Brighter use of resources

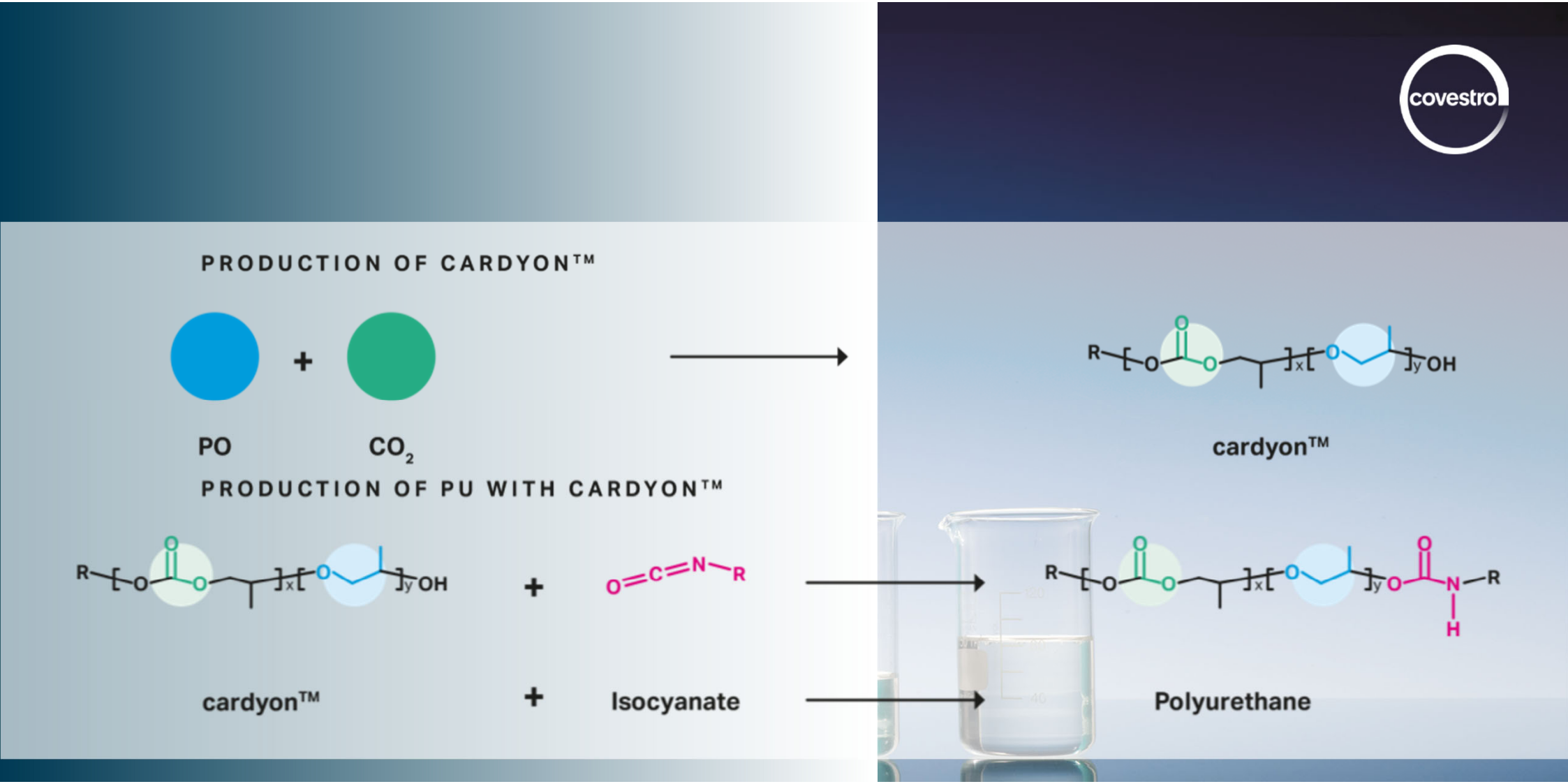
Fondation de la Maison de la Chimie

Dr. Christoph Gürtler

2020-11-16

DIRECT USE OF CO_2

A climate gas as useful resource



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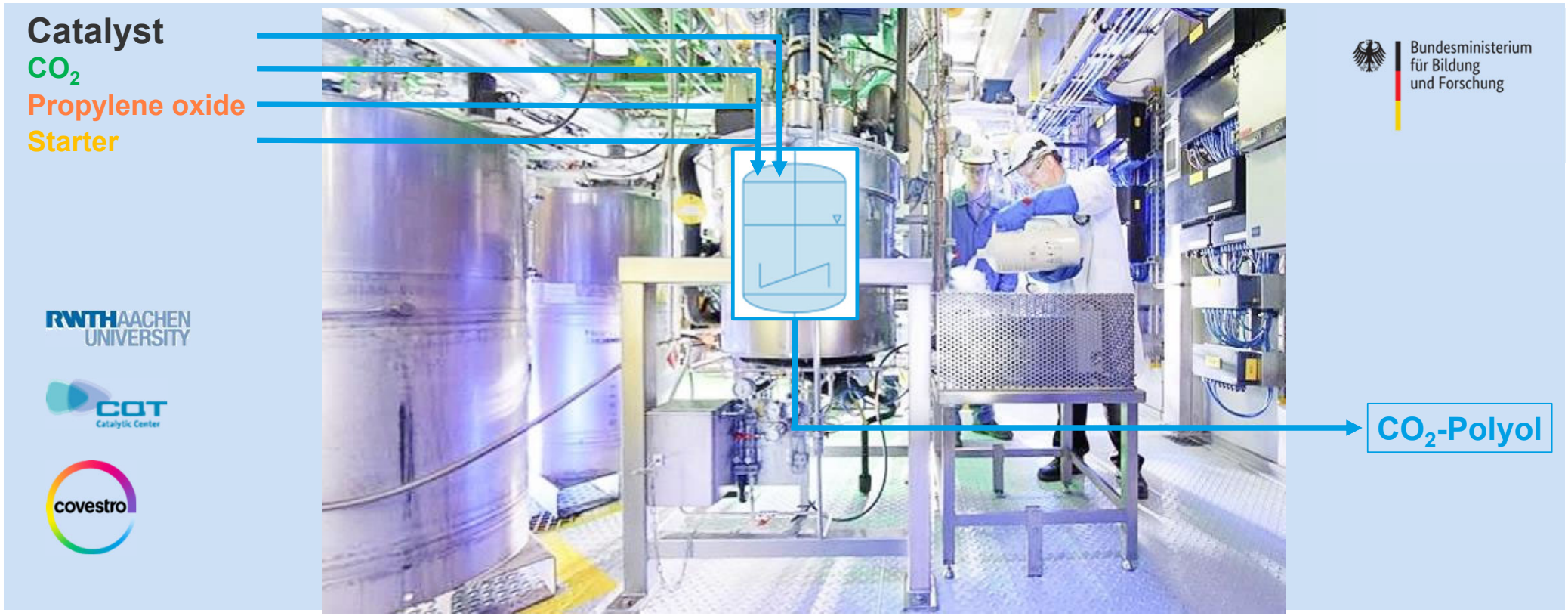
On the way to the chemical process for CO_2-polyols

