Powering the Future

Advancing Electrochemical CO_2 Conversion with the WaterProof Project

Annelie Jongerius - Carbeau

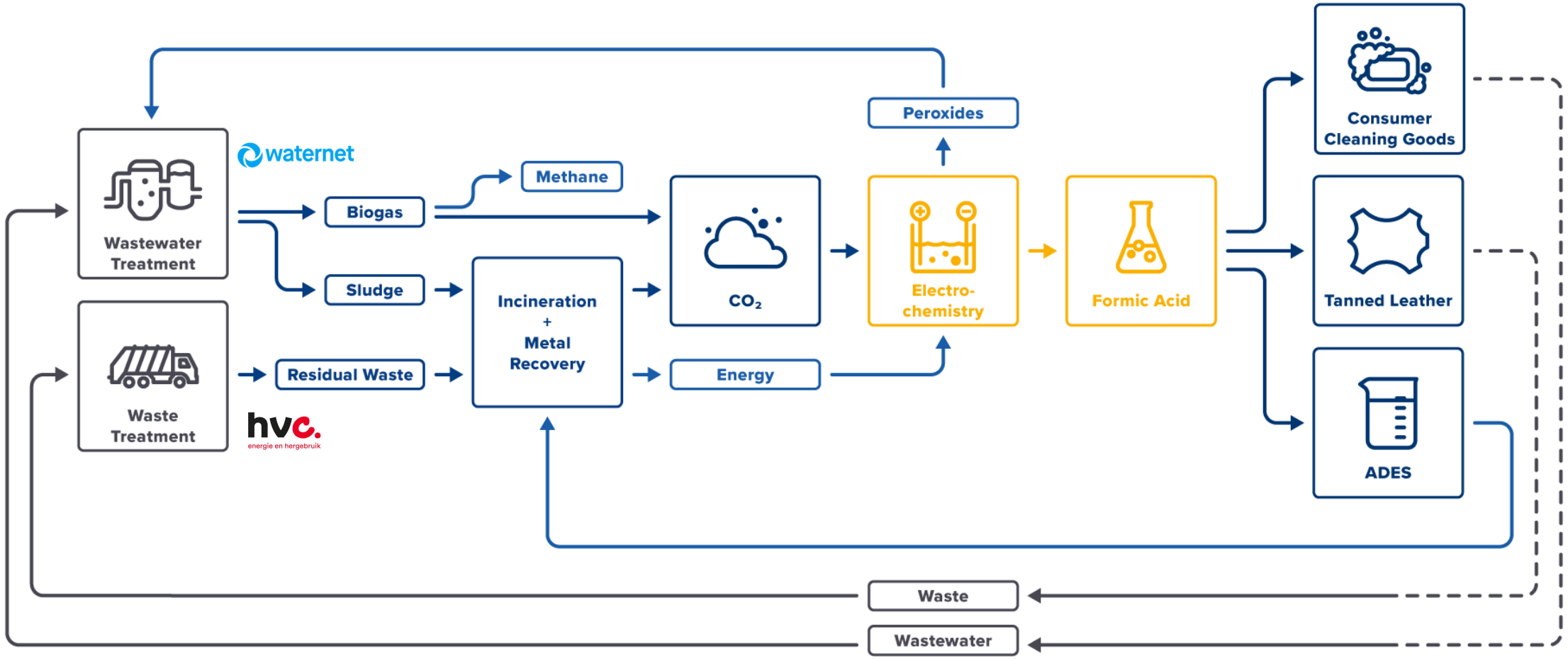
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Funded by the European Union

Agenda

9:30	**Welcome and reception**	
10:00	Introduction to the WaterProof Project	Annelie Jongerius (Carbeau)
10:30	Acidic deep eutectic solvents (ADES) synthesis an application to recover metals from wastewater sludge and incineration ashes	Guillermo Pozo Zamorza (Tecnalia)
11:00	Waste valorization trough CCU implementation	Jan-Peter Born (HVC):
11:30	Industrial Urban Symbiosis	Alena Jahns (IZES)
12:00	**Lunch, posters and plant visit at Brineworks**	
13:30	Carbeau campaign: Waterproof and beyond	Julia Krasovic (Carbeau)
14:00	Guest project introductions: ICO_2NIC	Frank Kensy (b.fab)
14:15	Guest project introductions: HICCUPS	Robert-Jan van Putten (Parana Materials)
14:30	Panel discussion	
15:00	Closing and wrap up	
15:13	**Handover certificates of participation**	

