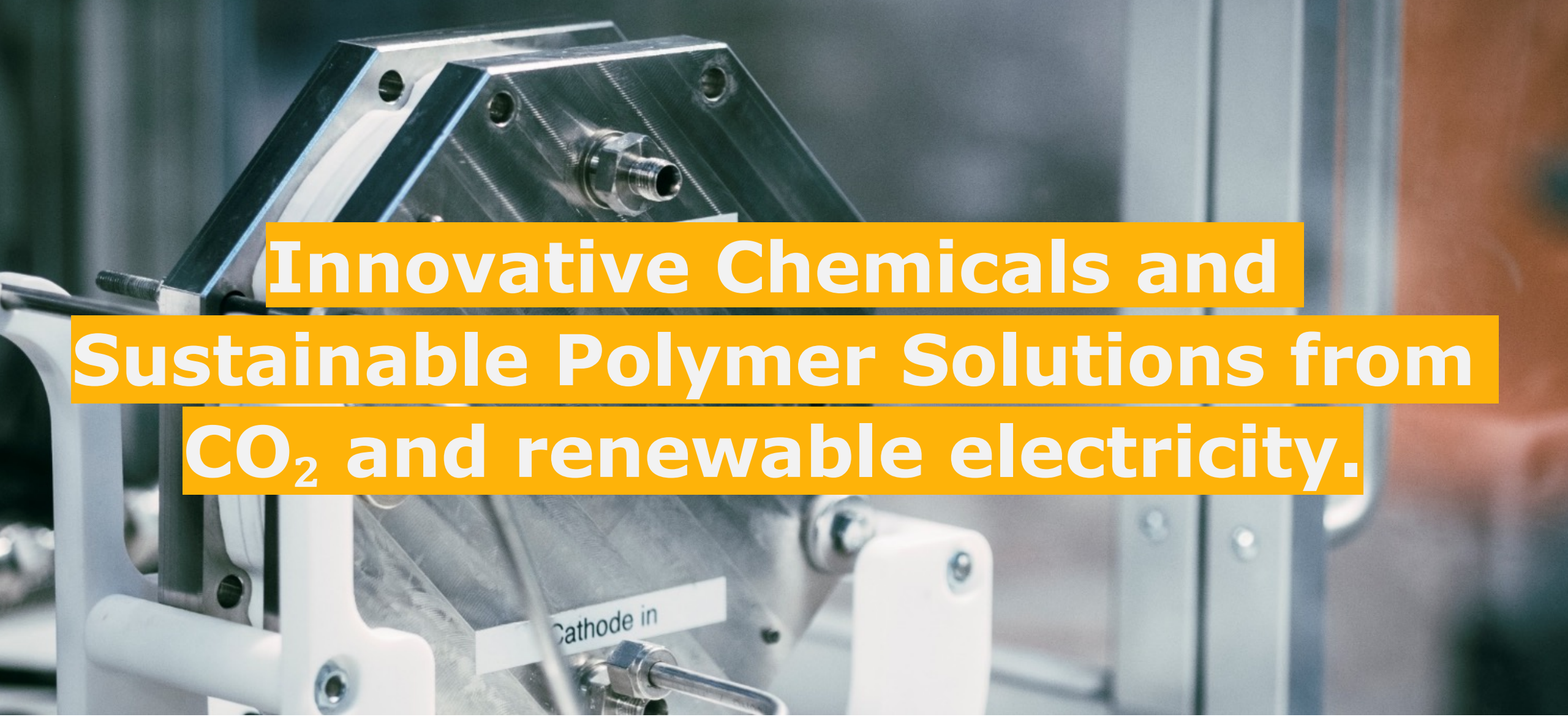

Innovative Chemicals and Sustainable Polymer Solutions from CO_2 and renewable electricity.

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WaterProof Webinar - CO_2-derived chemicals

