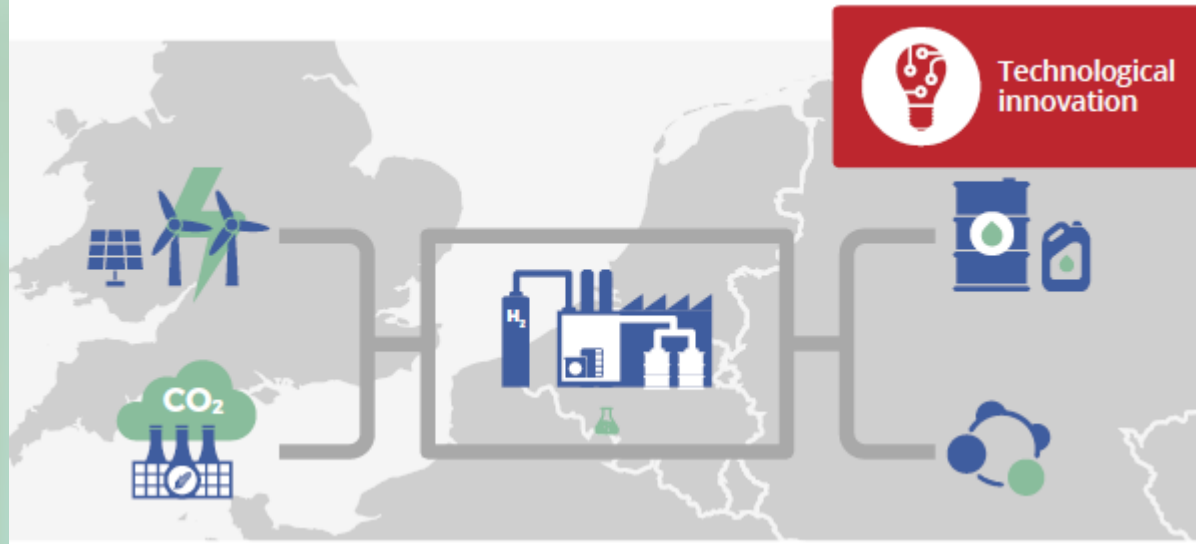
DIRECT ELECTROCHEMICAL CONVERSION OF CO_2 TO FORMIC ACID

FROM LAB TO INDUSTRY



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EUROPEAN UNION
European Regional Development Fund

e2c

CONVERGE
CarbON Valorisation in Energy-efficient Green fuels

Innovations in advanced biofuels production

May 18th 2022

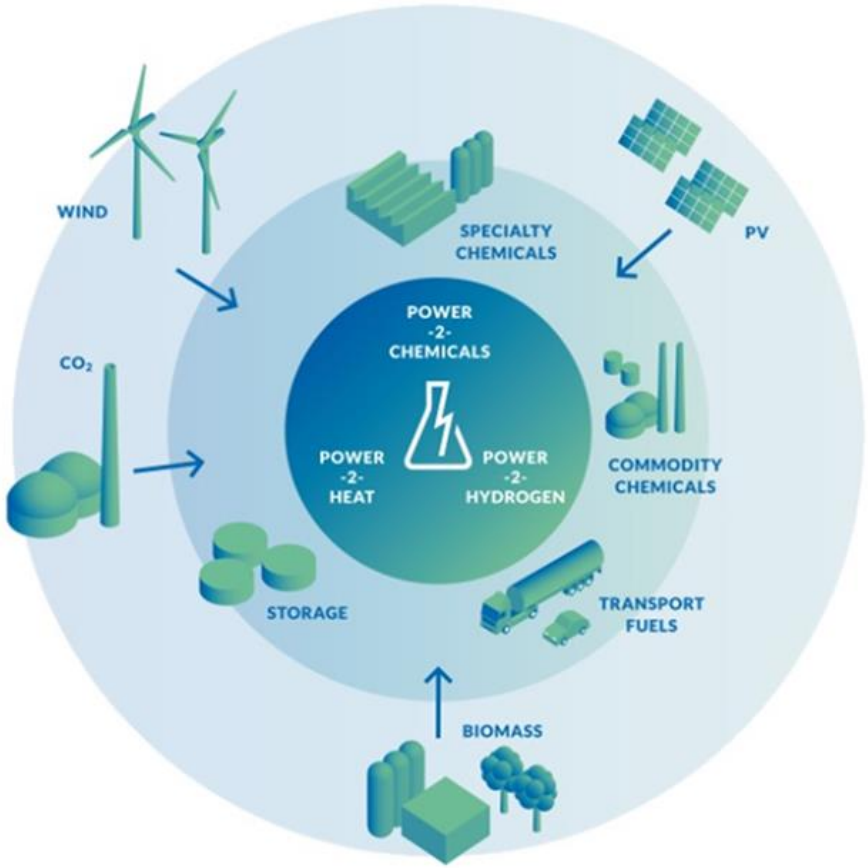
Carlos Sánchez Martínez

TNO innovation for life

VoltaChem: Electrification of the Chemical Industry

VOLTA CHEM

Electrification of the Chemical Industry

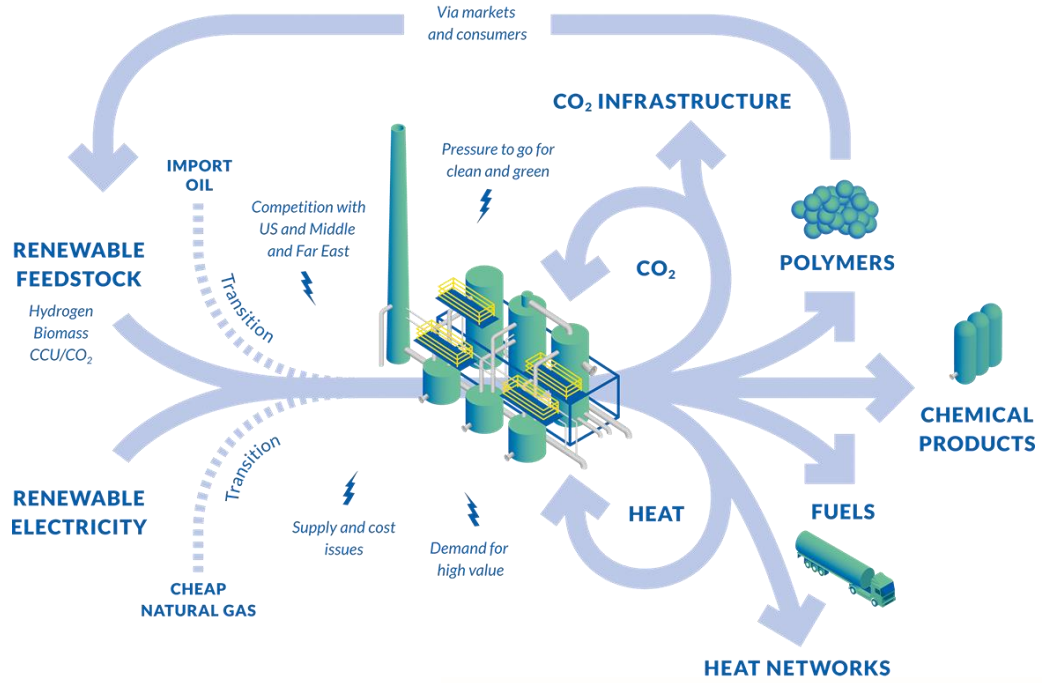


- Shared Innovation Programme
- Electricity + equipment + chemical sectors
- Realise C-neutral future in the industry