WaterProof Concept



The WaterProof Technology will convert CO_2 from wastewater and waste incineration to formic acid to make cleaning products, leather, and metal recovery agents

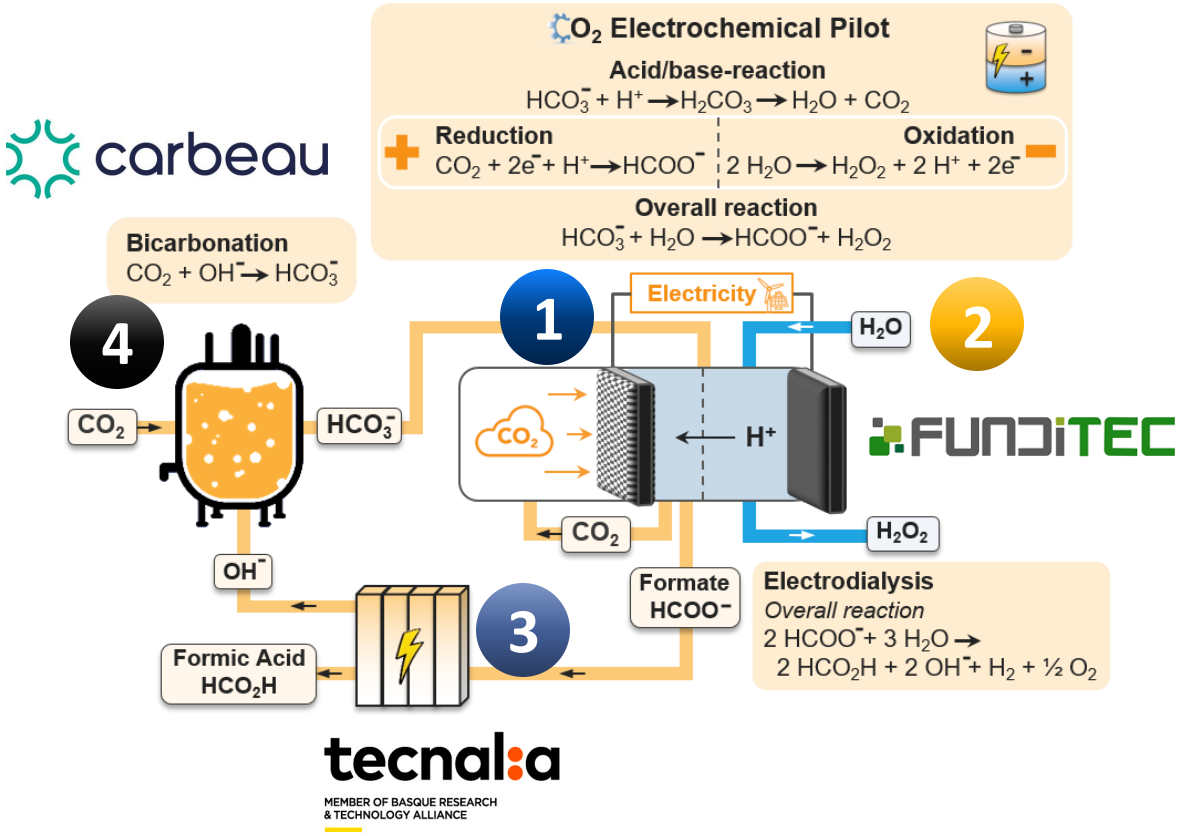
CO_2 conversion to formic acid

1. **GDE cathode:** Direct CO_2 feed avoids solubility limits and produces formate at industrial current densities

2. **Counter electrode:** Water oxidation produces OH radicals and H_2O_2 for waste water treatment