Novel, continuous process – well IP protected

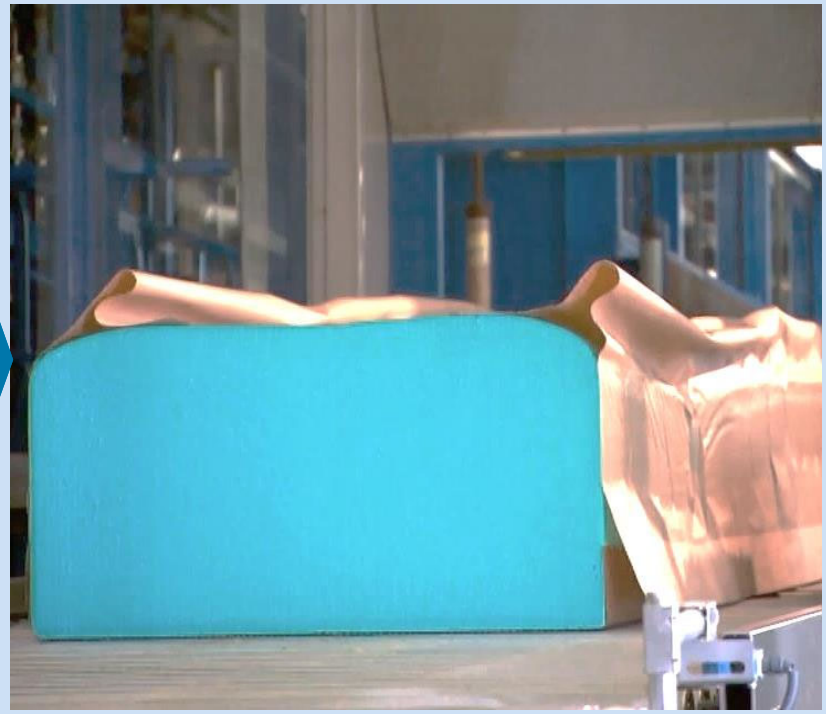


Towards industrial production and to the market

New product: cardyon® – up to 20% CO_2 content – Hightech plant with 5.000 t/y

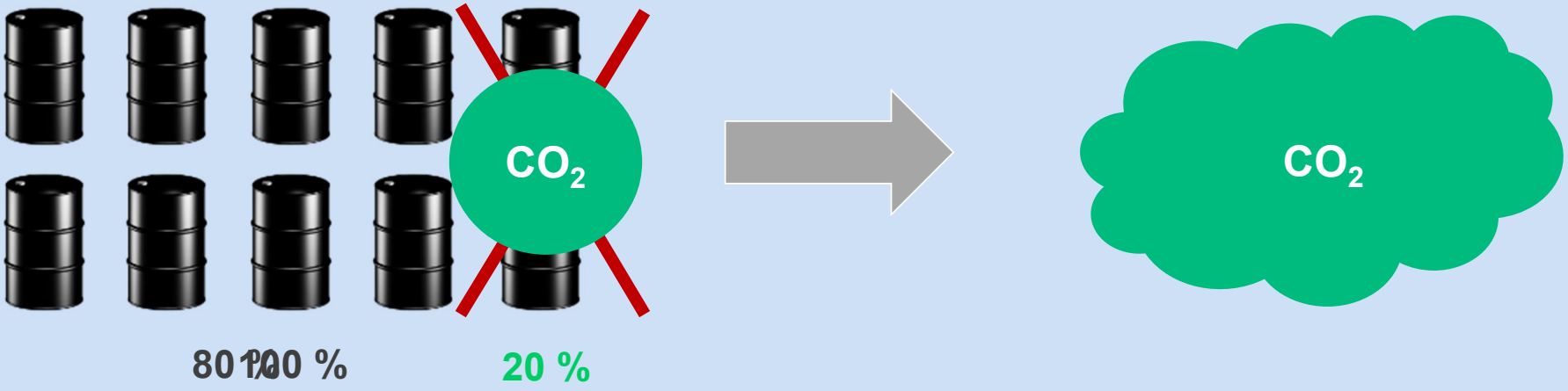
Sleeping on CO_2: Polyurethane foams

Production of PU Foams: New industry standard



Why should we use CO_2 as a feedstock?

Life cycle analysis (LCA) helps



- Savings of fossil resources
- Lower CO_2 emissions
- Positive impact on a series of other environmental parameters

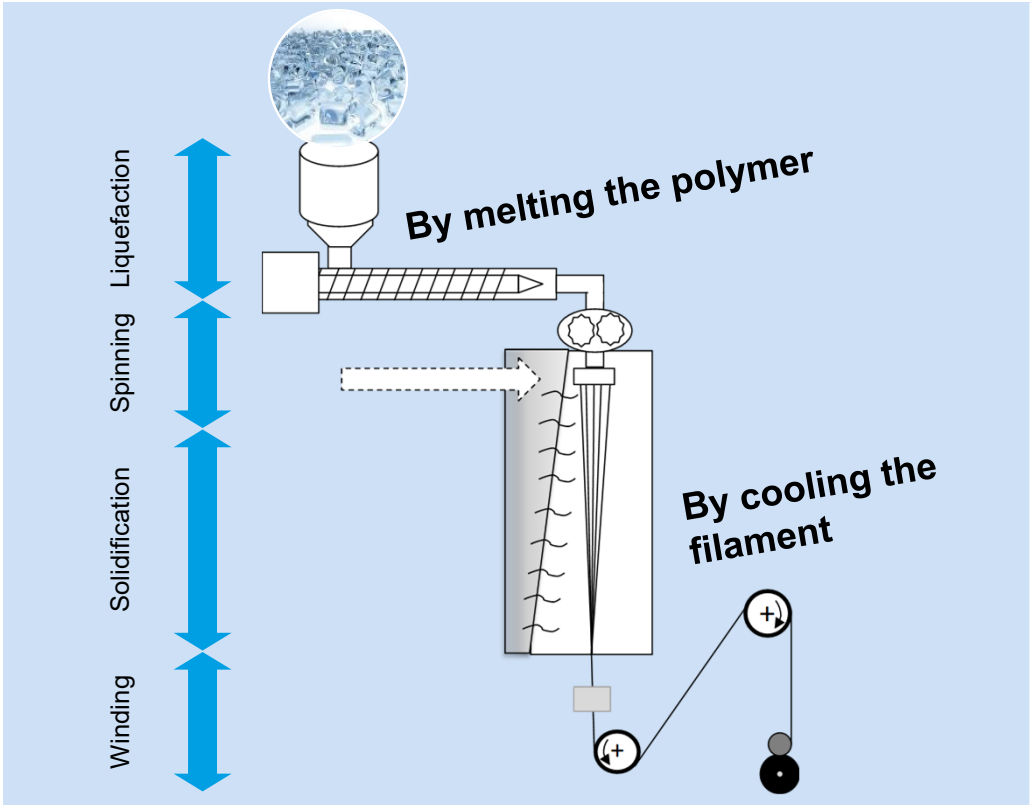
Prof. André Bardow

CO_2-Polyols: On the way to an all-round talent

Platform technology for numerous applications

Elastic fibers from PU – Additional contributions to sustainability

Why melt spinning process?