Power to chemicals	
Electro-organic synthesis	CO_2 electro-reduction
Electro-oxidation	Electro-reduction

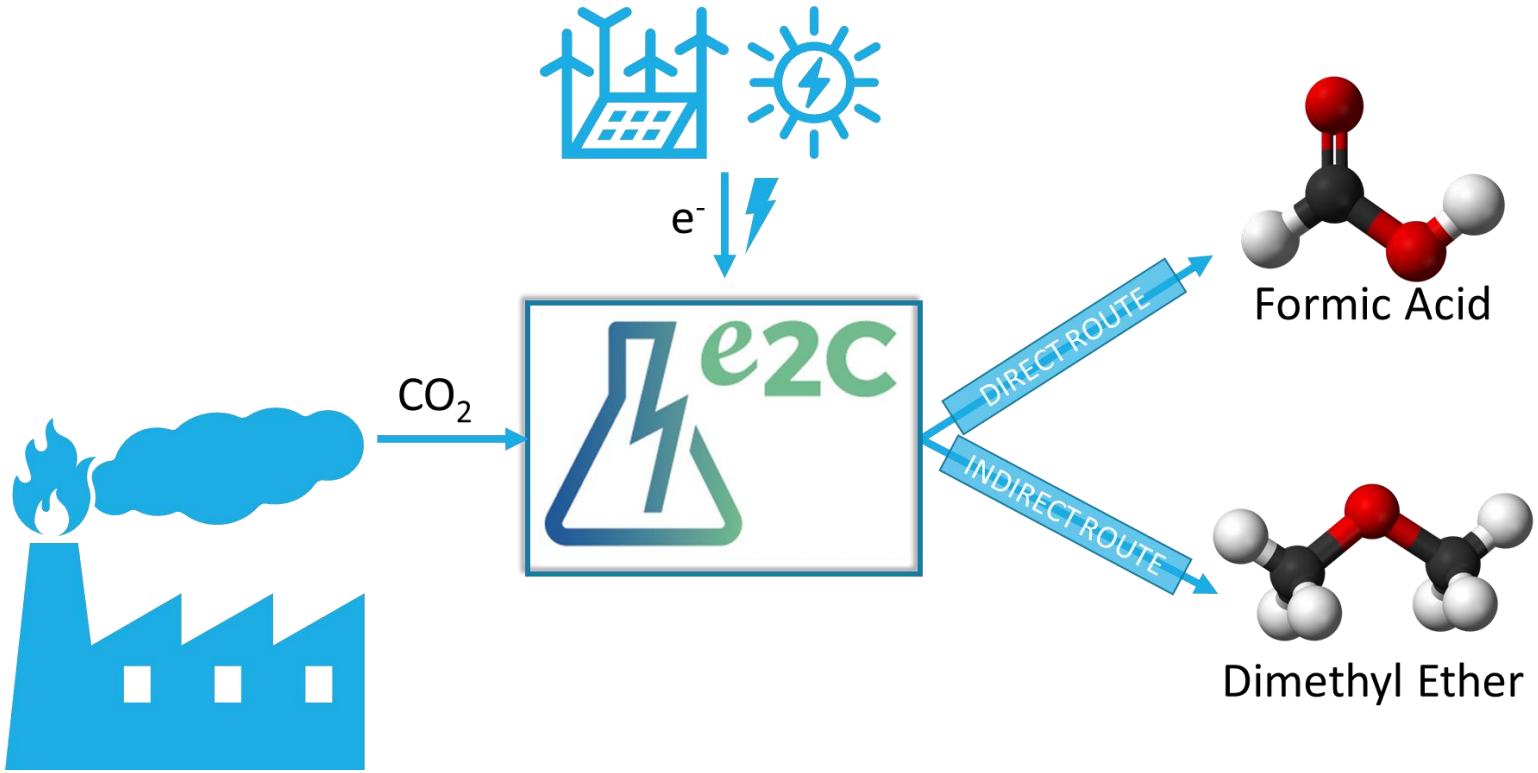
Feedstock *Recarbonization*

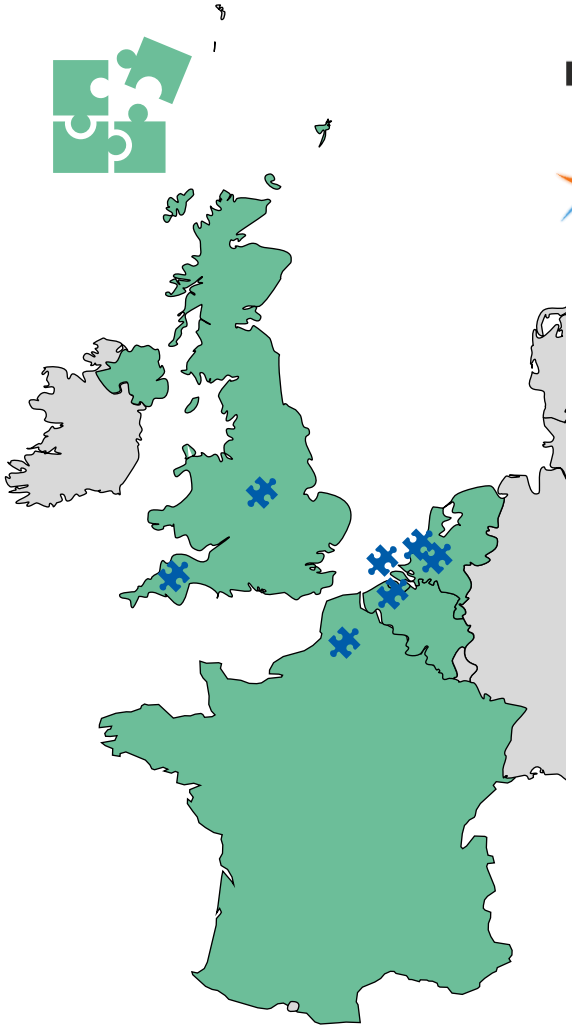
Energy *Decarbonization*



*e*2C: Electrons to high value Chemical products

- Develop Power-2-X technologies to decarbonize the industry with renewable electrons