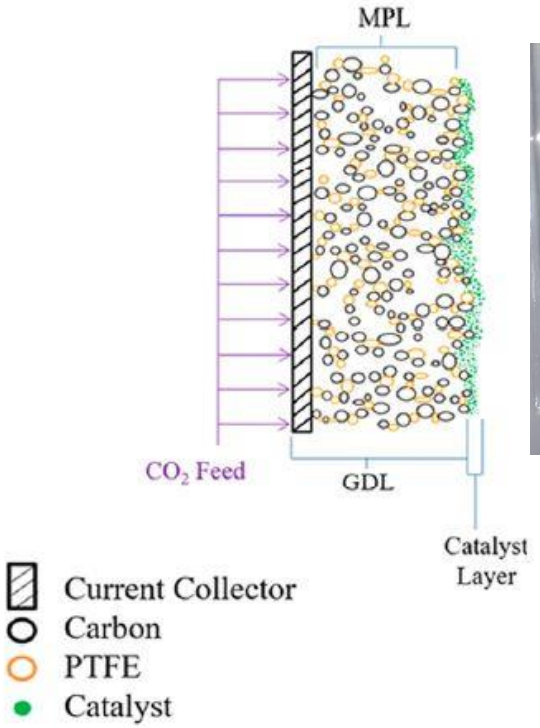
3. **Electrochemical acidification:** Formate is converted to formic acid using electrochemically generated protons

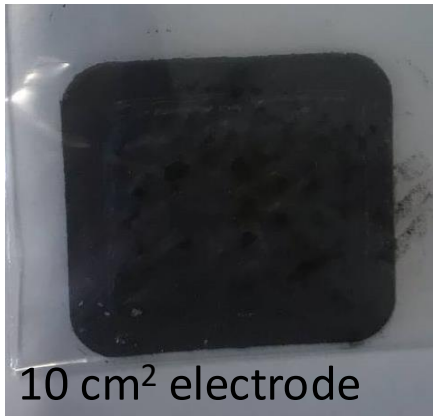
4. **CO_2 and K recycle:** KOH and CO_2 can be reacted to form bicarbonate which is recycled back in the reactor.



Catalyst and electrode R&D

GDL + catalyst layer combination is tested to determine performance and mechanical stability





Consistent research in improved high-throughput testing stations with identical configuration



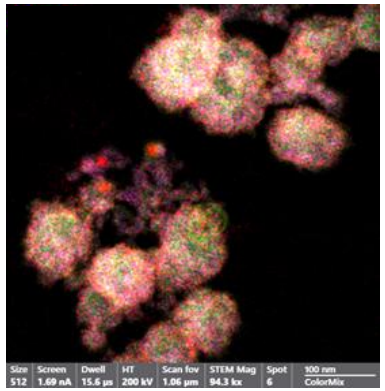
Catalyst and electrode R&D

Utrecht University

In-house:

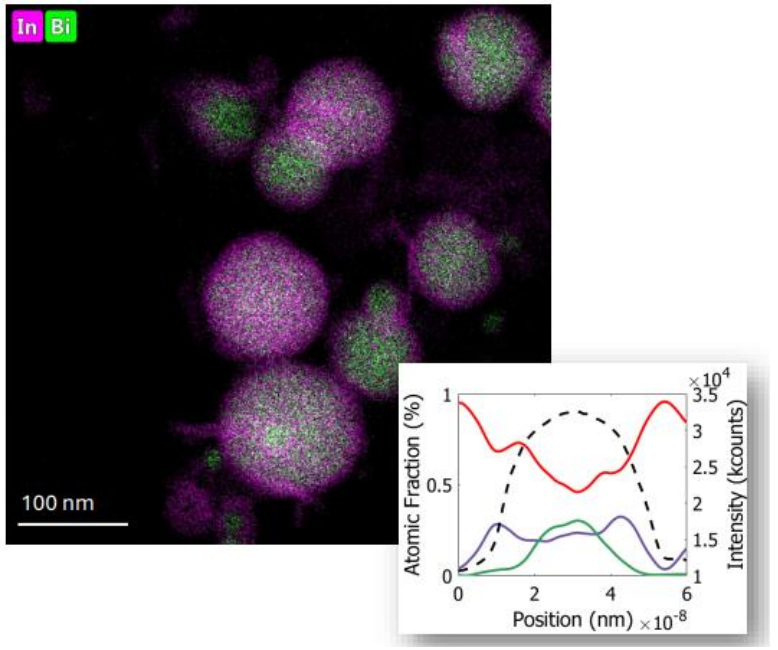
Catalyst development and testing

- Improved synthesis methods
- Catalyst composition
- Lifetime studies



Collaboration:

Detailed catalyst characterization and behavior



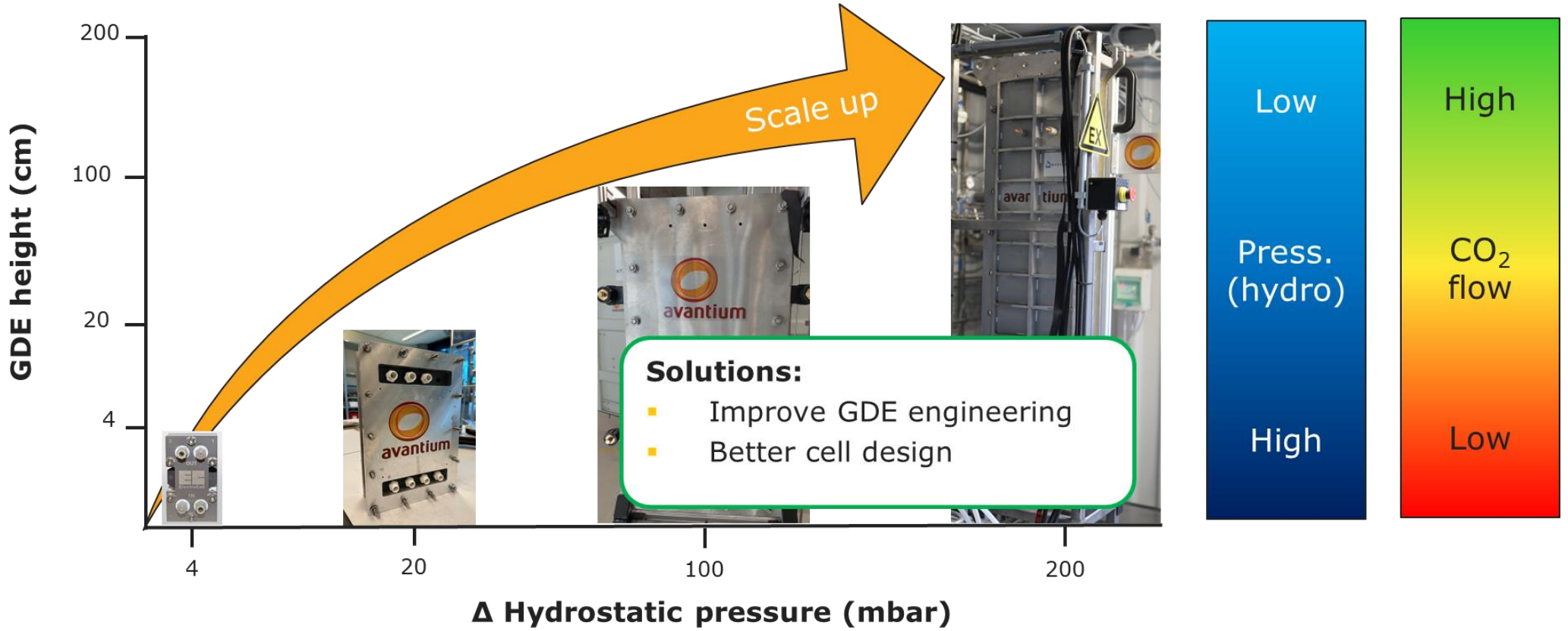
carbeau

M.F.Philips *et al., ACS Appl. Energy Mater.* **2022, 5**, 2, 1720-1730.
M. Biggiero *et al., submitted*
WO2025/229144 A1

Cell and GDE scaling challenge

Traditional GDEs have a low pressure drop (<100 mbar)