Dr. Eric Schuler – Electrochemical Process Engineer

WATER PROOF

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EURONEXT

Ticker: **AVTX**
Amsterdam & Brussels

Headquartered in **Amsterdam**

150+ patent families

300+ employees

>75% scientists
35 nationalities

releaf

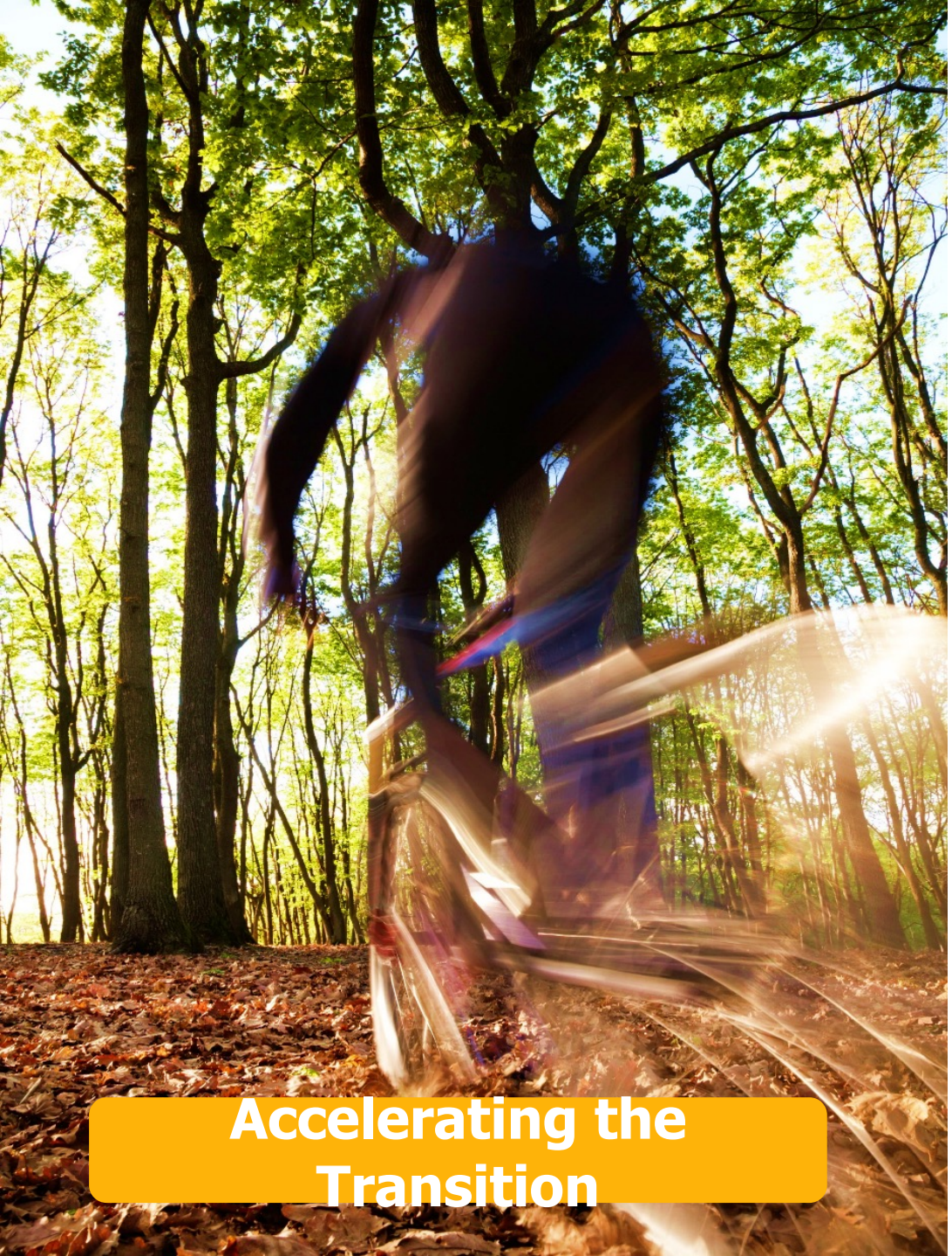
PEF a bio-based PET alternative

VOLTA

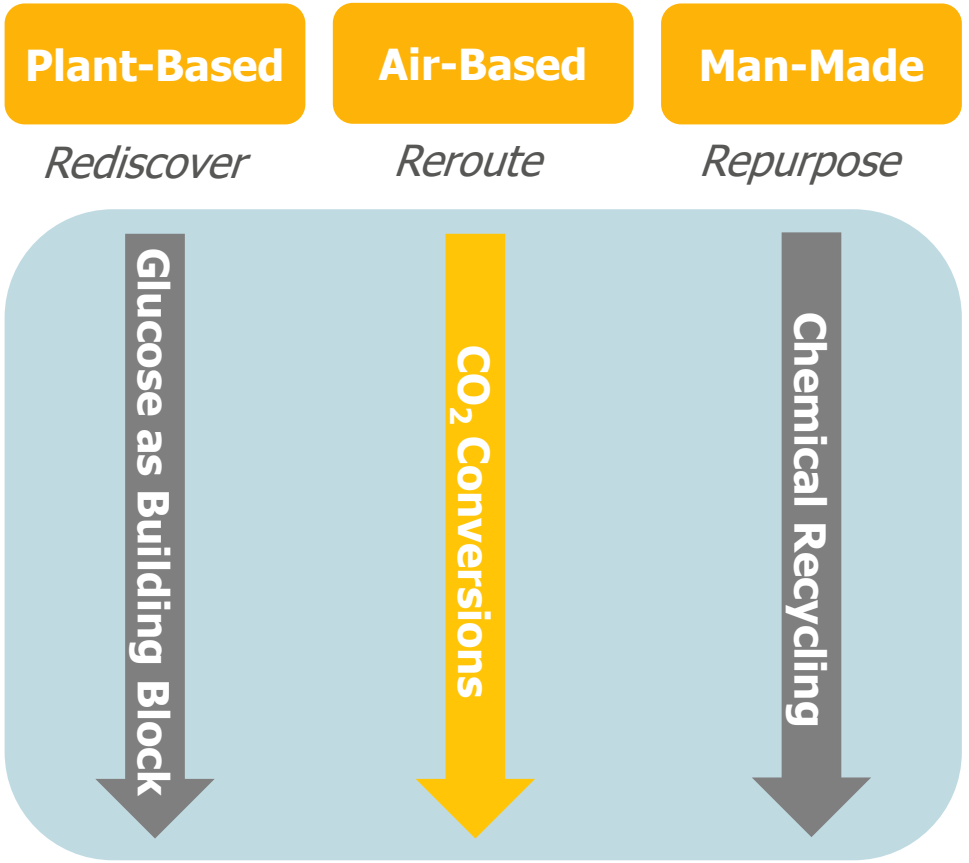
Converting CO_2 into chemicals & polyesters via electrochemistry

R&D Solutions

Foundational Technical Expertise
Leading Systems and Services Provider for Catalyst R&D



There are only three renewable carbon sources available in this world…



…that enable a circular economy

We are unique in converting CO_2 into sustainable ingredients

2012 Volta founded as Liquid Light

2016 Acquisition of LIQUIDLIGHT Princeton start-up with > $30M invested

2025 Technology frontrunner: >35 collaborations; extensive IP portfolio

Excellent electro-catalysis expertise	Winning technology for CO_2 conversion	Powerful economics by paired electrolysis	Ready to scale out	World leading IP position
Avantium is a leading catalysis company	High productivity High energy efficiency	Co-production: creating value at both electrodes	Scale out, not scale up Developing TRL6 scale	32 IP families 112 IP rights (36 US)
CONVERSION	INGREDIENTS	PROCESSES	ENGINEERING	DEPLOYMENT

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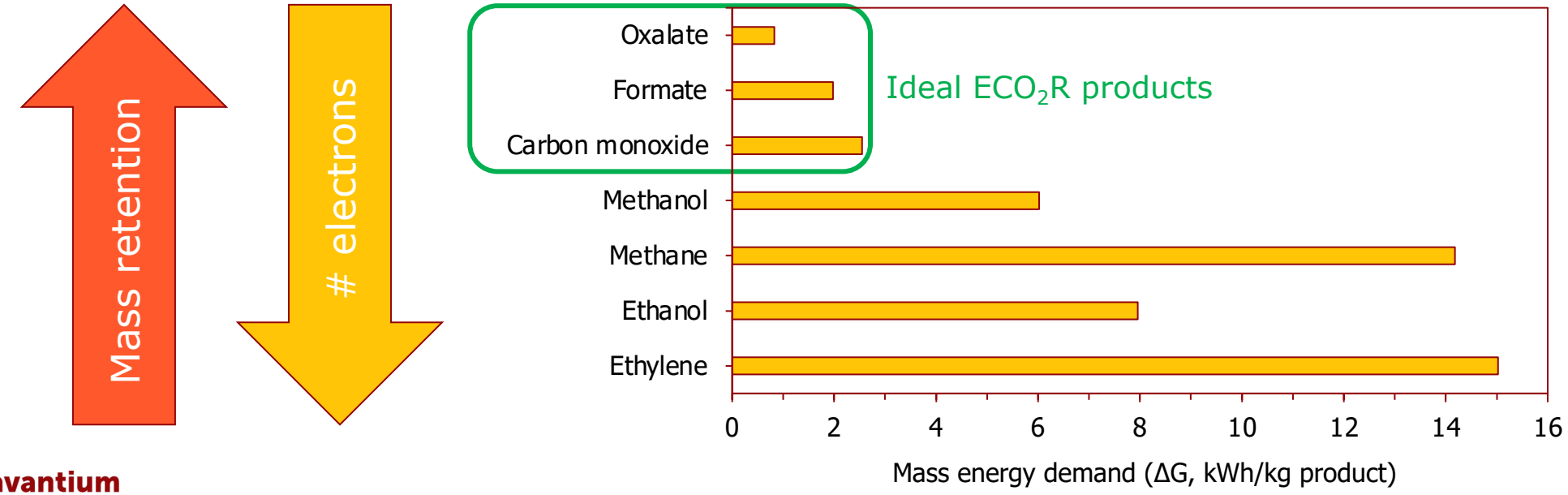
VOLTA Making use of electrons to convert CO_2

- Valorization of CO_2, reduces fossil carbon demand
- Abundant carbon source, needs to be removed from atmosphere
- Potential to couple with renewable electricity
- Broad product range for low temp. ECO_2R



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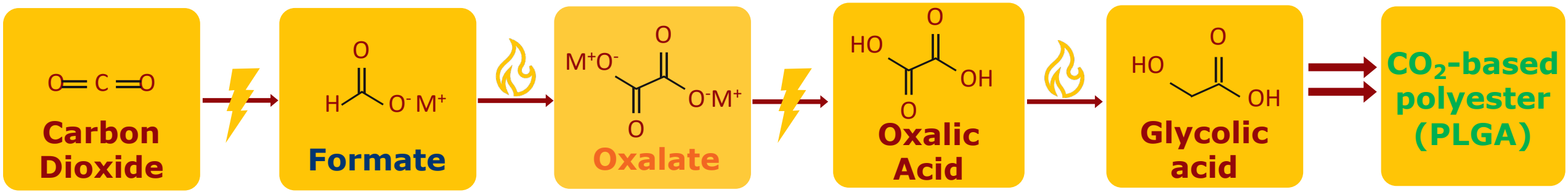
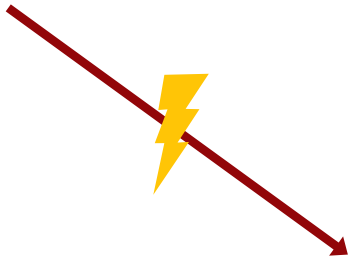
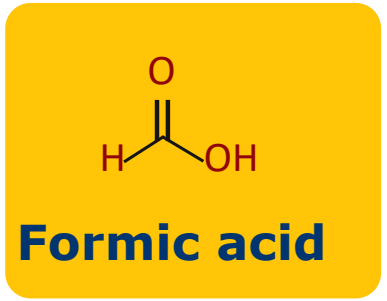
Pathway to products from CO_2