TNO innovation for life

vito vision on technology

Universiteit Antwerpen

University of Exeter

TU Delft Delft University of Technology

Université de Lille 1 Sciences et Technologies

CO2 Chem

VOLTA CHEM

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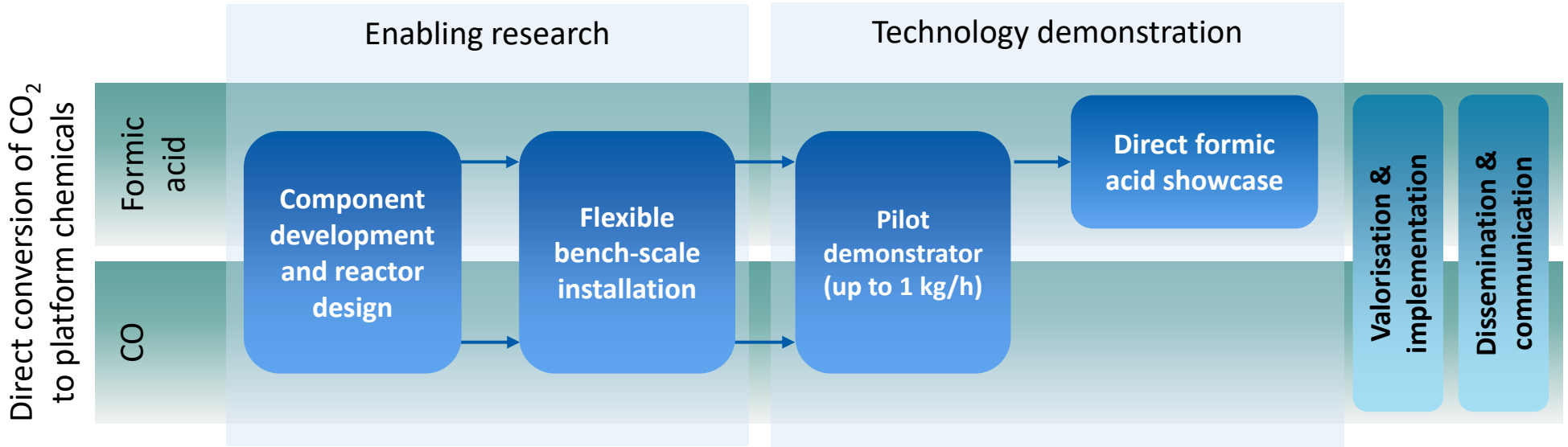
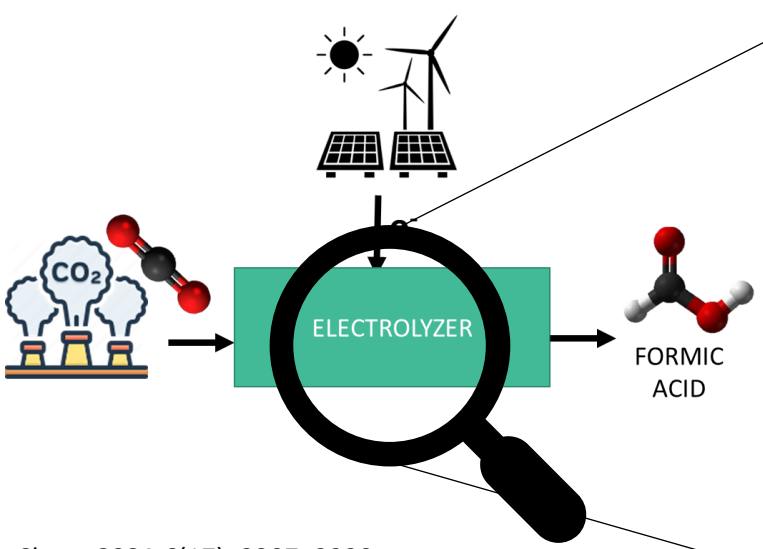
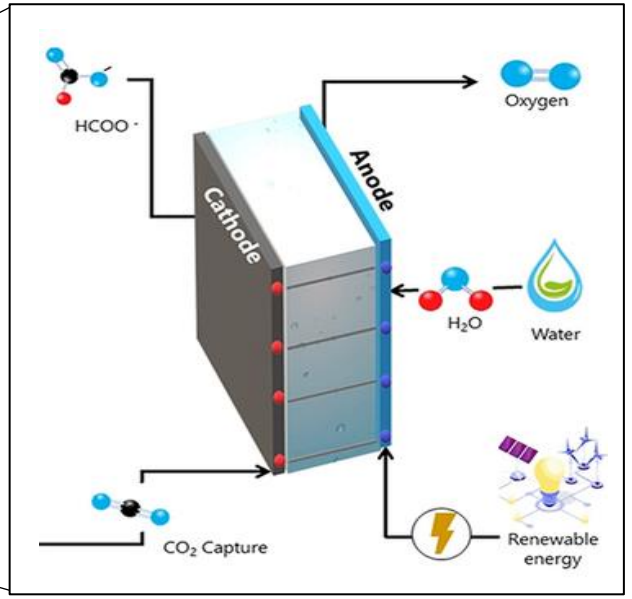
Direct Route: CO_2 electrochemical reduction to FA







Anode (OER)	$H_2O \leftrightarrow {}^1/_2\, O_2 + 2H^+ + 2e^-$
Cathode (CO_2R)	$CO_2 + 2H^+ + 2e^- \leftrightarrow HCOOH$
$\boldsymbol{CO_2 + H_2O \rightarrow HCOOH + {}^1/_2\, O_2}$	

ChemElectroChem, **2021** *8*(17), 3207–3220

Direct Route development line

Enabling Research

User requirements Formate/ formic acid (TNO)

Electrocatalyst development (Universiteit Antwerpen)

Electrolyte development (TU Delft)

GDE development (VITO)

Reactor development

Three compartment electrolyzer development (TNO)

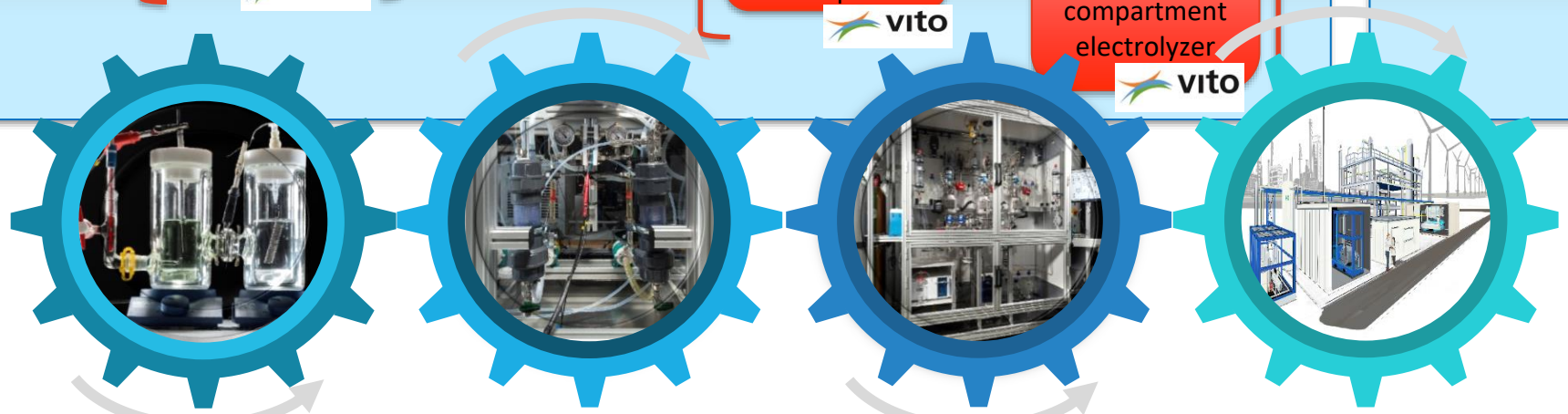
Two compartment electrolyzer development (VITO)