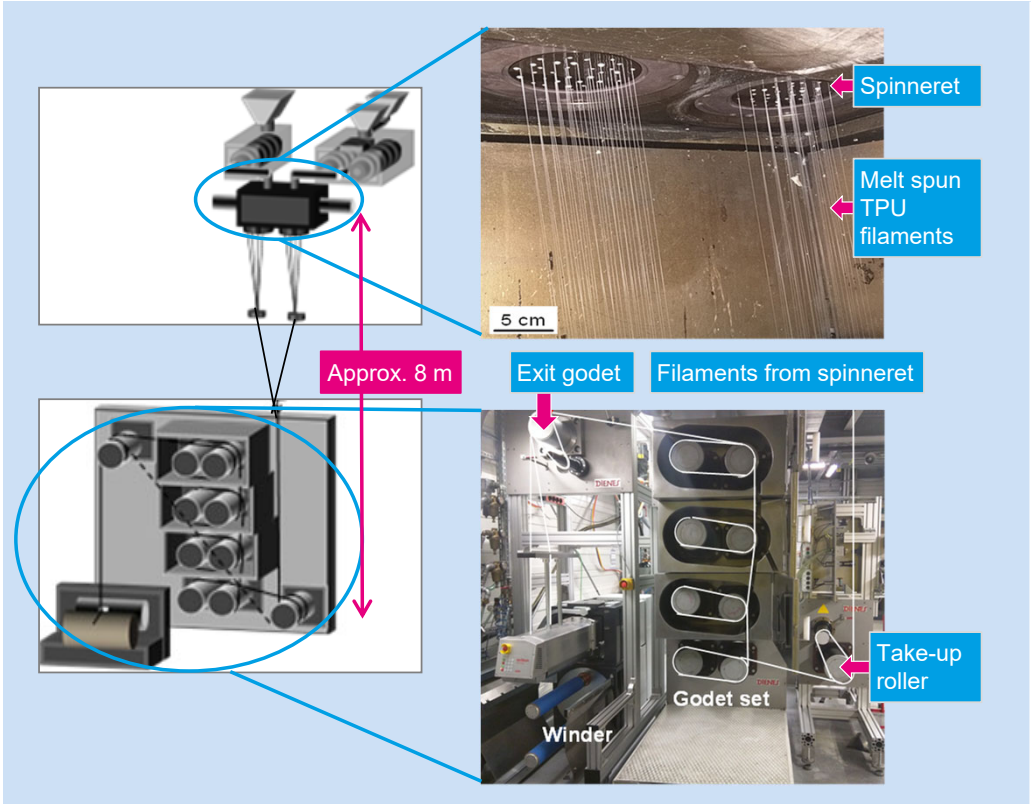
Melt spinning process for elastic polyurethane filaments

- No need for solvent
- Higher production speed
- **More sustainable compared to C3 TPU** (> 10% improvement in Carbon Footprint, even better compared to C4 polyether)
- Potentially more economic

https://learning.climate-kic.org/en/courses/co2-re-use-training-hub-course/technology-and-innovation/technology-and-innovation/2019-04-24-04-20-371

Melt spinning of CO_2-based TPU

Multifilament melt spinning at technical scale



- Equivalent to industrial scale
- Stable extrusion process
- Continuous filament build-up
- Aimed to filament fineness
  156 dtex to 1240 dtex
  (1 dtex = 1g material per 10 km fiber)
- Melt spinning demonstrated at 3,000 m/min
  vs. conventional dry spinning at 2,000 m/min
- Reproducible process