- Beauty industry





- Drop-in for existing market
- Emerging applications

Electrochemical

Thermochemical

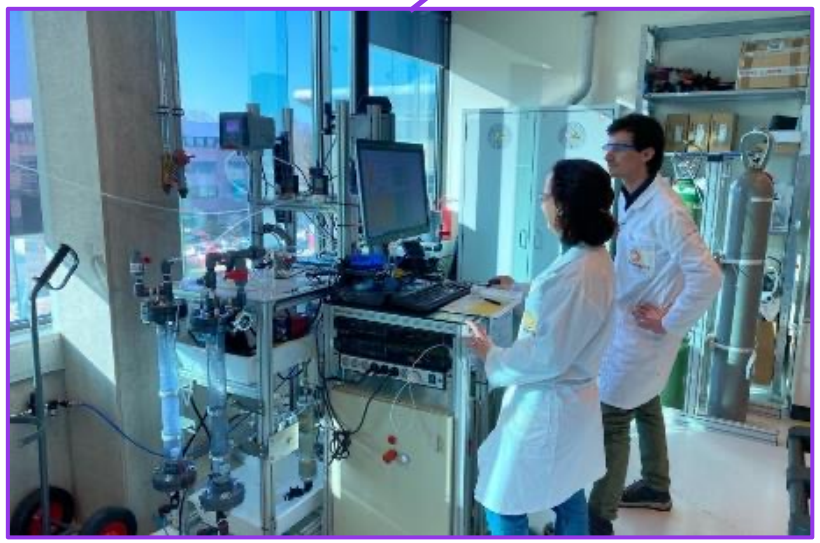
WATER PROOF

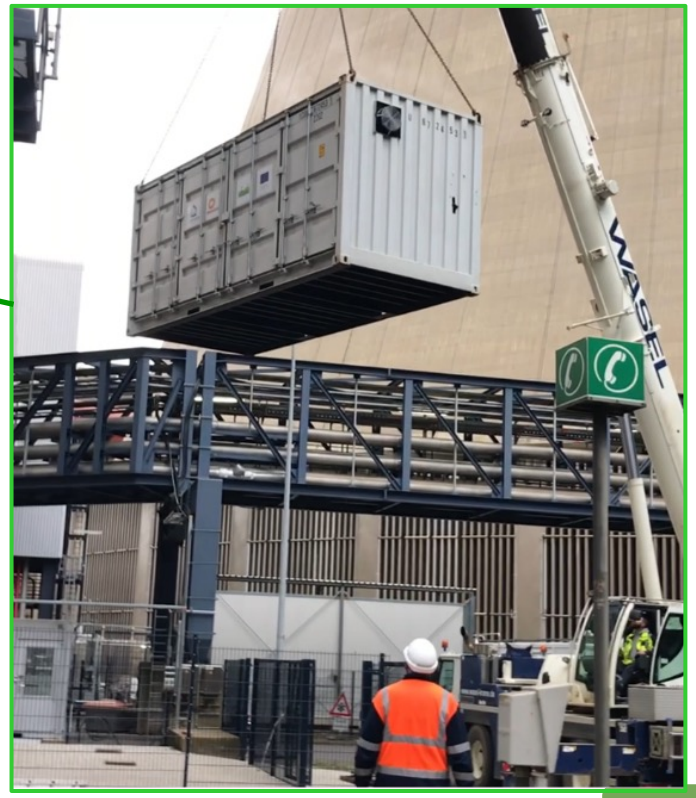
ICO_2NIC

Making Formate at Relevant Scale

Technology Readiness Level (TRL)

TRL	1	2	3	4	5	6	7	8	9
Innovation phase	Applied research								
				Development					
							Deployment		





First step - Making Formate at Scale

2023	2025	2027
Single cell (0.2 m^2)	Cell stack (1 m^2)	Cell stack (6 m^2)
250 g/h formate	1.5 kg/h formate	50-ton/year formate
5000-hour stability	Salt recovery & product separation	Fully integrated upstream & downstream

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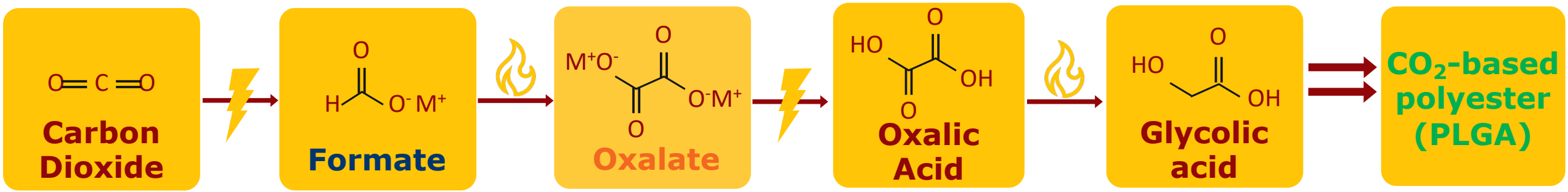
Towards a relevant process – critical numbers

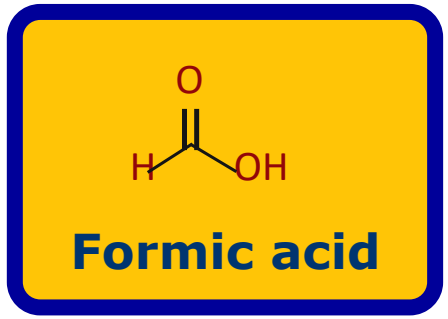
- Currently, ECO_2R to formate is at TRL 5
- WaterProof aims to develop to TRL 7
- Which technology milestones must be achieved for TRL 9 commercialization?

Milestone	Values	Industry status
Electrodes with high selectivity at high current density	>90% FE at 200 mA/cm^2	
High conversion efficiency (CO_2, energy)	~50% CO_2, energy	
High product concentration	>20% liquid/gas [product]	
Electrode lifetime	2-5 years stability	
Scalability	>1 m^2, stacked	