Feasibility study formic acid in three compartment electrolyzer (TNO)

Feasibility study formate in two compartment electrolyzer (VITO)

Technology Demonstration

Pilot demonstrator (up to 1 kg/h)



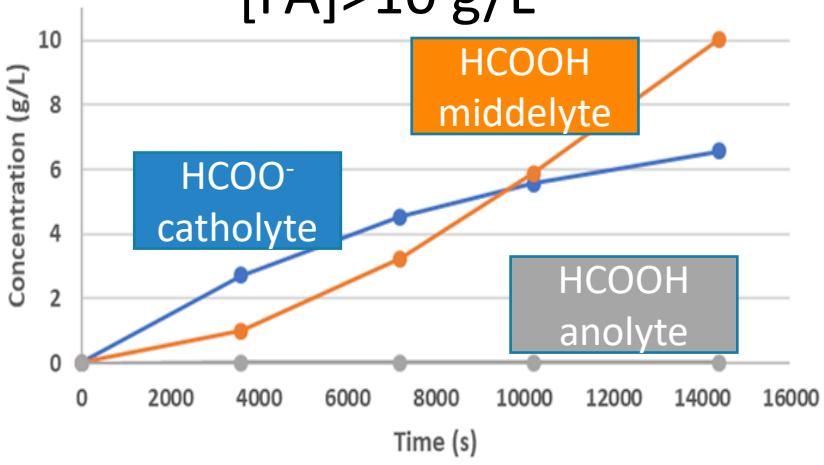
TRL 3

TRL 6

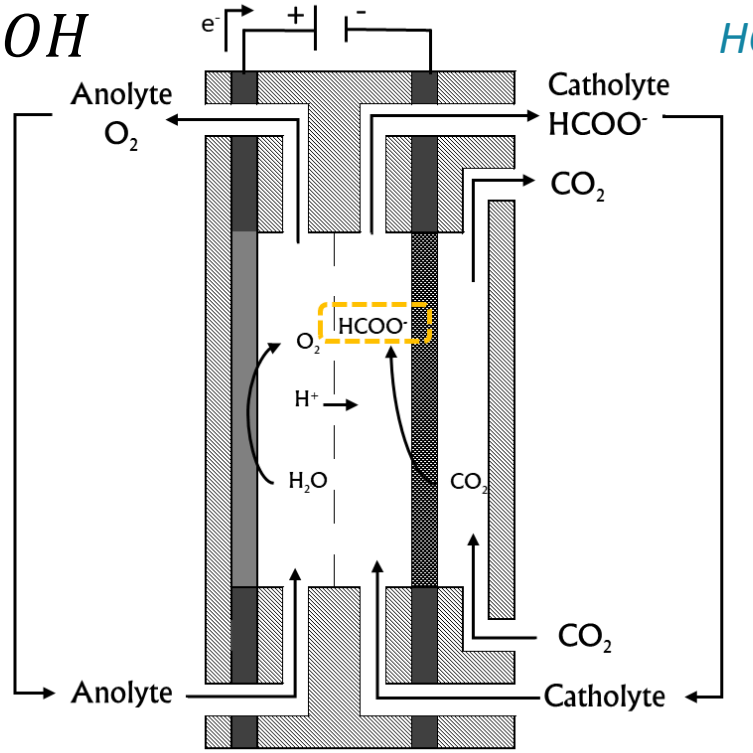
Electrode area	1 cm^2	0.60 m^2
Electrolyte volume	100 mL	100 L

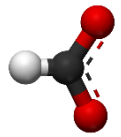
Reactor development: 3-comp. vs. 2-comp.

- Alkaline catholyte conditions: $HCOO^-$ production
  - $H^+ + HCOO^- \leftrightarrow HCOOH$
  - pK_a (FA) = 3.75
- *3-comp. approach*: <u>in-situ FA formation</u>
  - [FA]>10 g/L