Projects **Dream Products** and **CroCO$_2$PETs** were funded by

Climate-KIC is supported by the EIT, a body of the European Union

Textiles made with melt-spun CO_2-TPU

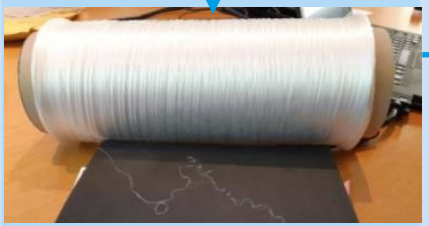
Open innovation along the value chain

Textile process chain matched

Polymer production

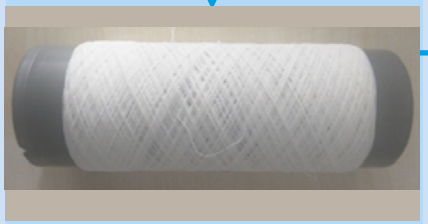
CO_2-based TPU

Melt spinning



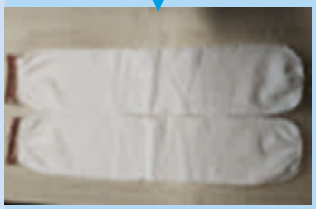
Multifilaments

Yarn covering

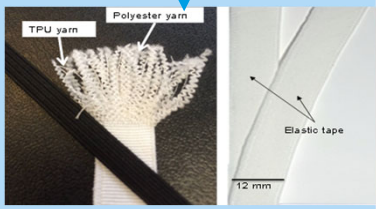


Covered TPU filaments

Knitting and weaving



Stocking

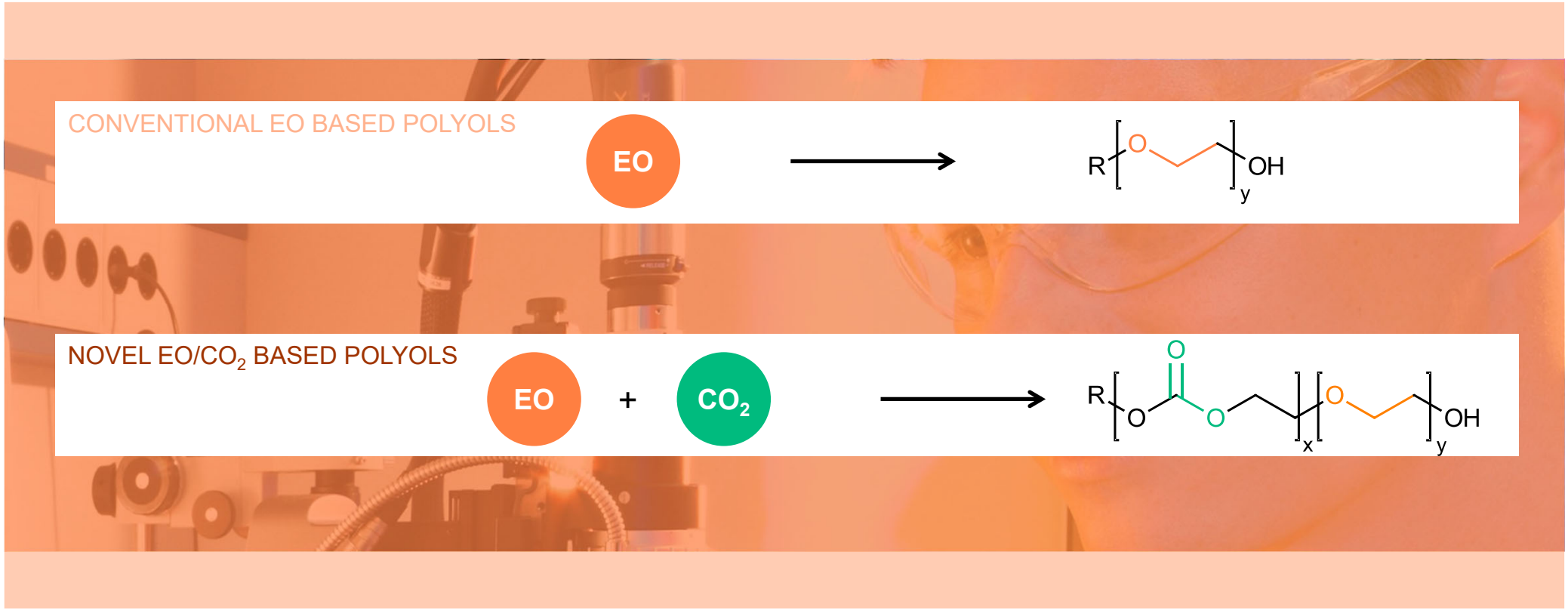


Woven elastic tape

PARTNERS IN TEXTILE INDUSTRY

EO/CO_2 Technology

From propylene oxide to ethylene oxide based CO_2-polyethers



First stage of development achieved – Next in progress

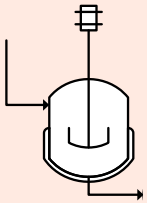
Projects DreamResource & DreamResourceConti*

2016 – 2020
DREAMRESOURCE
Synthesis & process concept

2019 – 2022
DREAMRESOURCECONTI
Up-Scaling

Technology

- ✓ Proof of concept successful completed
- ✓ Up to 16 % CO_2-content
- ✓ First production on mini plant-scale @Covestro
- ✓ Broad material testing



- ○ Continuous process development & scale-up
- ○ Increase CO_2-content up to 25 % by improved process
- ○ Increase raw material efficiency for variety of applications

Application


Molded foam


Rigid foam


Surfactants


TPU


Additives

Projekt partners

covestro, puren gmbh, BYK Additives & Instruments, PSS, TU Berlin, LTT Lehrstuhl für Technische Thermodynamik RWTH Aachen University, CAT Catalytic Center, Institut für Umweltforschung

covestro, TU Berlin, LTT Lehrstuhl für Technische Thermodynamik RWTH Aachen University, CAT Catalytic Center, Institut für Umweltforschung

*Projects DreamResource (FKZ 033RC002) and DreamResourceConti (FKZ 033R222) received public funding of the Federal Ministry of Education and Research.

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EO/CO_2-polyols for rigid foam application

Close interdisciplinary cooperation between industries

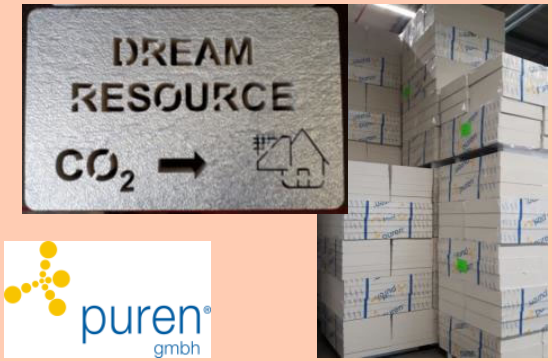
Lab scale

Iterative development process of initial sampling on lab scale

Mini plant scale

First up-scaling activities enabled sampling of 400 kg CO_2-based material

Application tests



First application tests (pilot status) on foaming plant resulted in CO_2-based insulation boards @puren gmbh

Q3 2018 | Q1 2020 | Q2 2020

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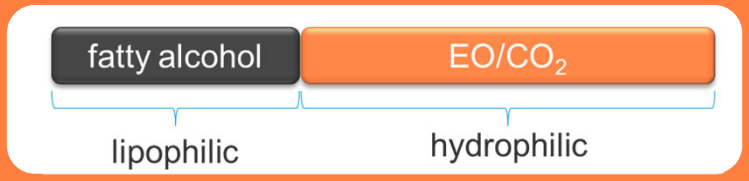
Advantages through CO_2

Improved sustainability and characteristics of surface-active materials

- **CO_2-based surfactants** show improved qualities
  - Hydrophobic impact of CO_2 leads to **reduction of needed material**
  - Modified phase behavior enables **better processability**
  - **Faster degradability** of novel material improves environmental impact



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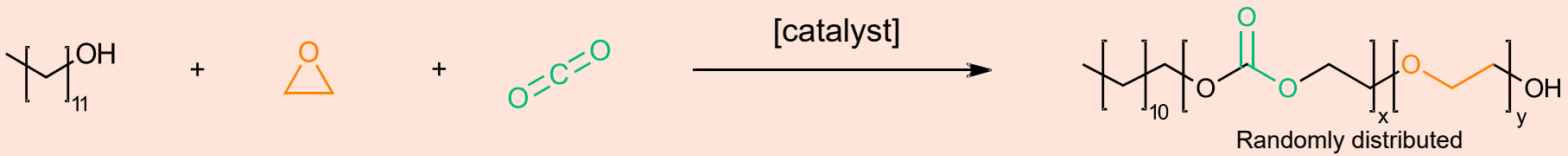
Characterization of EO/CO_2-surfactants by TU Berlin

Major features of detergents can be obtained



No	Surfactant	M_n [g/mol]	CO_2 content [wt.-%]	$CMC_{25°C}$ [mmol/L]	σ_{CMC} [mN/m]	$IFT_{25°C}$ [mN/m]	HLB
1	C_{12}-EO/CO_2-OH	1,390	5.9	0.053	34	5.8	14.3
2	C_{12}-EO/CO_2-OH	1,220	5.4	0.091	36	6.2	14.4
3	C_{12}-EO/CO_2-OH	1,350	3.9	0.099	36	6.6	14.9
4	C_{12}-EO/CO_2-OH	1,270	2.3	0.118	36	6.9	16.5
5	C_{12}EO-OH	1,170	0	0.175	33	7.2	16.4

Increasing CO_2-content leads to:

- Increased hydrophobicity
- Reduction of critical micelle concentration (cmc)
- Decreasing interfacial tension (IFT)
- Decreased HLB value

