Science For A Better Life

CO_2 as building block for the chemical industry

United Nations Climate Change Conference, Bonn, Germany

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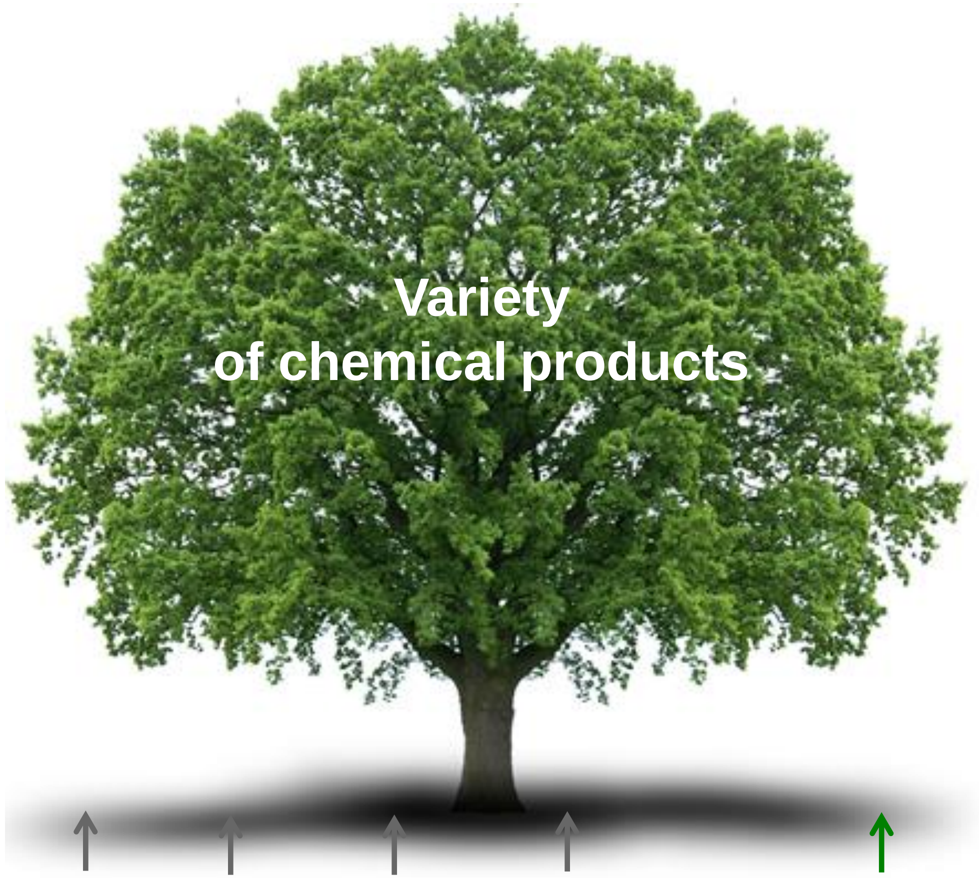
Raw materials – CO_2 as alternative carbon source

> 40.000
Chemical products

~ 400
Bulk chemicals and key intermediates

~ 40
Basic chemicals

4
Raw materials



Oil | **Natural gas** | **Biomass** | **Coal** | **CO_2 as alternative carbon source**