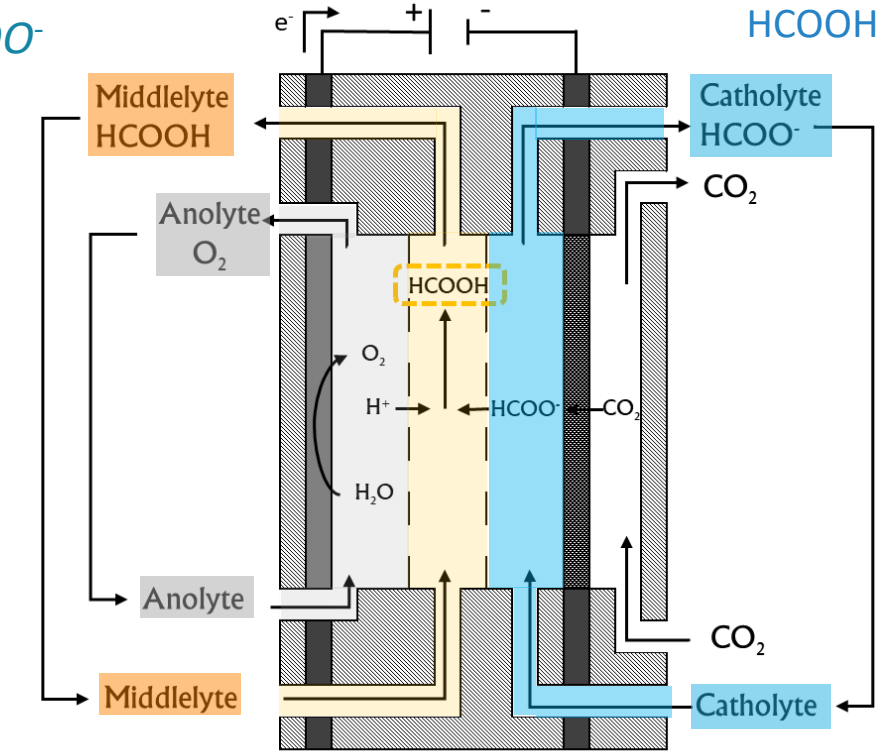
2-comp. electrolyser

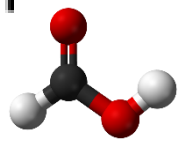




Formate
$HCOO^-$

3-comp. electrolyser

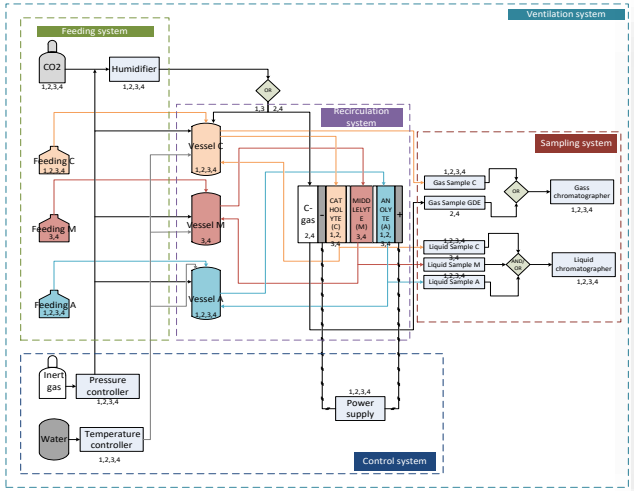




Formic Acid
HCOOH

Direct Route bench-scale system: ELEKTRA

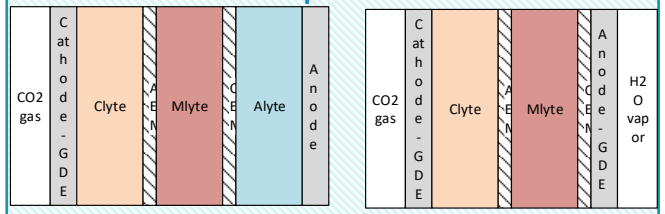
Design ✓ Building ✓ Automation ✓ Commissioning ✓ Testing



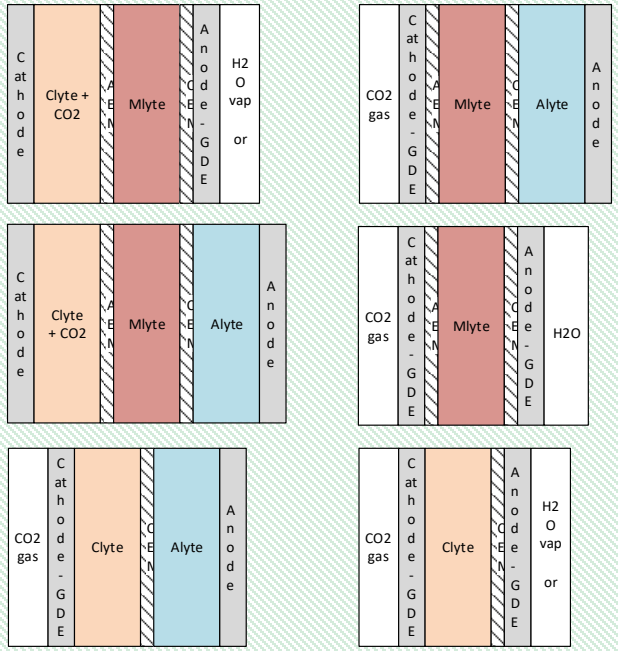
- High-pressure system: 30 bar & 85° C
- Automated monitoring system
- On-line gas stream analysis
- 3-electrolyte loops
- Pressure equilibration system
- Vapour delivery unit for feed gas conditioning (φ, T, p)

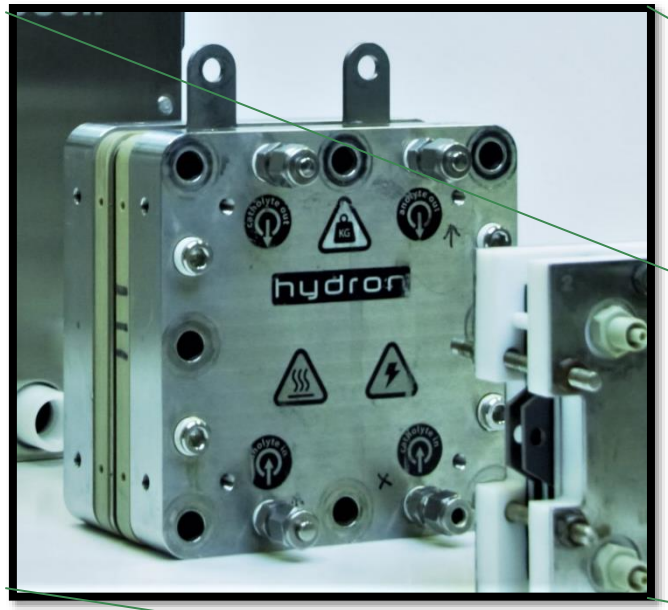
High-p flexible reactor for CO_2-2-FA

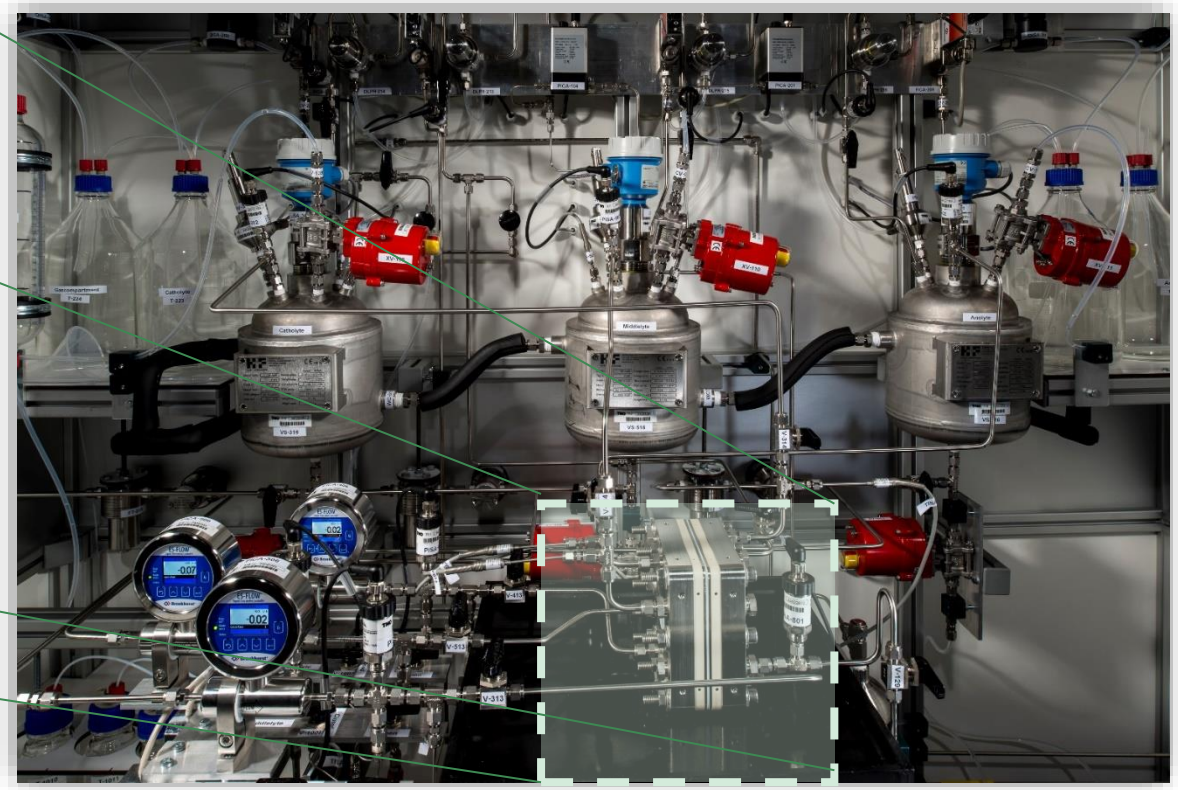
4-compartment



3-compartment







- 100 – 400 cm^2
- 30 bar rated
- Plate & GDEs
- Multiple liquid & gas compartments
- Flexible configurations & internals