Conclusion
Detergent properties within reach

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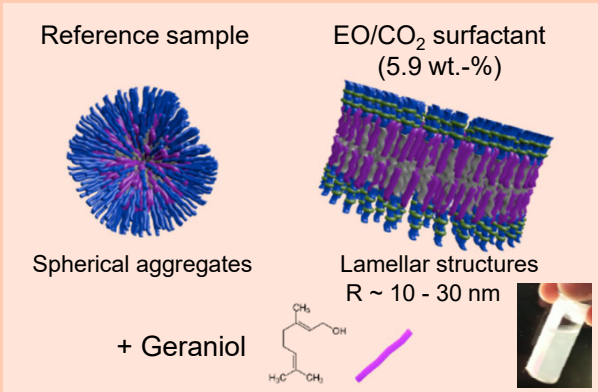
Characterization of EO/CO_2-surfactants by TU Berlin*

Foam stability

- Determination of foamability and half-life times of foams

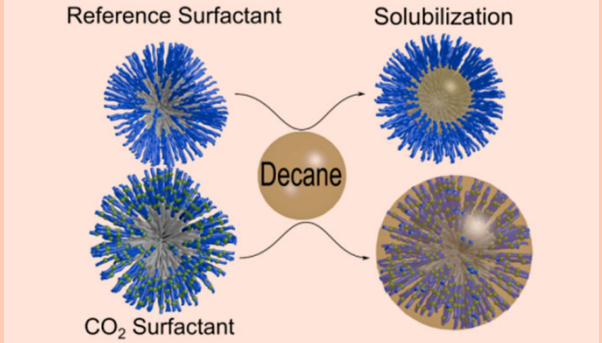
➢ Comparable foam stability as reference products



Addition of Co-surfactant

- Addition of Cosurfactant:

➢ CO_2 Surfactant: spherical micelles grow from spherical into cylindrical structures up to lamellar structures (birefringent)



Oil solubilization

- Highest solubilization capacity with increasing CO_2-content

➢ CO_2 hydrophobic group in head group enhances the oil solubilization

*M. T. Lima, S. N. Kurt-Zerdeli, D. Brüggemann, V. J. Spiering, M. Gradzielski, & R. Schomäcker, *Colloids and Surfaces A: Physicochemical and Engineering Aspects* **2020**, *588*, 124386.
V. J. Spiering, A. Ciapetti, M. T. Lima, D. W. Hayward, L. Noirez, M.-S. Appavou, R. Schomäcker, M. Gradzielski, *ChemSusChem* **2020**, *13*, 601.

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The next step – use of mixed gas streams

Industrial symbiosis: Steel industry – Chemical industry

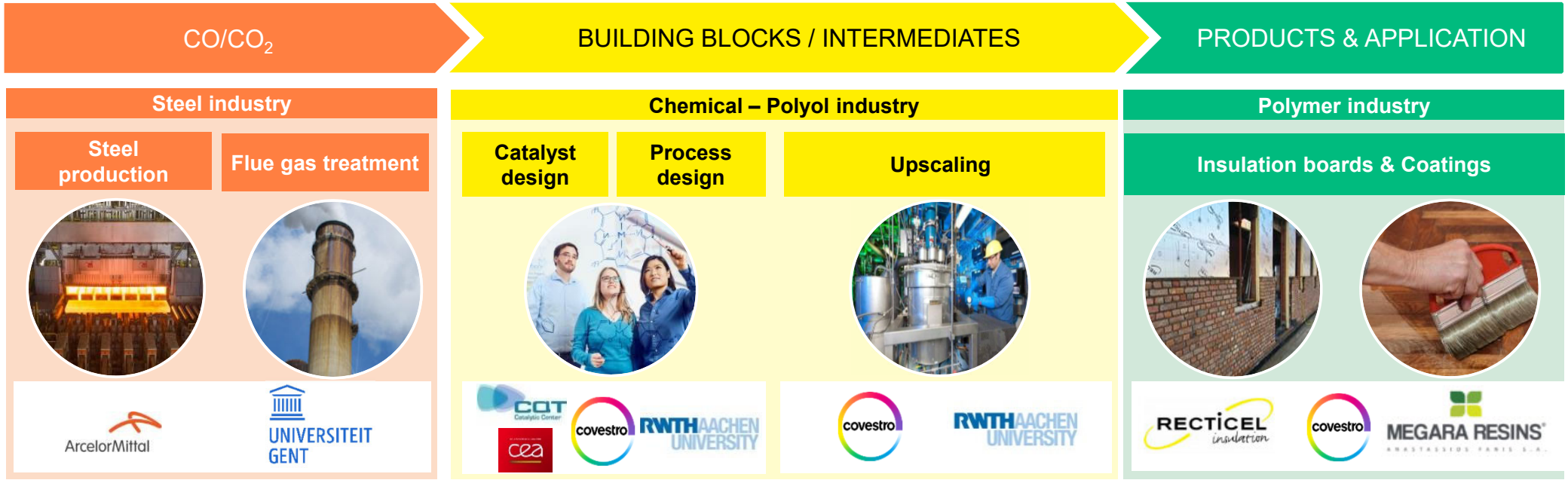
Carbon4PUR

- Pan-European research project:
  14 partners from 7 countries
- Using flue gas (CO_2 and CO) from steel plants for chemical precursors
- Significant Carbon footprint reduction of intermediates
- EC contribution: 7.75 mln. €,
  duration: Oct. 2017 – Sept. 2020

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 768919

Carbon4PUR – Methodology

Industrial symbiosis: Steel industry – chemical industry, 7.75 mln. € EC contribution, Oct. 2017 – Sept. 2020