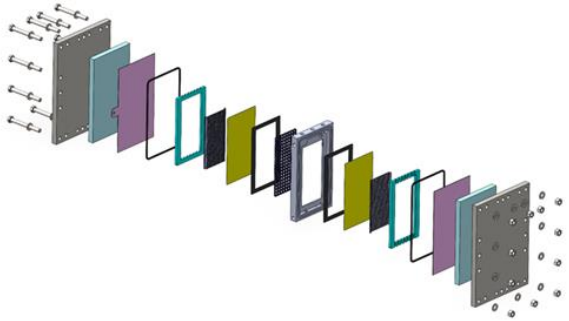
$P_{Hydrostatic} > P_{drop}$ GDE

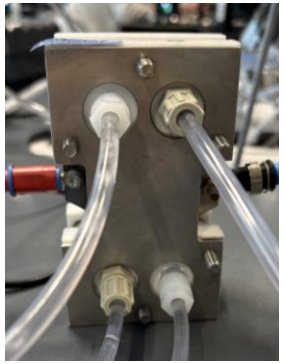


New cell designs WaterProof

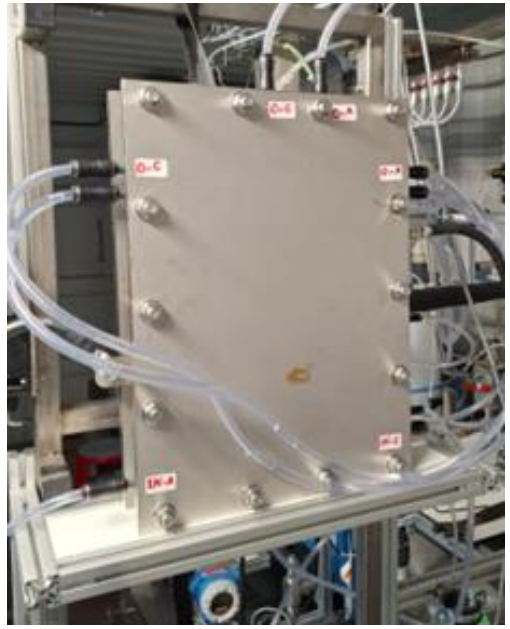
Improved designs for 500 cm² and 2000 cm²

- Lowered cell voltages
- Easier assembly and connecting
- Stacking
- Benchmarked in lab against 10 cm²



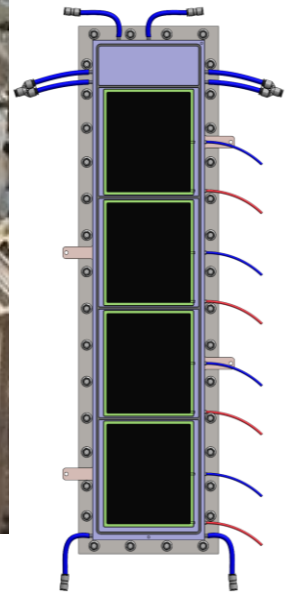


10 cm²



500 cm²





2000 cm²

Collaboration on electrode upscaling

Transfer the manufacturing process from a laboratory scale to an industrial scale