Pathway to products from CO_2



- Beauty industry



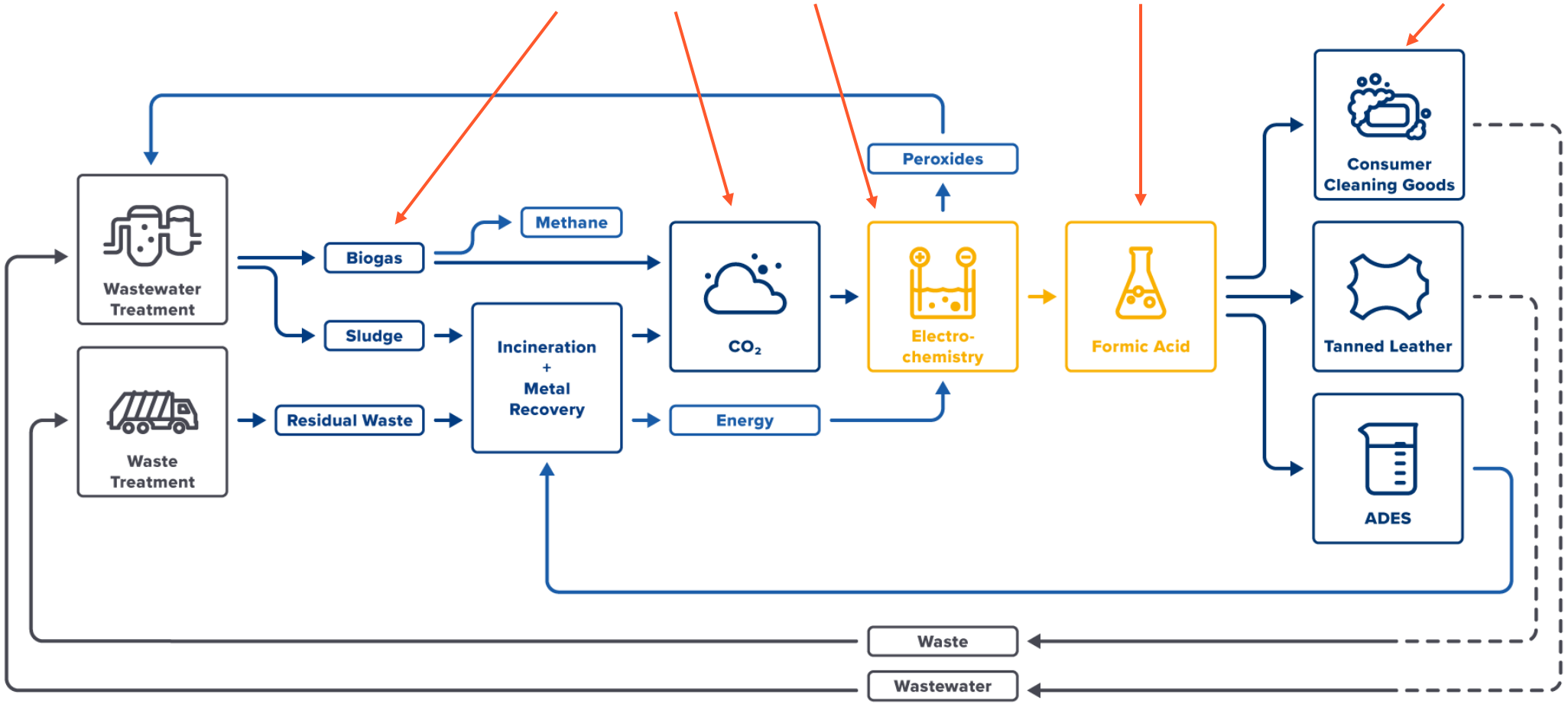
- Drop-in for existing market
- Emerging applications

Electrochemical

Thermochemical

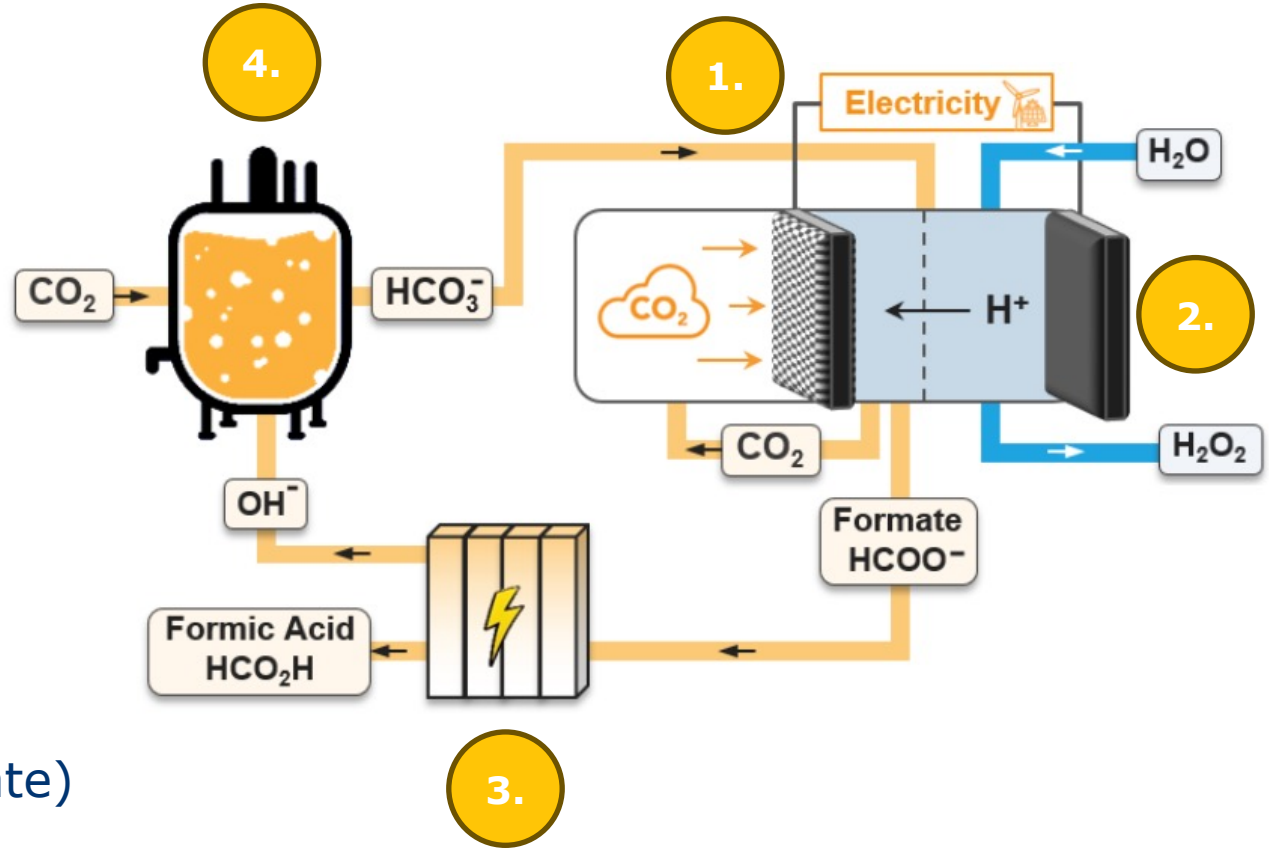
Formic acid from Biogenic CO_2

The WaterProof technology converts biogenic CO_2 via electrochemistry into formic acid for various applications