New raw material CO_2
Motivation for its chemical use

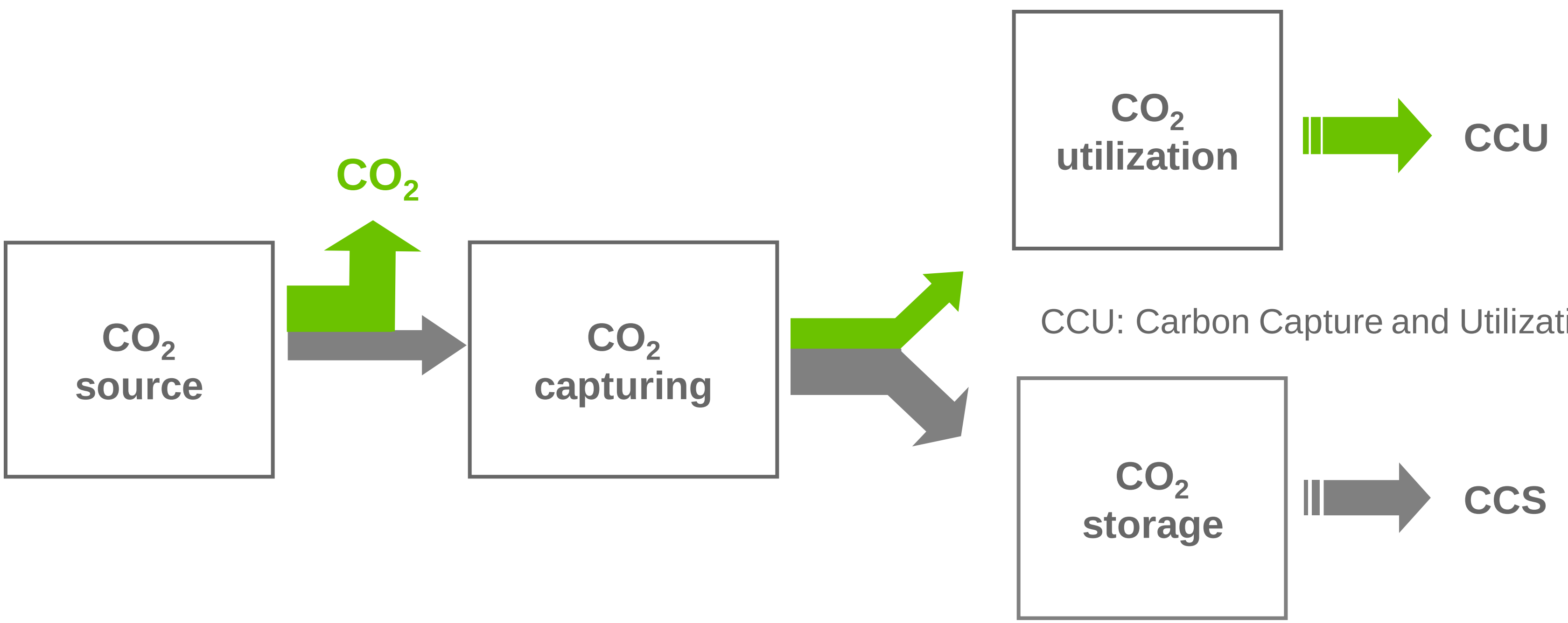
Sustainability

- Resource efficiency
  - Saving scarce fossil fuels
  - Broadening raw material base
- Climate protection
  - Using CO_2
  - Avoiding CO_2 emissions

Value creation

- Market needs
  - Comply with growing desire for sustainable products
- Profitability and competitiveness
  - Improved products and processes

Options for CO_2 – CO_2-storage und CO_2-utilization



CCU: Carbon Capture and Utilization

CCS: Carbon Capture and Storage

Only small amounts of the anthropogenic CO_2 can be utilized in a chemical way - adequate innovation in catalysis might offer great potential

Strategies for CO_2 conversion and utilization

Existing

Urea
(80 m. t/a)

Methanol
(2 m. t/a)

Cyclic carbonate
(0.04 m. t/a)

Salicylic acid
(0.025 m. t/a)

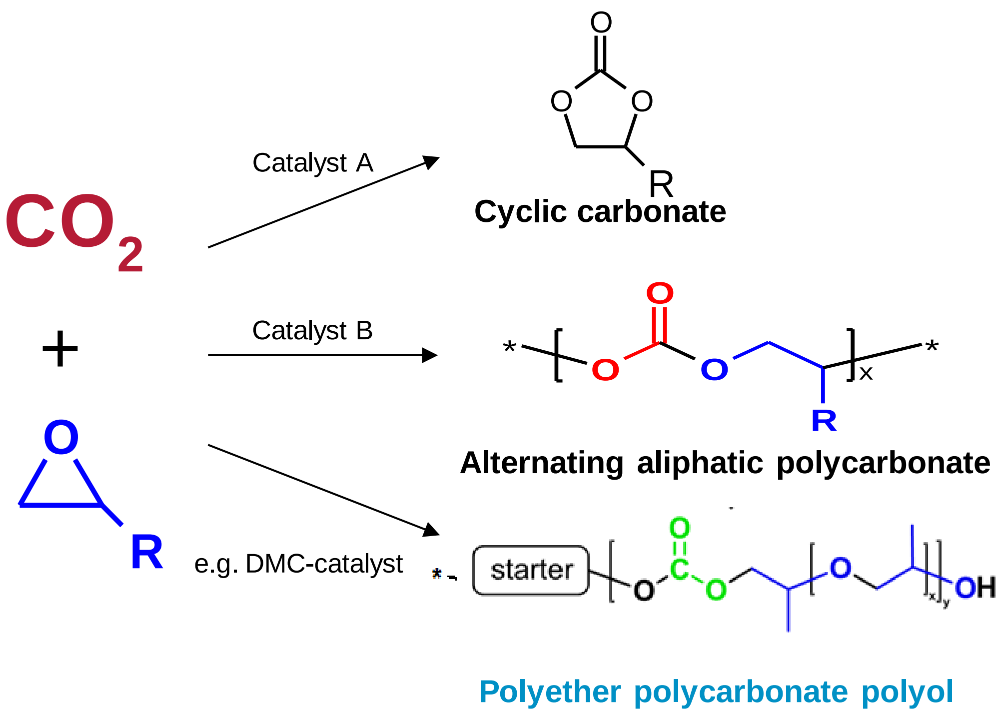
Emerging

- CO_2 based polymers
- Dry reforming
- CO_2 hydrogenation to formic acid
- Fuels (DME) etc., Intermediates
- ….

