic chemicals via $CO_2$ electrolysis, very high current densities and high selectivities must be achieved. For both, methanol and ethylene, catalytic processes using green $H_2$ and renewable energies are currently more competitive.
  Basic chemicals using $CO_2$ electrolysis?

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# Thank you for your kind attention!