Pilot demonstrator: ZEUS

Up to 1 kg FA/h

- 2.5 – 10 kW total input
- Upstream CO_2 absorption
- Downstream FA separation

Operation modes

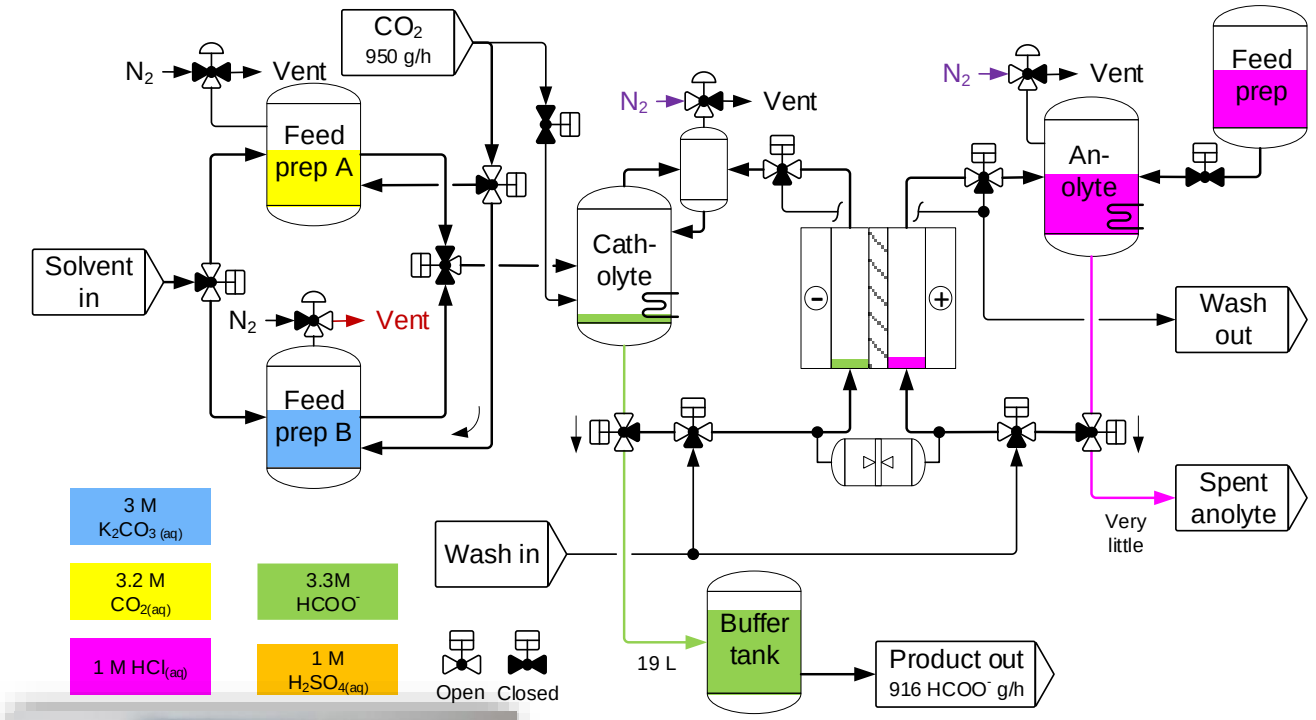
- Real-loaded CO_2 capture solutions
- Gaseous CO_2 feed to stack

Stack reactor of 15 cells

- 400 cm^2/cell
- Total area: 0.60 m^2
- Flexible reactor configuration

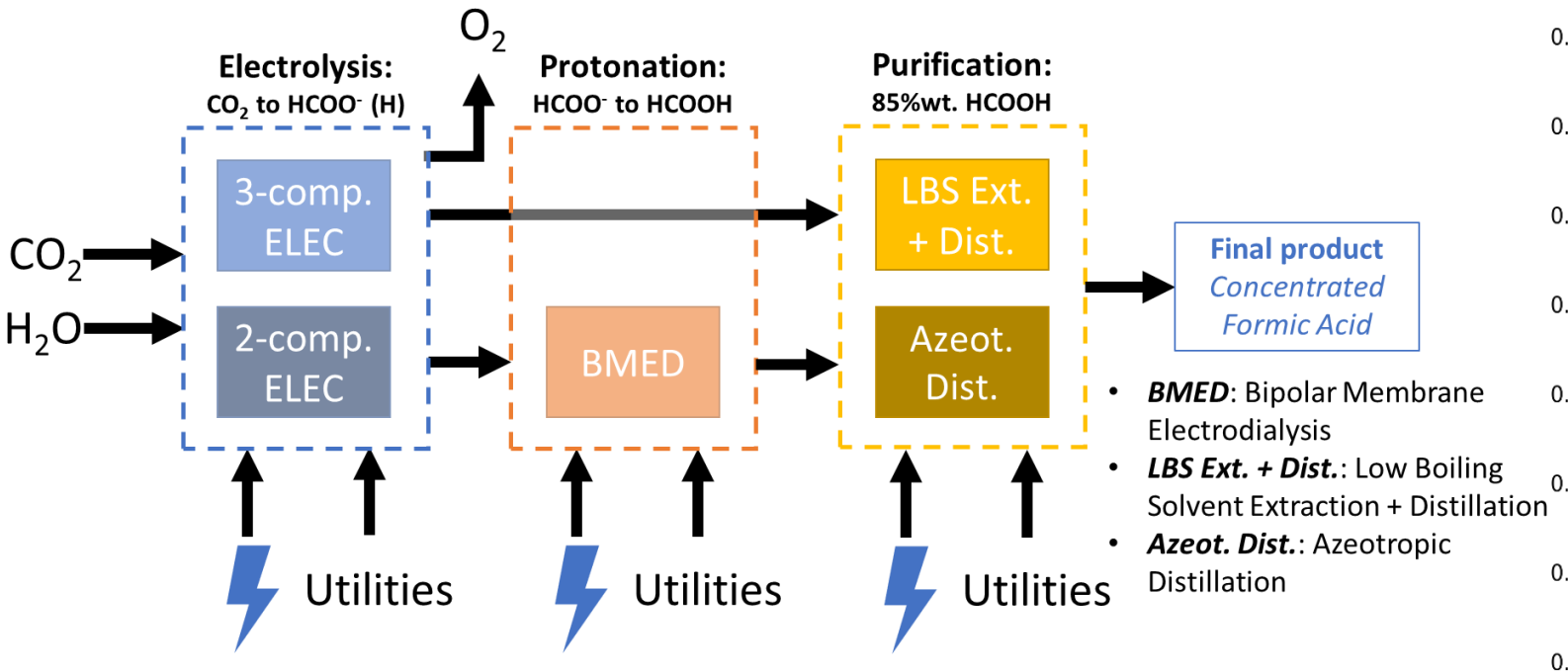
Fully automated pilot

- Feed preparation system in between batches
- Continuous operation: feed & bleed
- > 100 h unmanned operation
- Automated rinsing and washing procedures
- Inline sampling system
- High-p & T (30 bar, 85 °C)