Exploratory

- Isocyanates
- Organic carbonates
- Lactone synthesis
- Carboxylic acids
- ….

Industrial application of epoxide/CO_2 chemistry for carbonate syntheses



- **Green solvent**
- **Synthesis of dimethyl carbonate**

- **High molecular weight**
- **Binders for ceramics**
- **Biodegradable/compostable polymers**

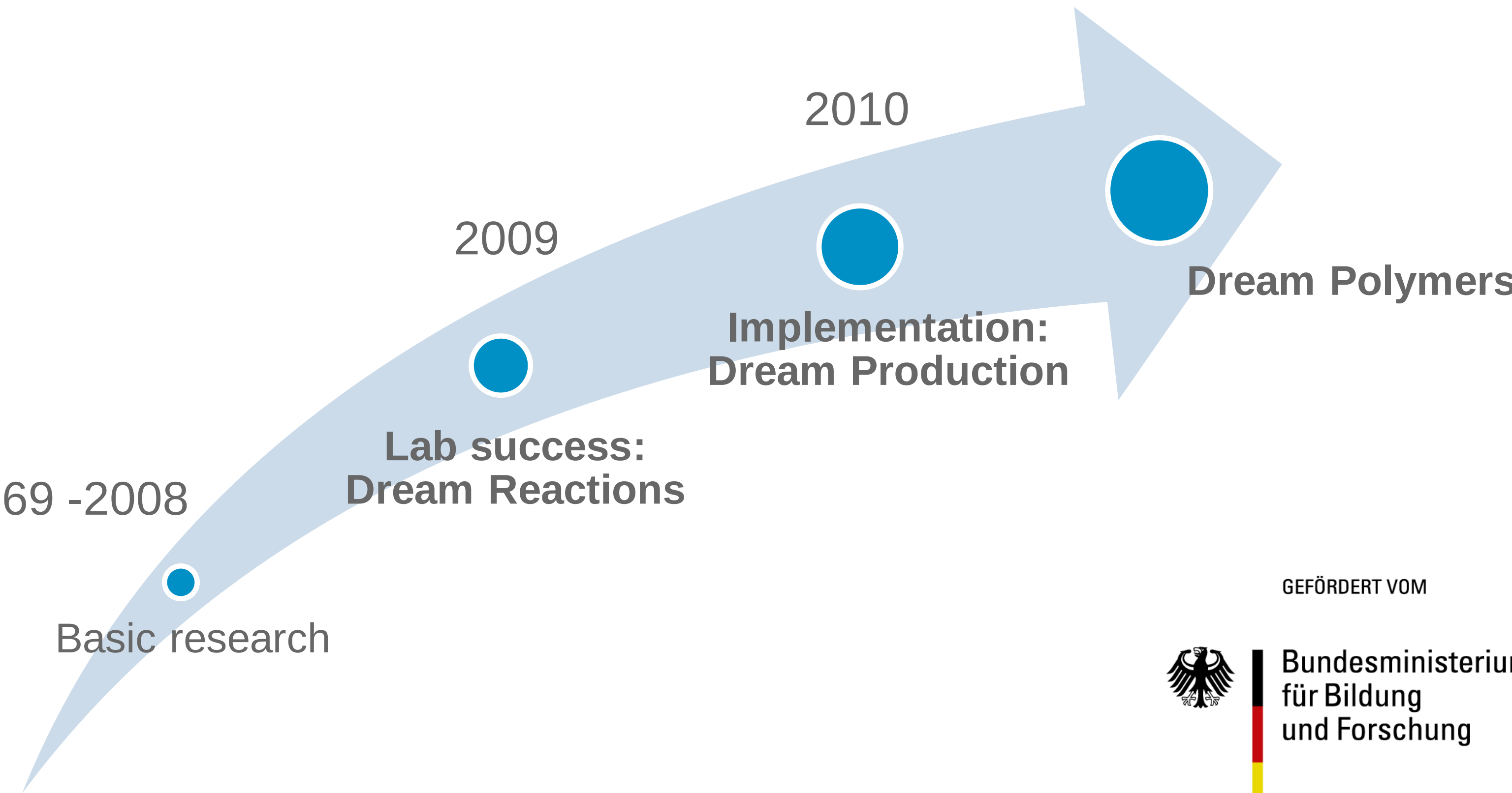
- **Low molecular weight**
- **Terminal OH-functionalities yields polyols for polyurethanes synthesis**