Manual



Roll-to-roll

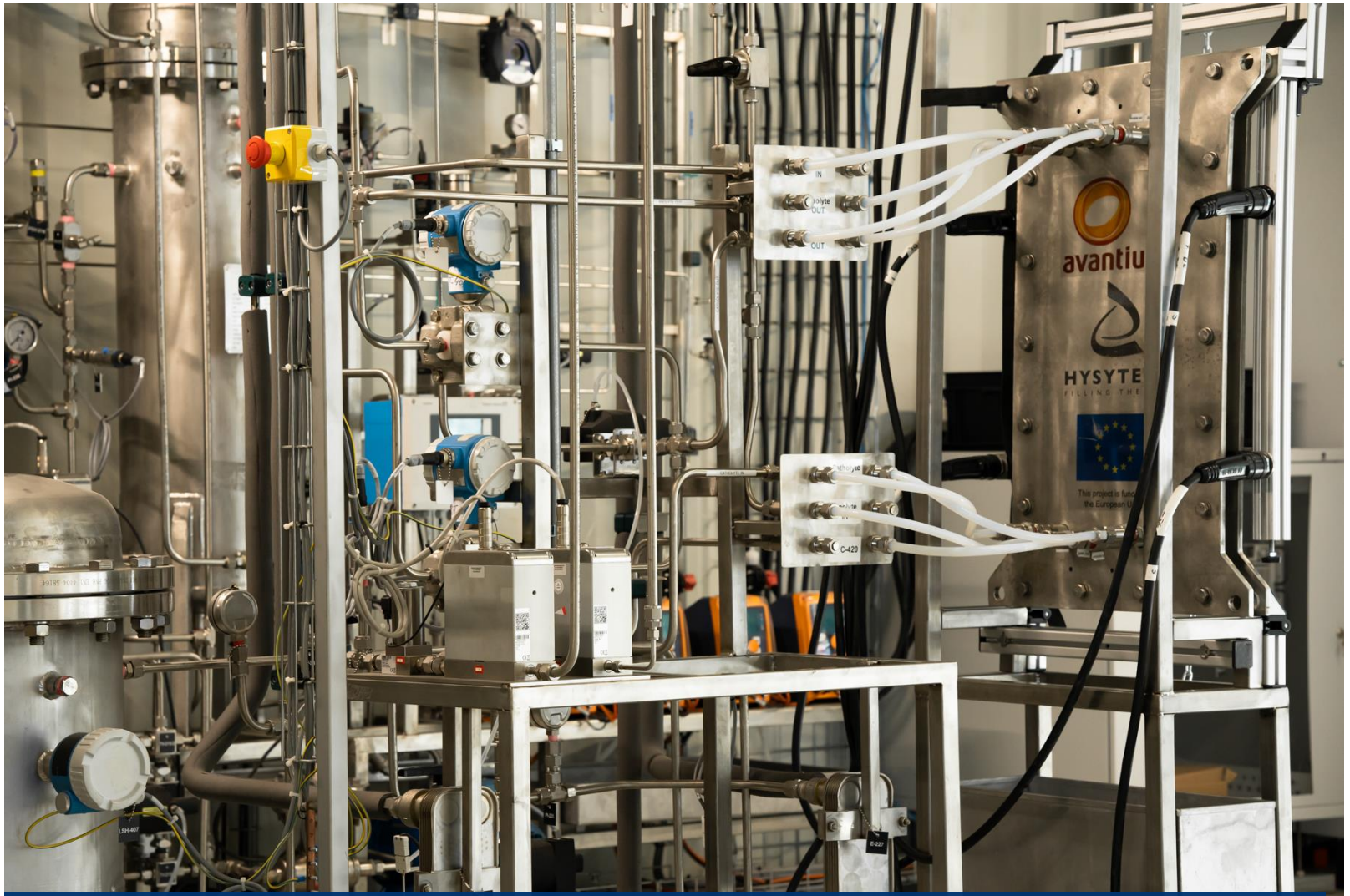


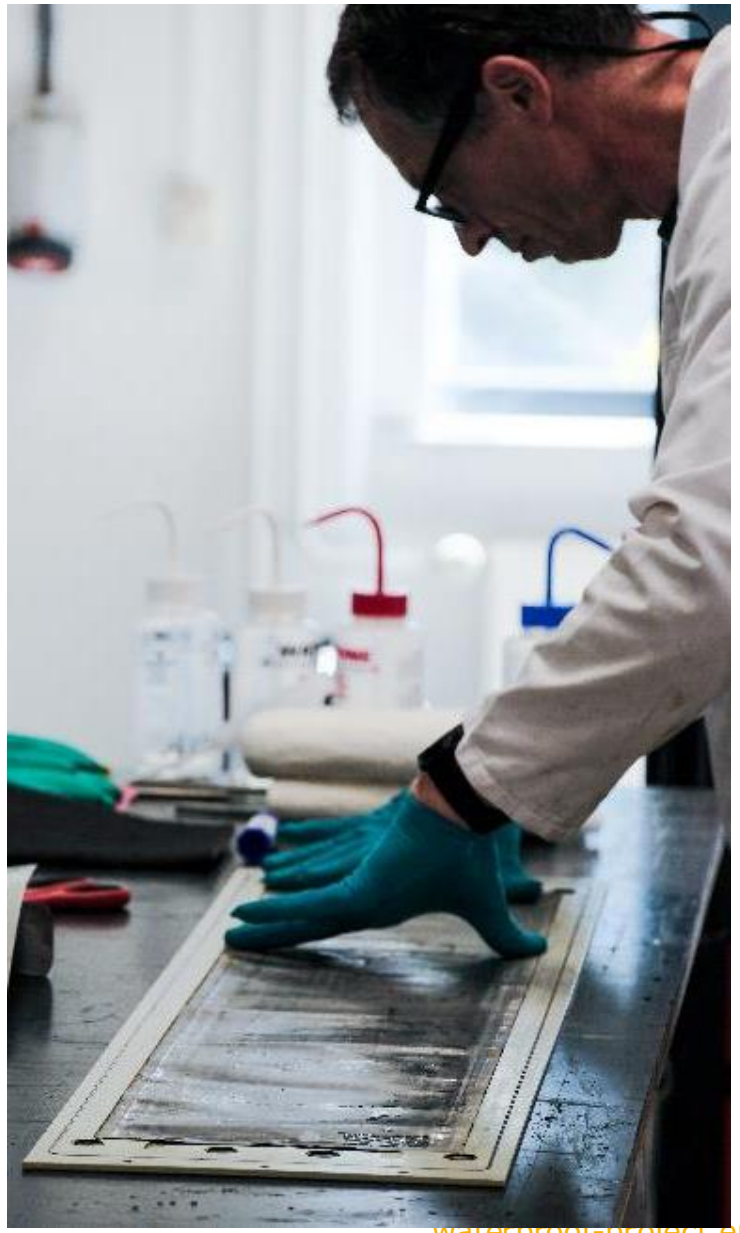
Characteristics of the gas diffusion layer