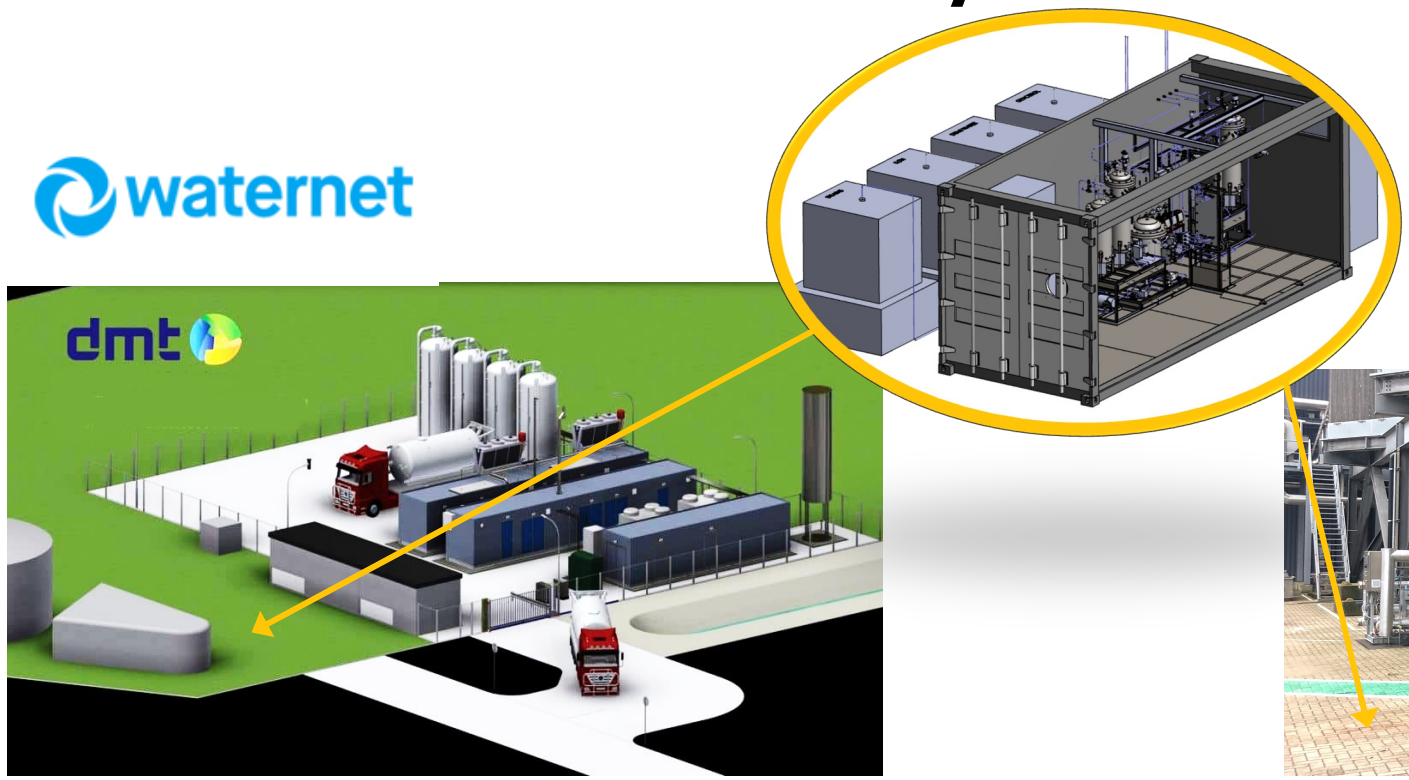
CO_2 Conversion Technology

1. Electrochemical CO_2 Reduction (ECO_2R)
   - CO_2 → $KHCO_2$ (potassium formate)
2. Anodic reaction
   - H_2O → H_2O_2 (hydrogen peroxide)
3. Electrodialysis
   - $KHCO_2$ → H_2CO_2 (formic acid)
4. Bicarbonation (electrolyte recovery)
   - $KOH + CO_2$ → $KHCO_3$ (potassium bicarbonate)



Demonstration sites

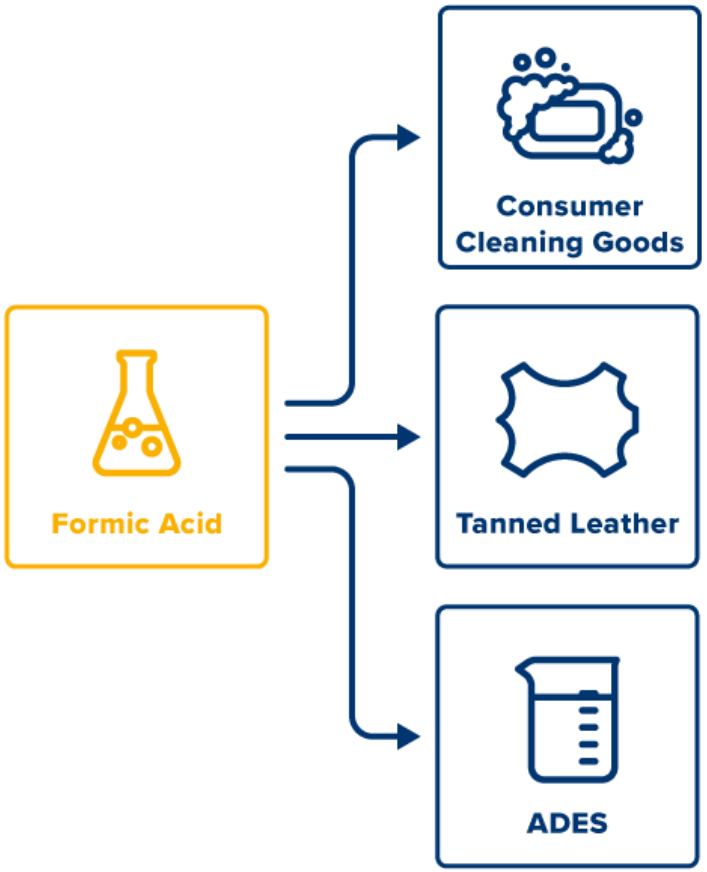
The CO2 Conversion Pilot Facility will be installed, integrated and tested:



Site 1: Water treatment facility Amsterdam
Biogas from water treatment is treated to produce green natural gas (mostly CH_4) and a CO_2 stream.

Site 2: bio-energiecentrale Alkmaar
Flue gas from B-wood incineration
CO_2 capture and liquefaction installation

Product Implementation and Value Chain Circularity

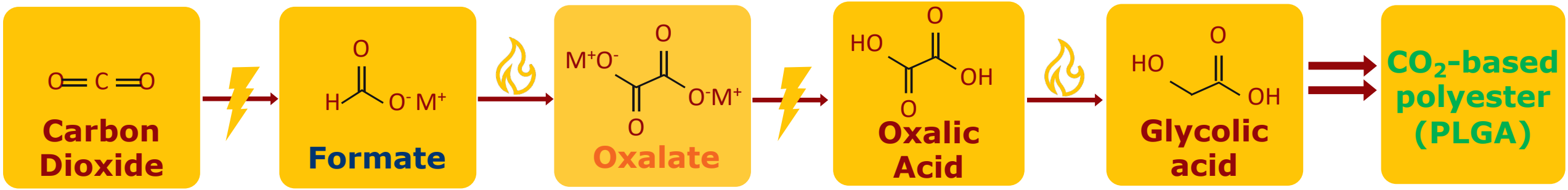


Testing formic acid as sustainable and circular descaling agent for limestone in **toilet cleaner** on a scale of 100 kg.

Testing formic acid produced in **leather tanning** processes to produce sustainable fish leather.