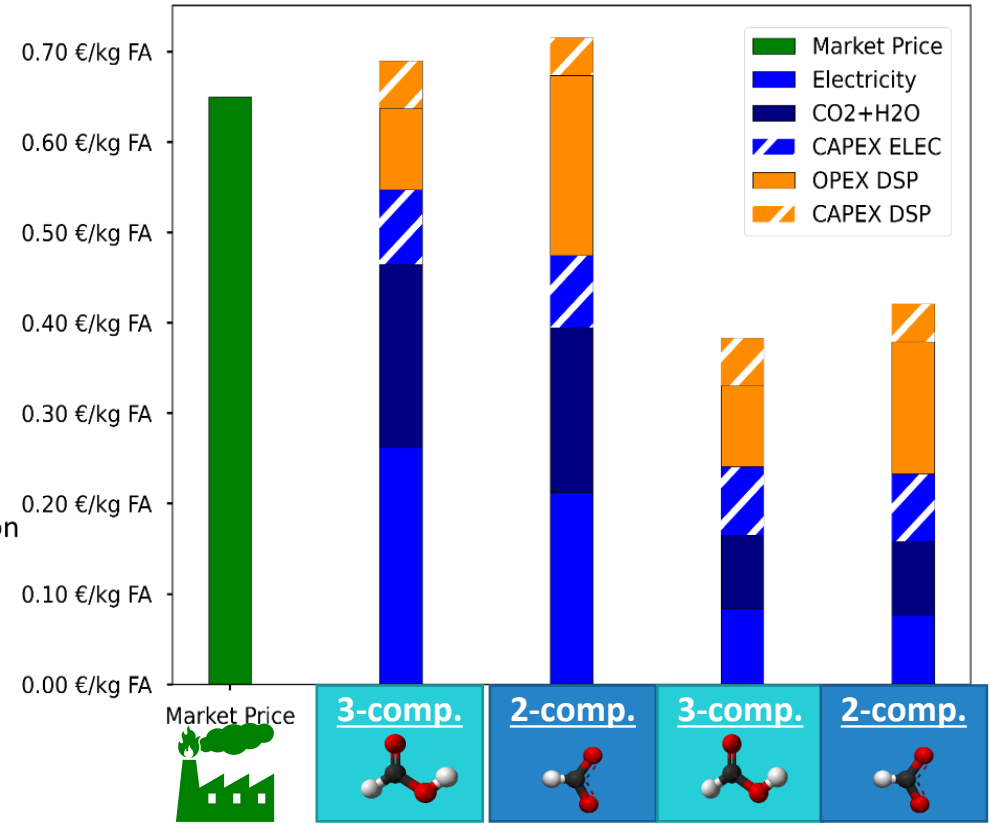


Delivered & commissioned by end 2022

Techno-economics & business case Direct Route



- ***BMED***: Bipolar Membrane Electrodialysis
- ***LBS Ext. + Dist.***: Low Boiling Solvent Extraction + Distillation
- ***Azeot. Dist.***: Azeotropic Distillation



2-comp.
Formate ($HCOO^-$)
- Better electrolysis performance
- Costly protonation

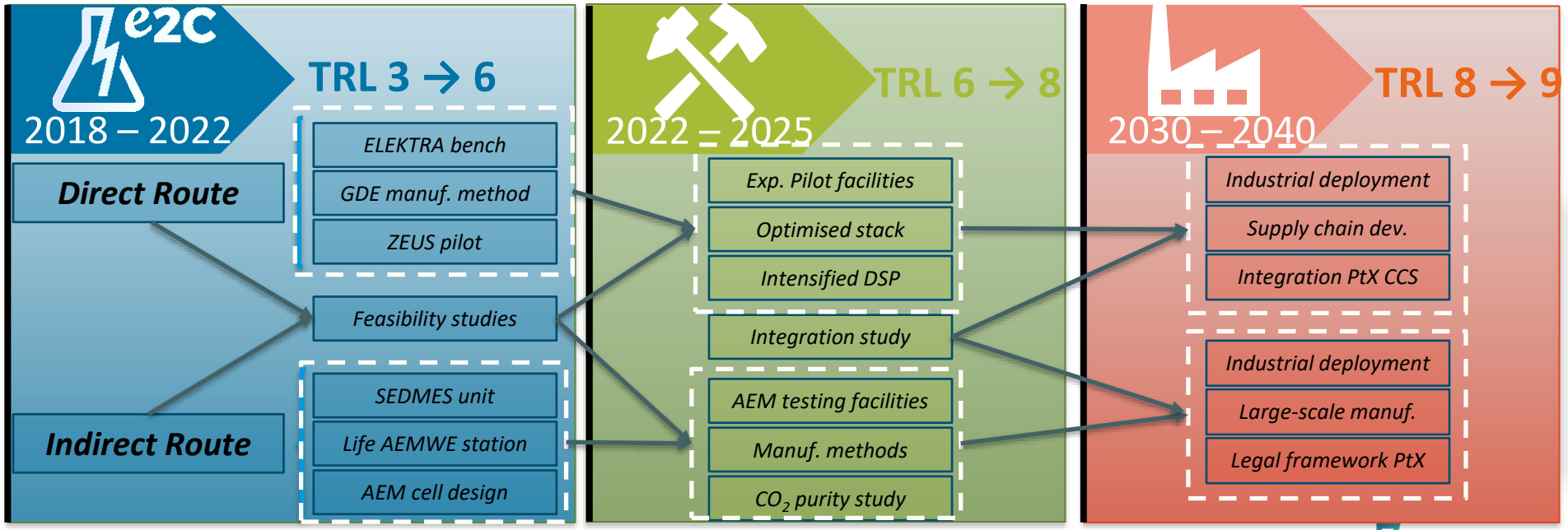
3-comp.
Formic Acid
- Direct FA production
- 1-step DSP