- Controlled porosity and pore structure
- Hydrophobicity
- Mechanical durability and compressibility
- Even surface and uniform structure

carbeau

Coatema® Coating Machinery GmbH





Pre-pilot demonstrators

WaterProof pilot











Coraltech BV

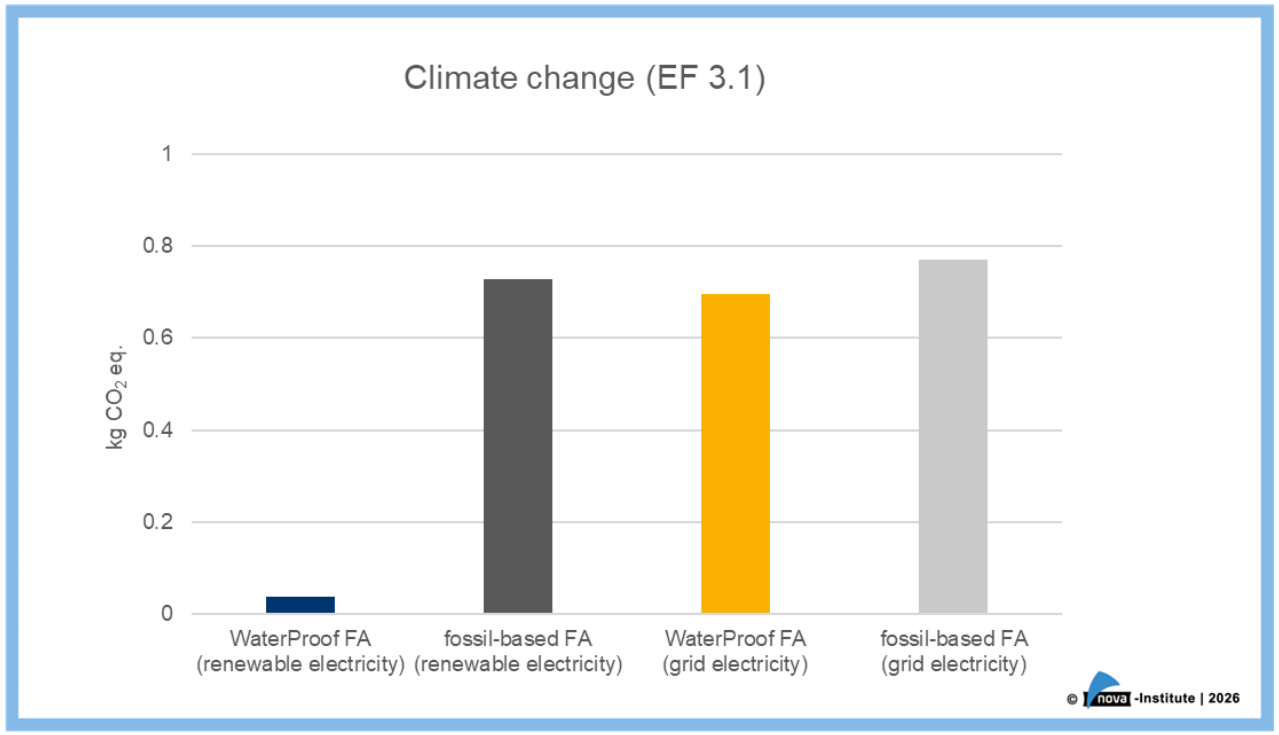




hvc. energie en hergebruik

Comparing fossil-based vs. WaterProof Formic acid

CCU route can deliver substantial climate benefits with low-carbon electricity



- WaterProof FA shows very low GHG emissions with renewable electricity (~0.04 kg CO_2-eq/kg)
- 90–95% reduction vs. fossil benchmark under renewable scenario
- With grid electricity, WaterProof FA increases to ~0.69 kg CO_2-eq/kg
- Still slightly below fossil-based FA under grid conditions (~0.77 kg CO_2-eq/kg)
- Electricity supply is the dominant driver of climate impact (clear hotspot)
- Strong sensitivity to power source decarbonisation