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

Pathway to products from CO_2



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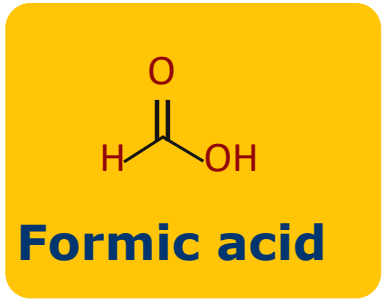
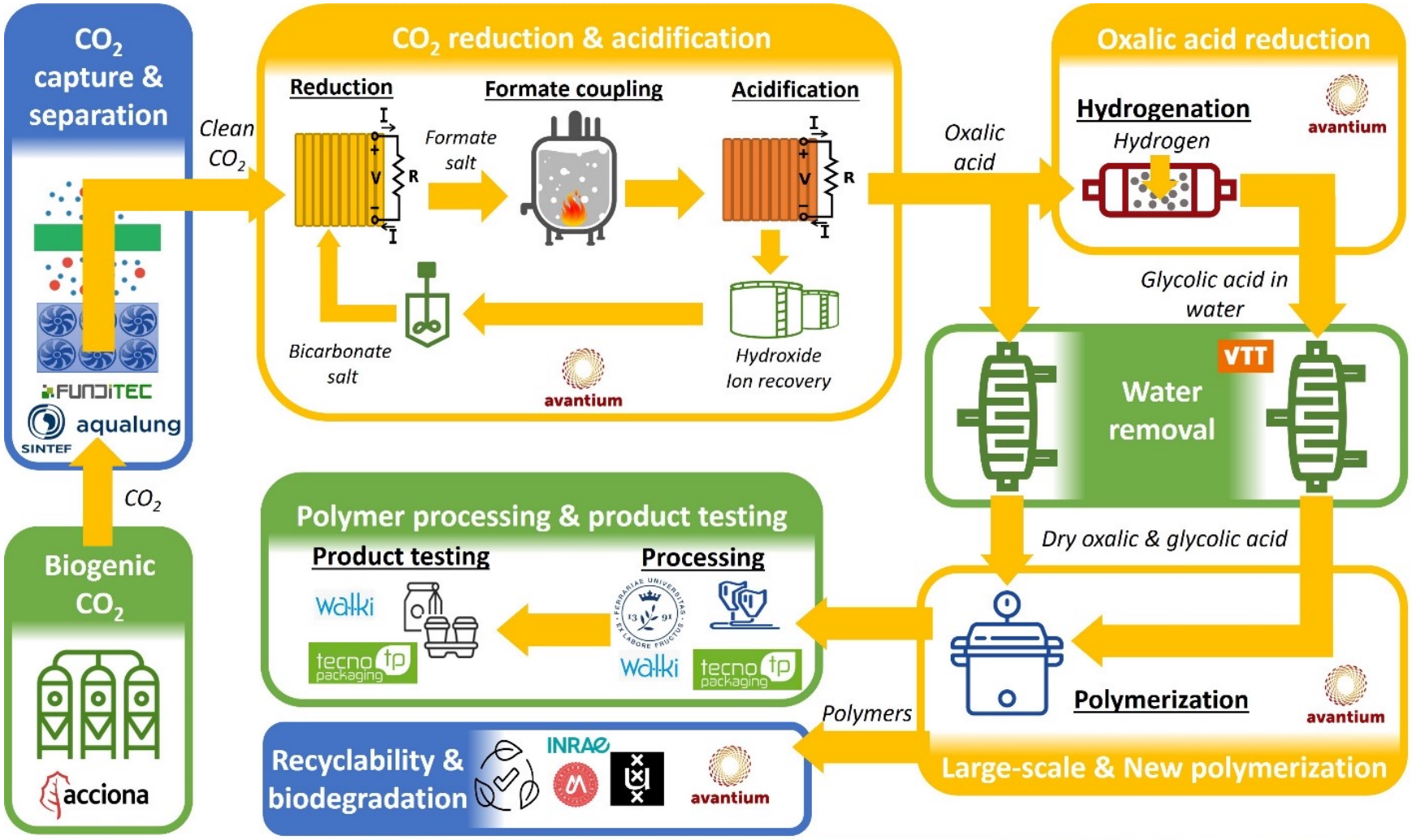


- Drop-in for existing market
- Emerging applications

Electrochemical

Thermochemical

Polymers from CO_2



Let’s make Plastic its great?

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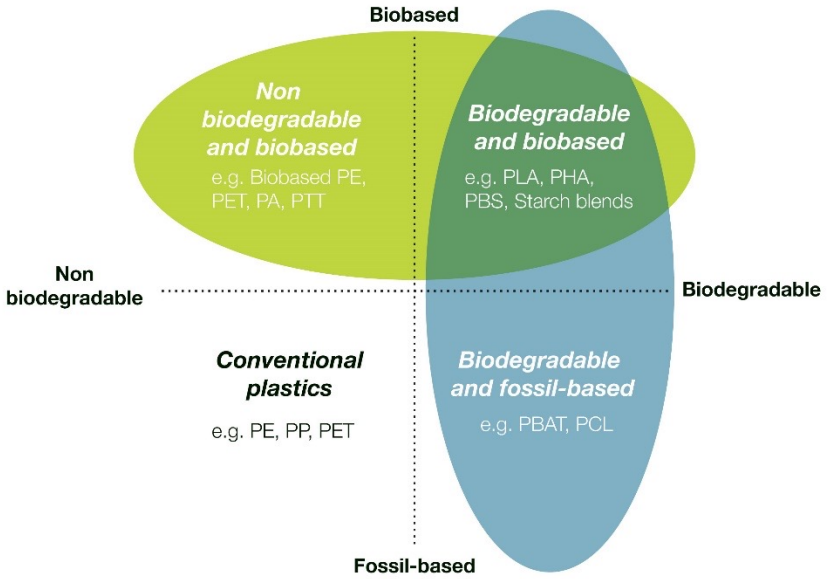
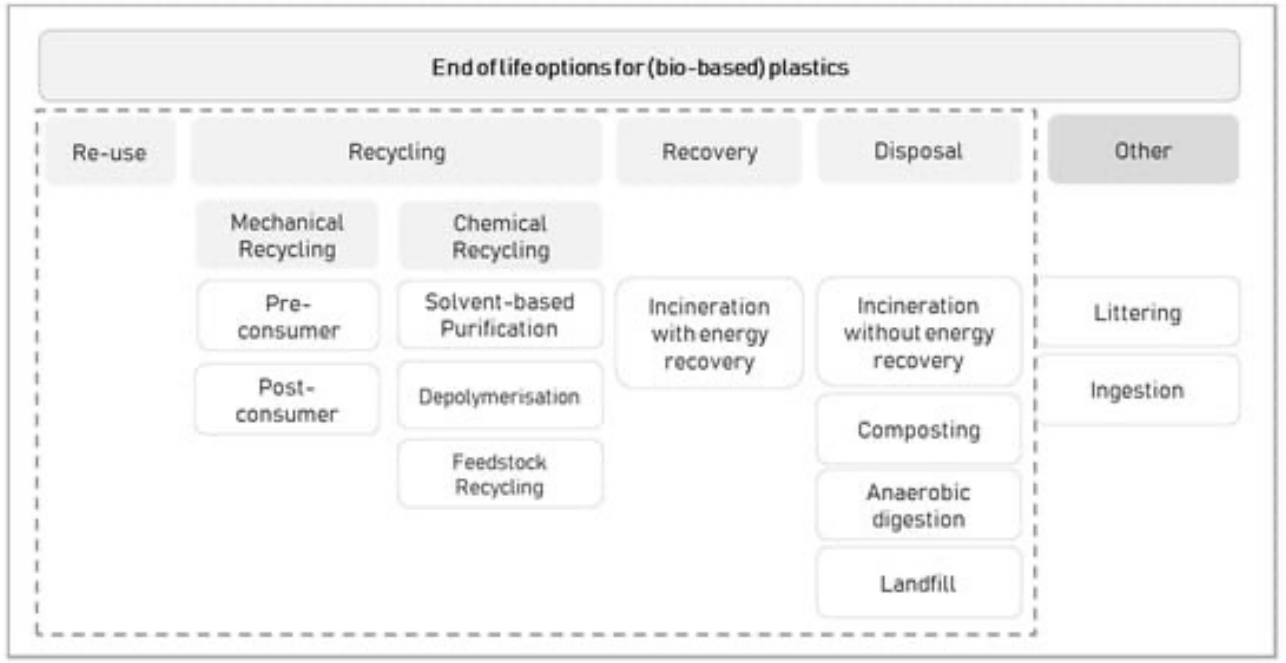
Villarrubia-Gómez, P.; Almroth, B. C.; Eriksen, M.; Ryberg, M.; Cornell, S. E. Plastics pollution exacerbates the impacts of all planetary boundaries. *One Earth* **2024**. https://doi.org/10.1016/j.oneear.2024.10.017.

A more circular approach to plastics

- 10% of all plastic waste is being recycled, 14% is incinerated, the rest goes to landfill or ends up in the environment
- A new approach to plastics: recyclable/biodegradable and bio-based





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UNIVERSITY OF AMSTERDAM

Spierling, S.; Venkatachalam, V.; Mudersbach, M.; Becker, N.; Herrmann, C.; Endres, H.-J. End-of-Life Options for Bio-Based Plastics in a Circular Economy—Status Quo and Potential from a Life Cycle Assessment Perspective. *Resources* **2020**, *9* (7), 90. https://doi.org/10.3390/resources9070090.

Bioplastics & Degradables | Plastics New Zealand. https://www.plastics.org.nz/environment/bioplastics-degradables.

Let’s make PLGA – its great!