Carbon4PUR - Turning waste gas into valuable polyurethanes

Process Development of multi-stage process

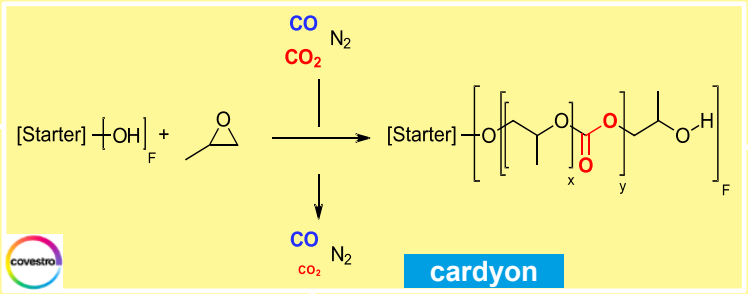
CO/CO_2

BFG:
24 % CO
24 % CO_2
47 % N_2
5.1 % H_2

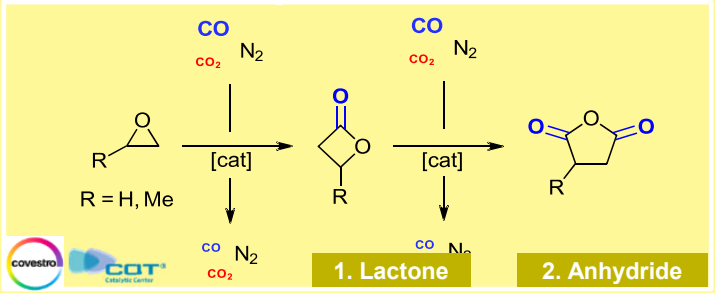
Steel production

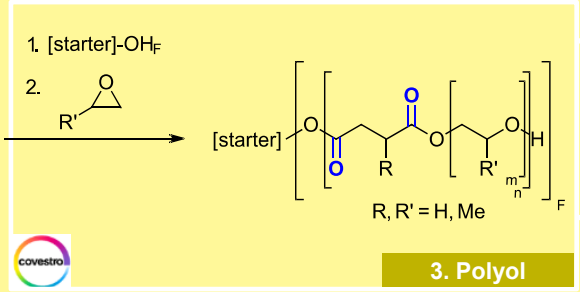
BUILDING BLOCKS / INTERMEDIATES

CO_2-conversion



CO-conversion





PRODUCTS & APPLICATION

CO_2-based coatings
CO- based coatings

MEGARA RESINS

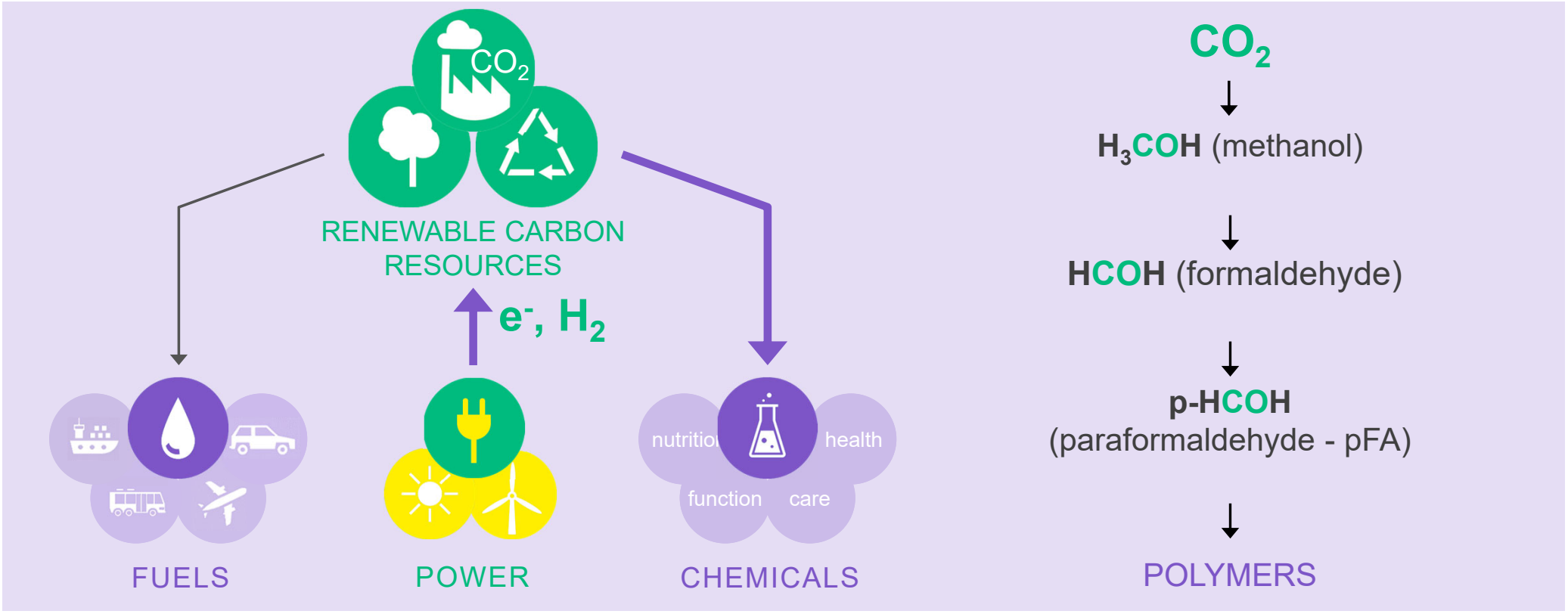
CO-based foams

RECTICEL

INDIRECT USE OF CO_2

Use case for Power-to-X sector coupling

Polymers made from CO_2 – via methanol and paraformaldehyde



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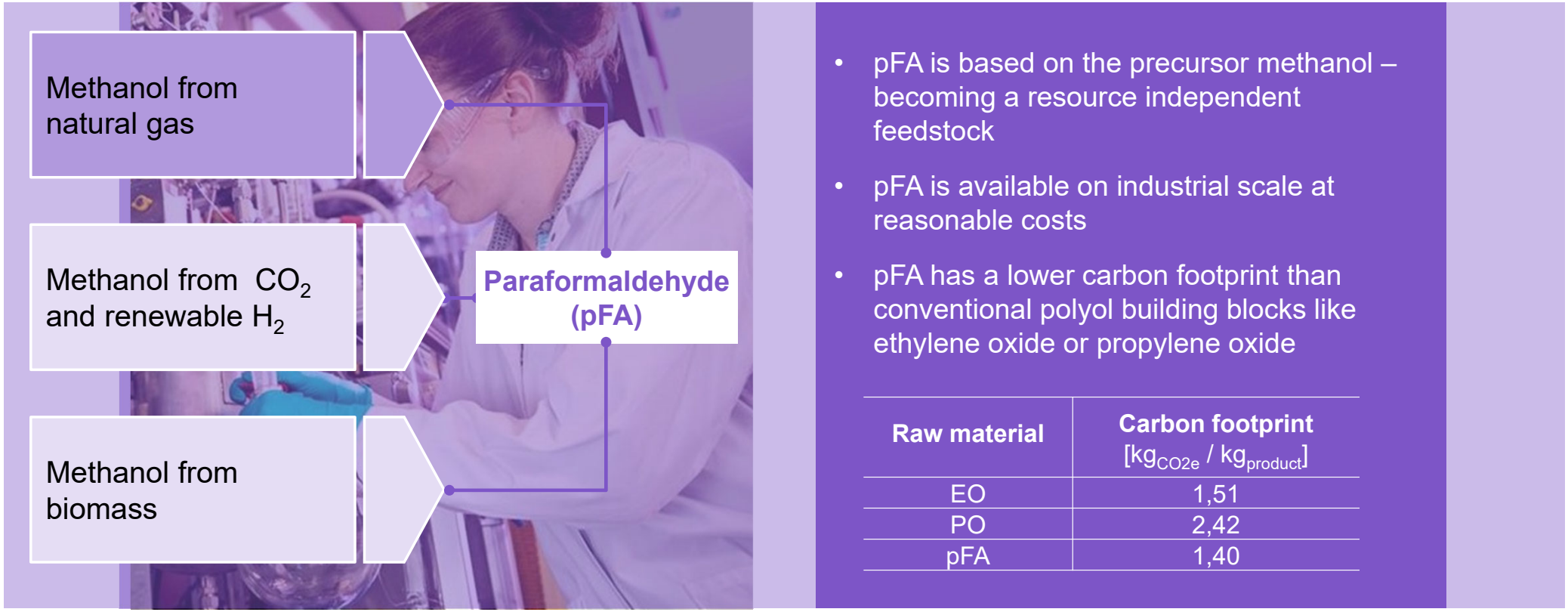
Why paraformaldehyde (pFA)?