Conclusions & next steps in CO_2-2-FA direct conversion

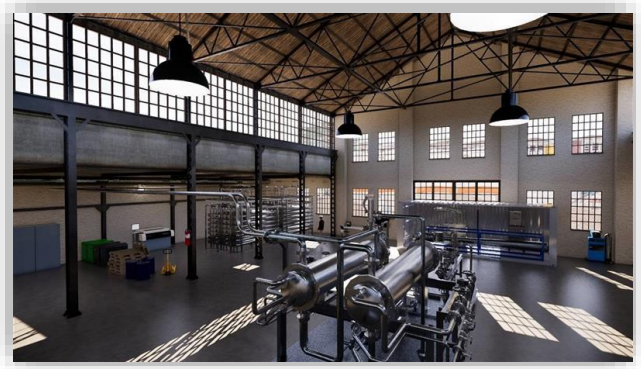
- Scale-up of Direct Route CO_2-2-FA
- Developed pilots to be placed in Field Lab
- Further research to be continued under *Kansen voor West II*
- Technology Implementation Plan Direct Route


TRL3


TRL6



FIELDLAB
INDUSTRIAL ELECTRIFICATION



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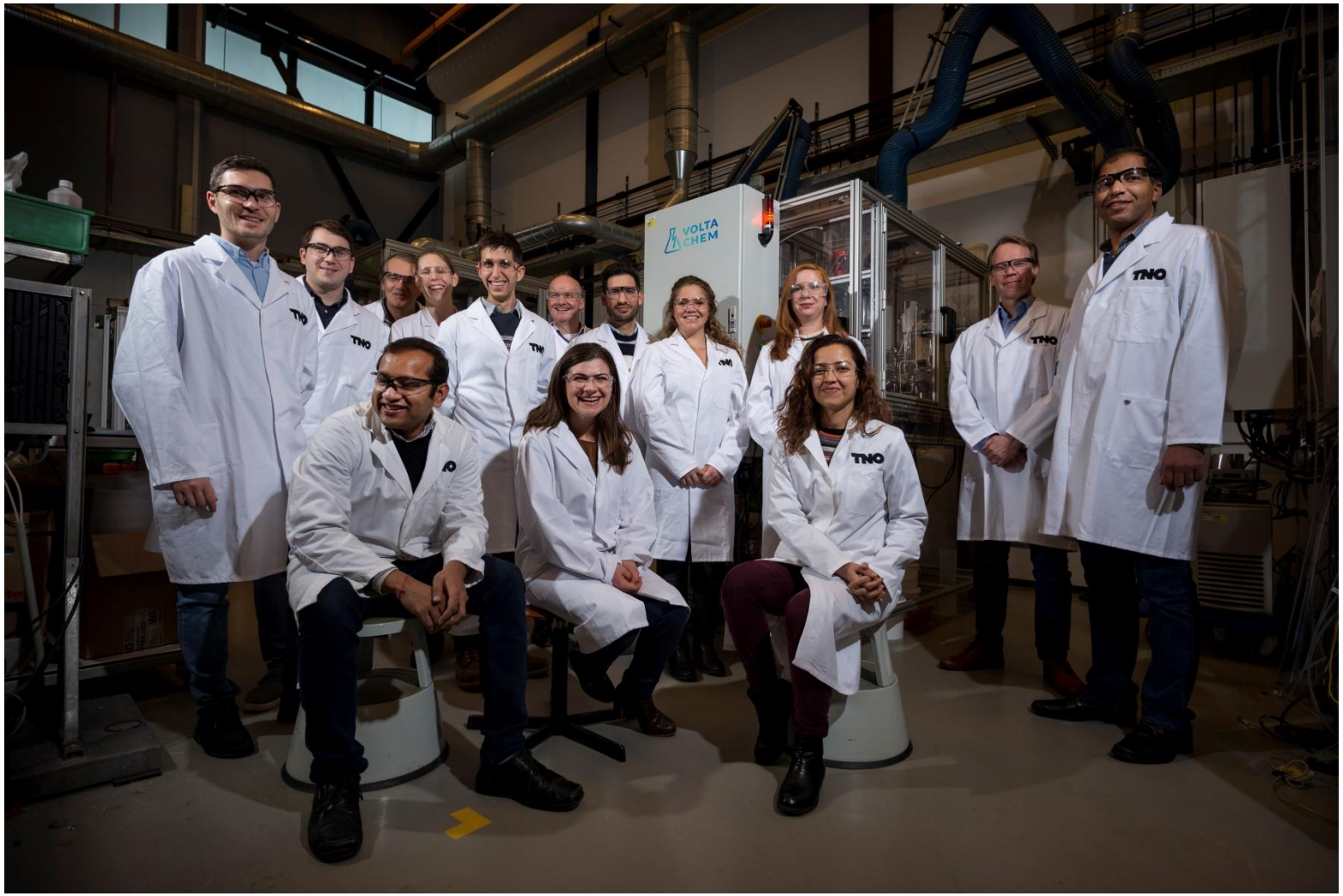
The team that made it possible



Thank you for your attention

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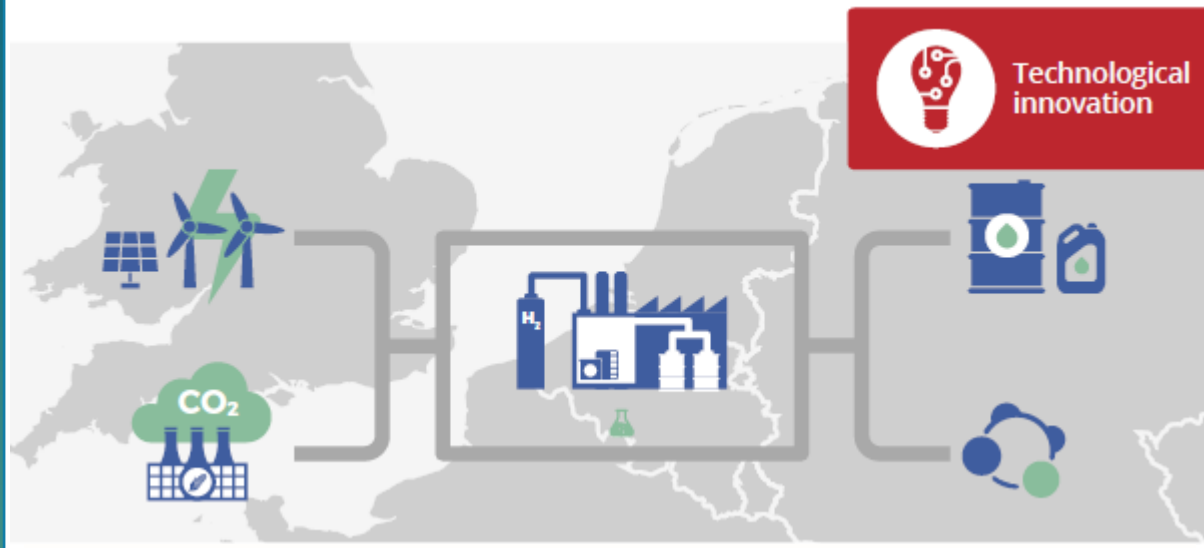
Twitter: @e2Chem2Seas

Web: www.voltachem.com/E2C



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TNO innovation for life

The University Of Sheffield.

University of Antwerp

Université de Lille

UNIVERSITY OF EXETER

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