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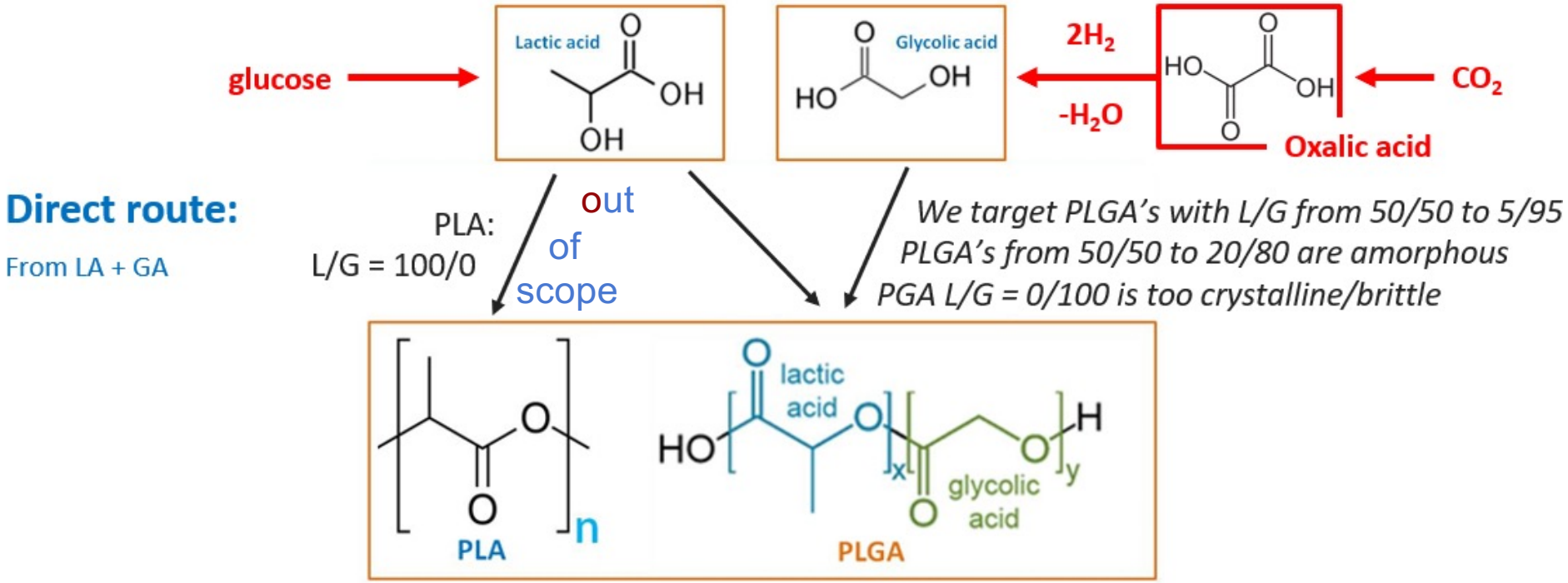
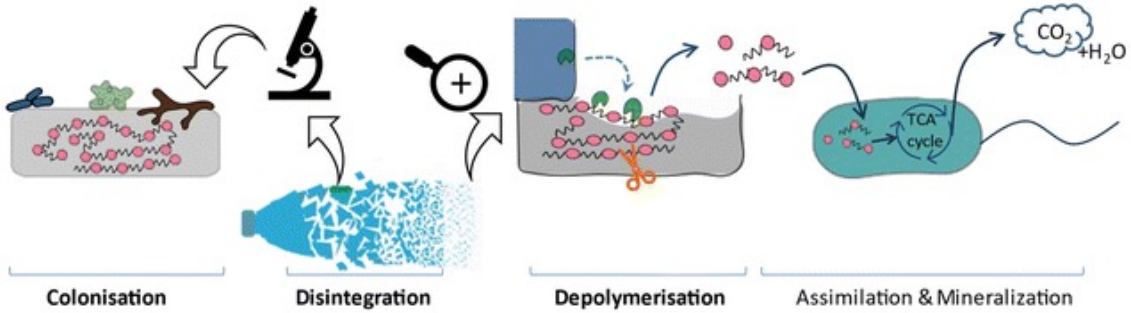
How Avantium plans to make PLGA?

- Avoid making and purifying glycolide.
- Removal of all water before final polycondensation step → Expensive!

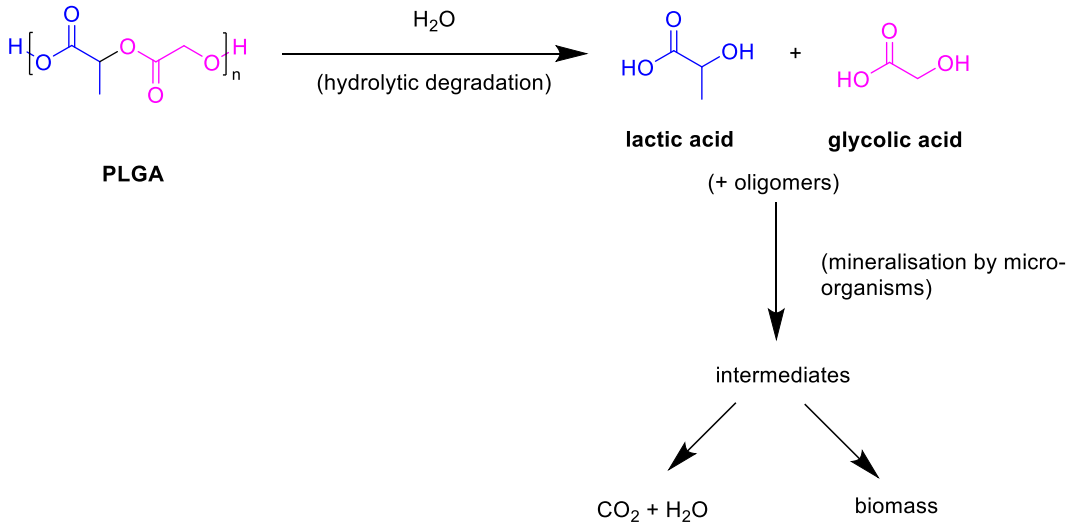


Biodegradation of polyesters

- Many poleysters also prone to (non-enzymatic) hydrolysis and biodegradation
- Biodegradation is a multi-phase process
- Term ‘biodegradable’ used interchangeable for industrially compostable and home-compostable



Biotic factors	Abiotic factors	Polymer qualities
Number and type of micro-organisms	Temperature	Mn
Enzymes involved	pH	crystallinity
	Moisture level	hydrophobicity
		chain flexibility
		end groups



Home-composting	Industrial composting
25°C	58°C
Less-controlled conditions	Controlled and optimized conditions (T, moisture content, micro-organisms present)