A sustainable C1 building block



- pFA is based on the precursor methanol – becoming a resource independent feedstock
- pFA is available on industrial scale at reasonable costs
- pFA has a lower carbon footprint than conventional polyol building blocks like ethylene oxide or propylene oxide

Raw material	Carbon footprint [kg_{CO2e} / $kg_{product}$]
EO	1,51
PO	2,42
pFA	1,40

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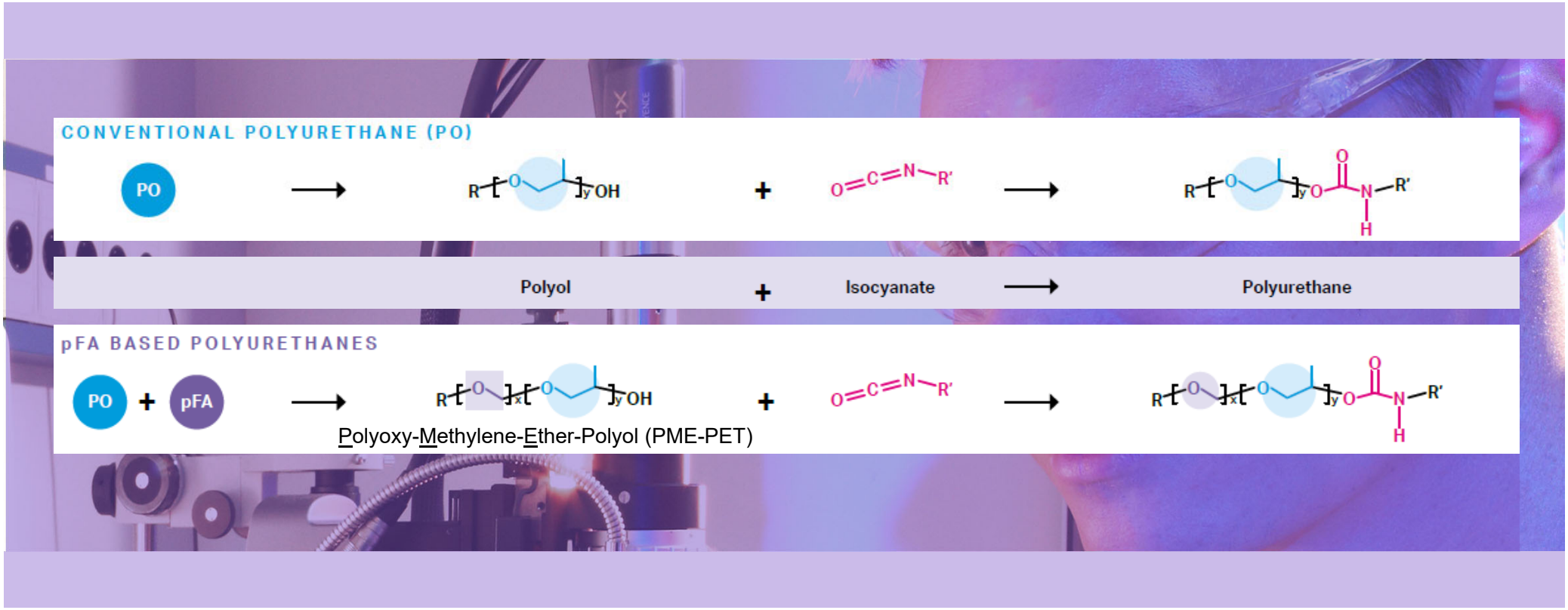
Replacing fossil alkylene oxides

Polyoxy-Methylene-Ether-Polyols (PME polyols)



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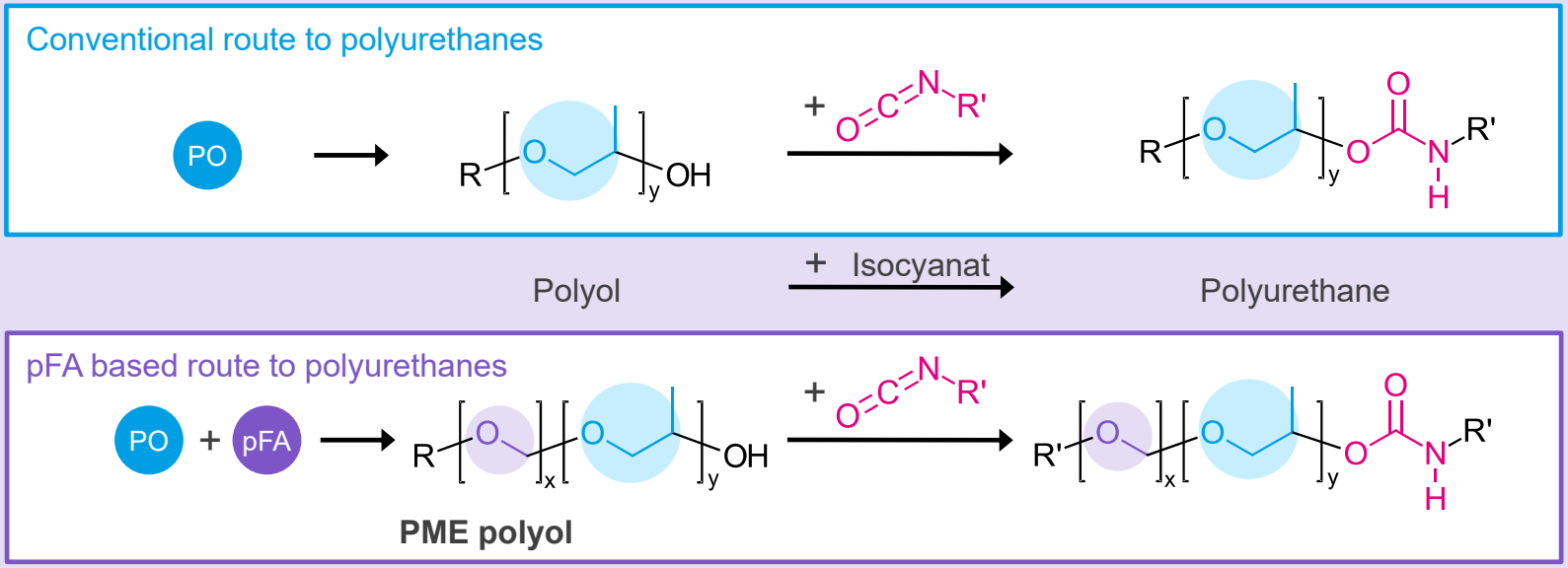
Replacing fossil alkylene oxides by paraformaldehyde

Polyoxy-Methylene-Ether-Polyols (PME polyols)