Formic acid functionality and applications

- Metal extraction and descaling
- pH control and neutralization
- Chemical synthesis

NORDIC FISH LEATHER iceland

tecnalia
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

Consumer cleaning products
Testing formic acid as sustainable and circular descaling agent for limestone in toilet cleaner





Leather tanning and dyeing
Testing formic acid produced in leather tanning processes to produce sustainable fish leather.

Production of acidic deep eutectic solvents (ADES)
Used to recover metals such as Cu and remove heavy metals such as Pb from different waste streams.



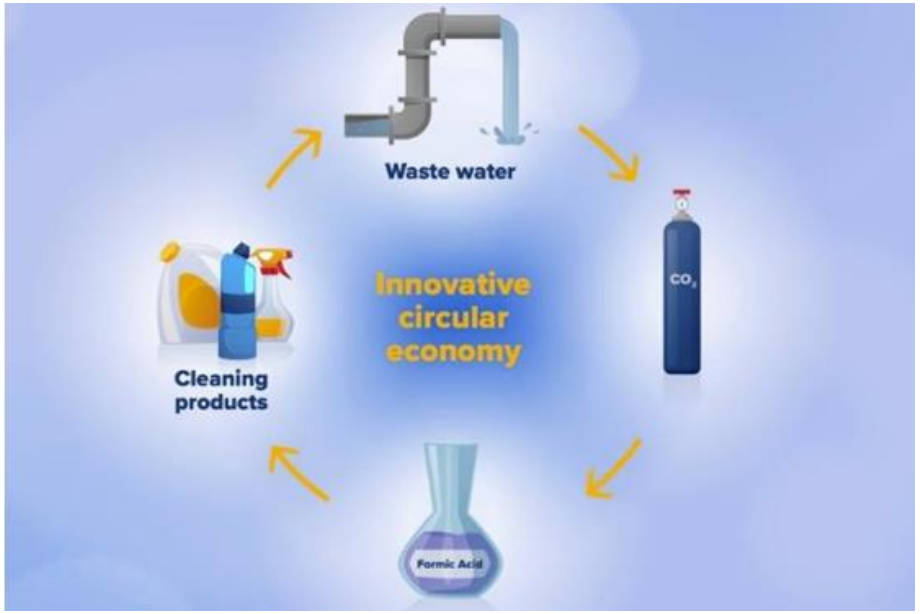
Consumer perspective on CO_2 based products

Literature study, online questionnaire and in person pre-study

Cleaning products are frequently purchased; how can consumers be encouraged to choose CO_2-based products?

- Sustainability is important, but after price and effectiveness
- Decisions are influenced by external factors:
  - Overall prices,
  - Surroundings in the store
  - Social context

- Public awareness of using CO_2 as a feedstock is limited
- High desire for information and transparency on packaging



Replication potential → Medellín (Columbia)

Replication advantages

- Concentrated, stationary cement emissions align with export-oriented textile and leather off-takers for green chemicals.
- Sufficient availability of renewable energy

Conditions for deployment

- Policy recognizes CCUS, but operational CO_2-utilization credits and incentives for downstream adoption remain absent.
- Large exporters show readiness. SMEs need financing and technical capacity to adopt green chemicals.



Cement-sector CO_2 and textile/leather demand offer a promising pathway for WaterProof formic acid.

WaterProof public deliverable D4.4: Replication assessment for inception in Medellín

Outlook CO_2 to formate



Pilot plant



2022	2026	Future
Single cell (0.2 m^2)	Stacked cells (1 m^2)	Full stack
250 g/h formate	5 kg/h formate	100-ton formate/year
1000+ hours stability	Salt recovery & product separation	Fully integrated upstream & downstream

Thank you for your attention!

Funded by the European Union

The Waterproof consortium

NORDIC FISH LEATHER iceland

Coraltech

avantium

hvc energie en hergebruik

waternet

FUNDITEC

tecnalia MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

nova Institute for Ecology and Innovation

dta

izes gGmbH Institut für ZukunftsEnergieSysteme

carbeau