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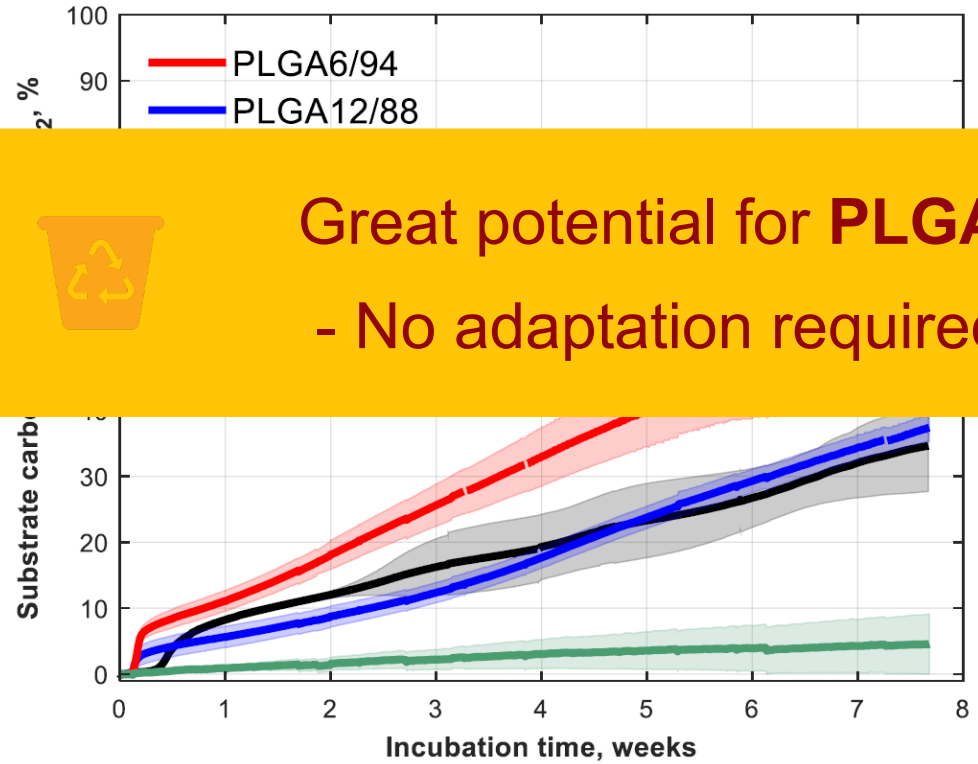
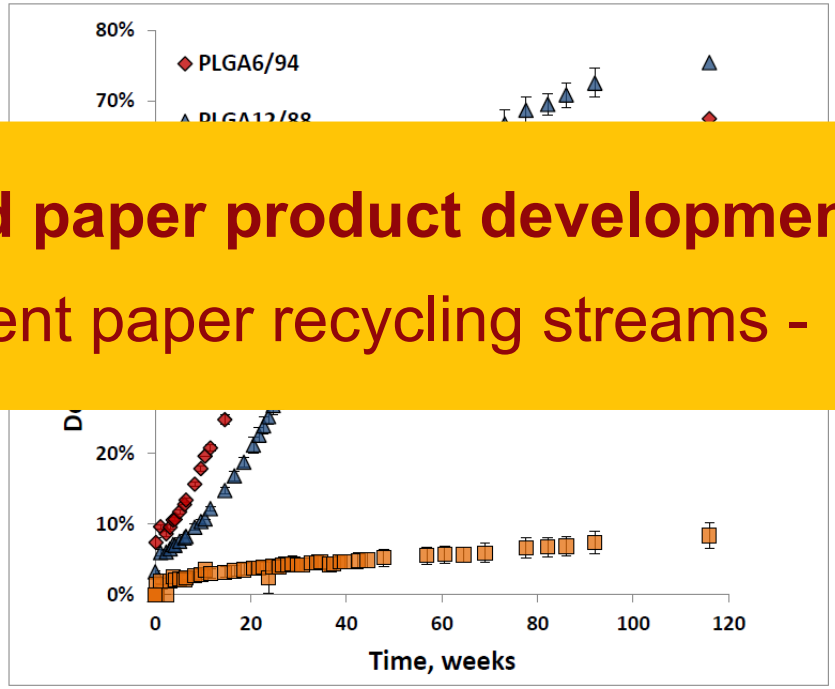
Biodegradability of PLGA

Ambient temperature soil (bio)degradation, compostable



Non-enzymatic hydrolytic degradation of PLGA determined with ^{1}H NMR



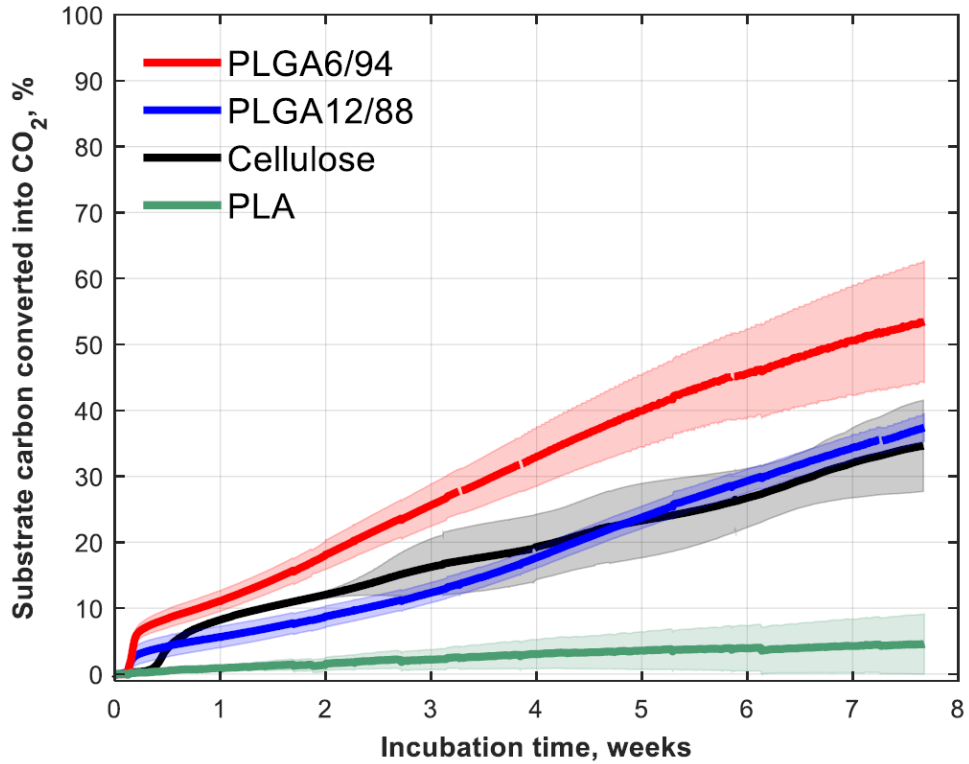
Great potential for **PLGA-coated paper product development**

- No adaptation required in current paper recycling streams -

Y. Wang *et al.*, *Polymers* **2022, 14**, 15.

Biodegradability of PLGA

Ambient temperature soil (bio)degradation, compostable



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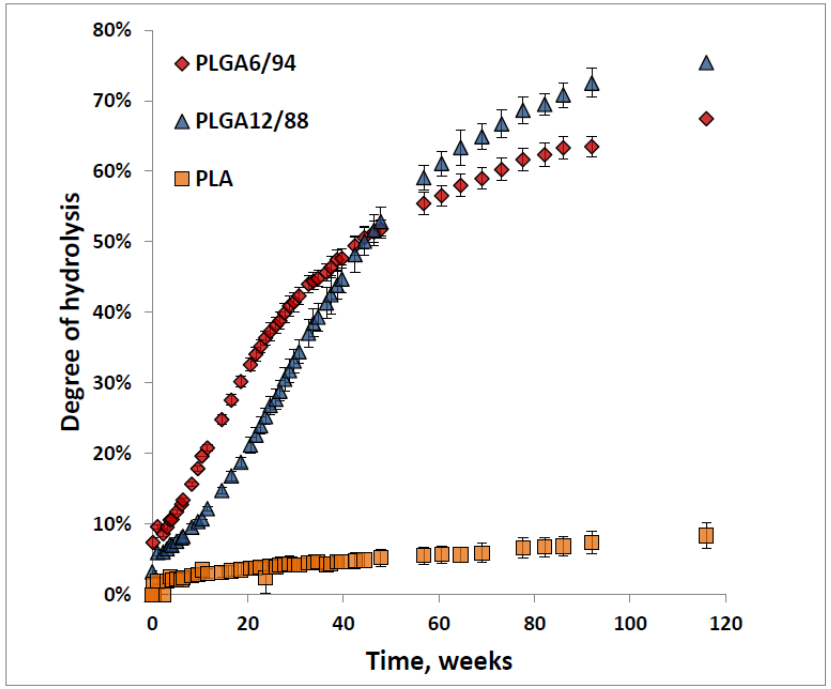

Y. Wang *et al.*, *Polymers* **2022, 14**, 15.

Thank you!

Funded by the European Union