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The formula for success

Close cooperation between academia and industry

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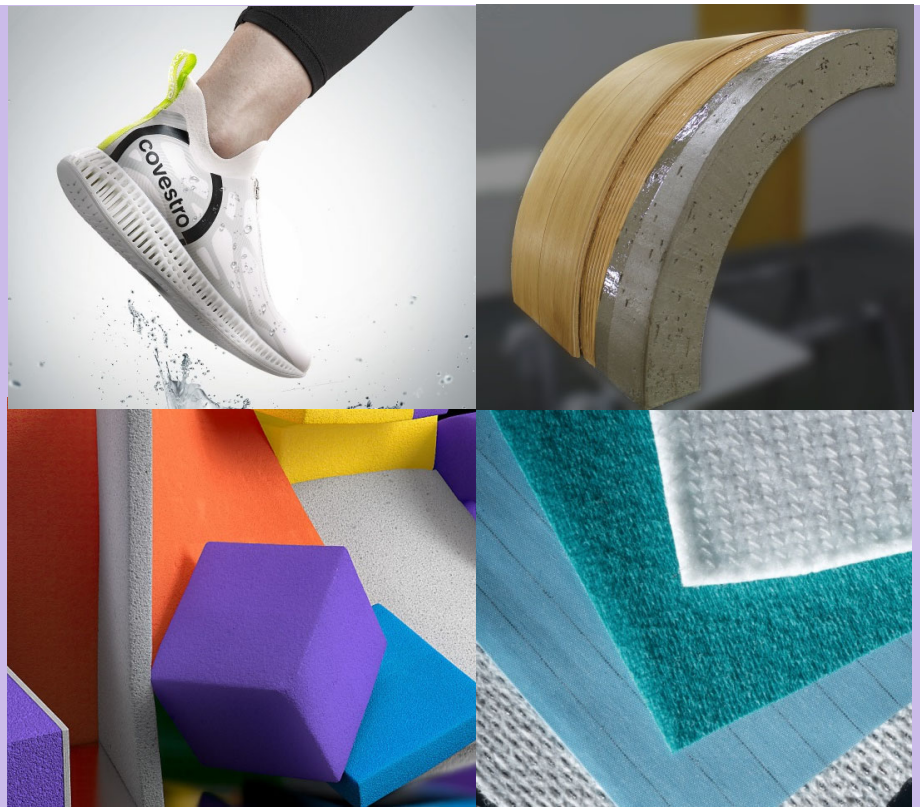
A wide range of possible applications



- Thermoplastic polyurethanes (TPU) are one focus application
- TPUs can be found in sporting goods such as skiing boots or sneakers
- Adhesives are another important focus
- First results in 1K and 2K adhesive systems have shown that the use of pFA-based polyols leads to faster film formation and drying time
- In addition, foam applications, coatings, resins, … are targeted

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DreamPolyolsConti – Chemical & process development

Towards an industrially feasible product and process

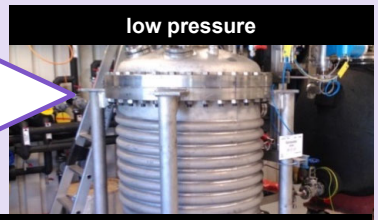
Chemical & Process Optimization

Lab-scale reactor

scale x 60

Polyol Production

scale x 10



Technical scale

Products & Application

Status

- ✓ Investigation of reaction
- ✓ **Recipe development**

- ✓ First production at technical scale
- ✓ **P2P** process

- ✓ **Low pressure**
- ✓ Catalyst loading reduced
- ✓ **About 1 t** of material

- ✓ TPU
- ✓ Adhesives
- ✓ Standard foam, viscoelastic foam, HR foam
- ✓ PUDs for textile coating, …

Outlook

- ➢ Catalyst optimization
- ➢ Extend analytical methods
- ➢ Prepolymers

- ➢ Development of continuous process
- ➢ Sample production

- ➢ Further material testing
  → Identify main application(s)

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TOWARDS A SUSTAINABLE FUTURE

Our future is being collectively shaped

Covestro projects are clearly aligned to the UN-SDGs

Research & Development

Our R&D project portfolio aligned with UN Sustainable Development Goals

Procurement

100% of suppliers compliant with our sustainability requirements

Production

Reduce specific CO_2 emissions by 50%

Products on the market

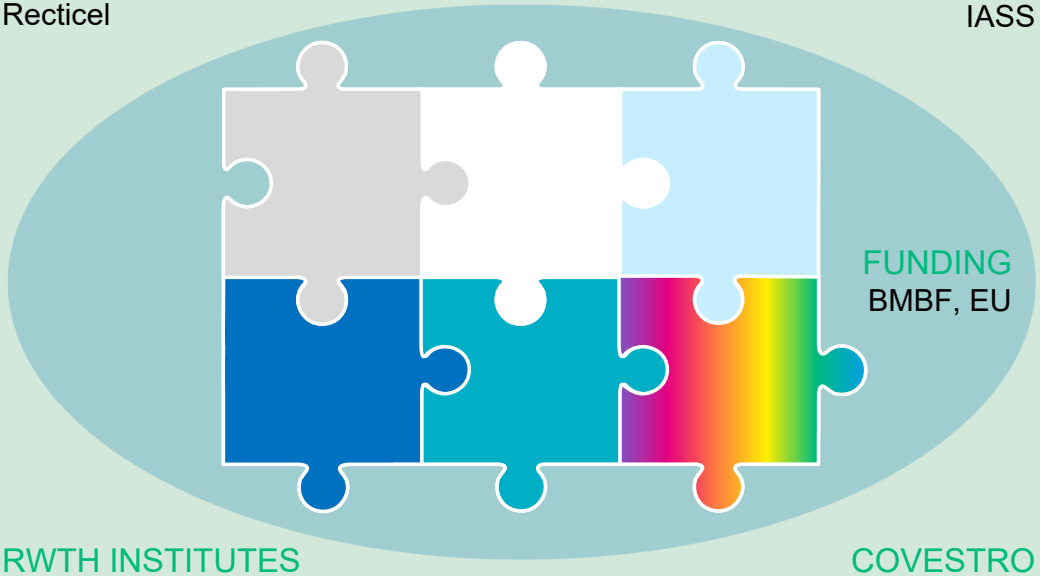
10 million people in underserved markets reached through our business solutions

Across the value chain

We aim to get the most value out of the carbon employed

Open innovation – the bigger picture

Partnerships as key success factor



Catalysis between academia and industry

- Bundling of forces and networks universities, industries, agencies, customers

Acceleration of research – increasing

- efficiency, better success rate from basic research to application

A climate for innovation

Support by politics

Stable frame conditions

Thank you!

Dr. Christoph Gürtler

Forward-looking statements

This presentation may contain forward-looking statements based on current assumptions and forecasts made by Covestro AG.

Various known and unknown risks, uncertainties and other factors could lead to material differences between the actual future results, financial situation, development or performance of the company and the estimates given here. These factors include those discussed in Covestro's public reports, which are available on the Covestro website at www.covestro.com.

The company assumes no liability whatsoever to update these forward-looking statements or to adjust them to future events or developments.

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