▶ Selectivity is strongly influenced by the catalyst /competing reaction

▶ Up to 43 wt% incorporation of CO_2 ($R = CH_3$) possible

▶ Homogenous and heterogeneous catalyst suitable

Research Case CO_2 –
Break-through at Bayer



GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

RWTH AACHEN UNIVERSITY

CAT Catalytic Center

Bayer Technology Services

Bayer MaterialScience

Dream Production –

From power plant to polyurethane

Bundesministerium für Bildung und Forschung

BAYER

Scrubbing and supply of CO_2

VORWEG GEHEN RWE

Process development and conversion of CO_2

Bayer Technology Services

Production and testing of polyurethanes with CO_2

Bayer MaterialScience

Fundamental research

CAT Catalytic Center

RWTH AACHEN UNIVERSITY

Life Cycle Assessment

Scientific breakthrough

Special catalyst found after 40 years

Success of close cooperation between Bayer and the CAT Catalytic Center in Aachen, Germany.

Dream Production –

Covering the value chain

Bayer Technology Services

Construction and operation of a pilot-plant

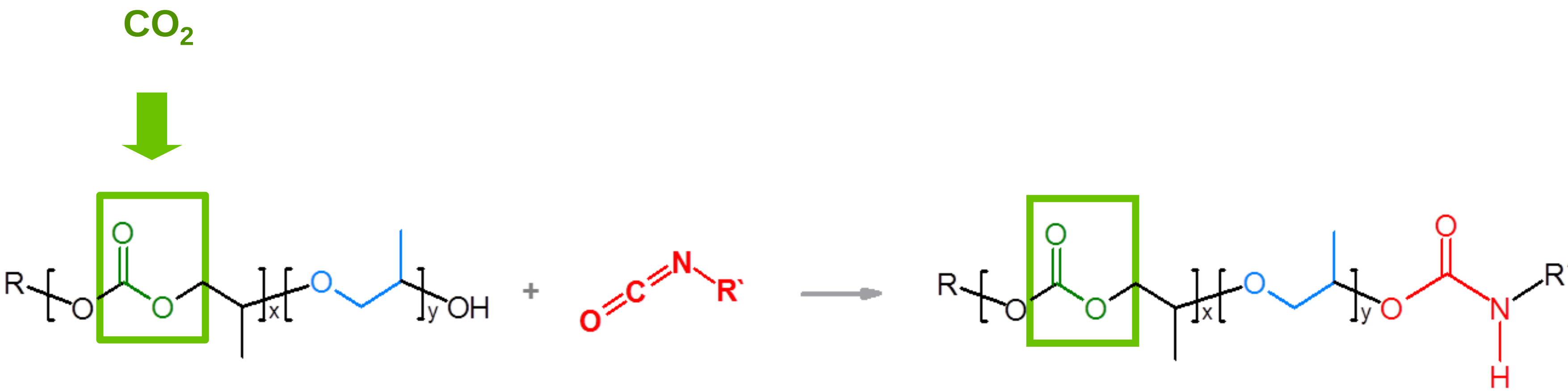
Samples

Dream Production –
Covering the value chain

Bayer MaterialScience

Slab stock plant for CO_2-PET testing in foams

Target product polyurethanes – Allrounder among plastics



Polyol

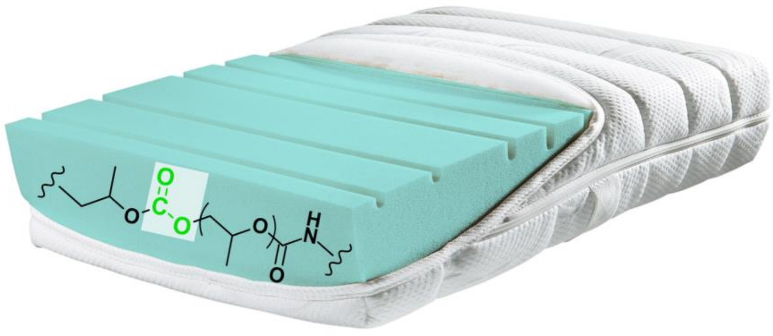
Isocyanate

Polyurethane

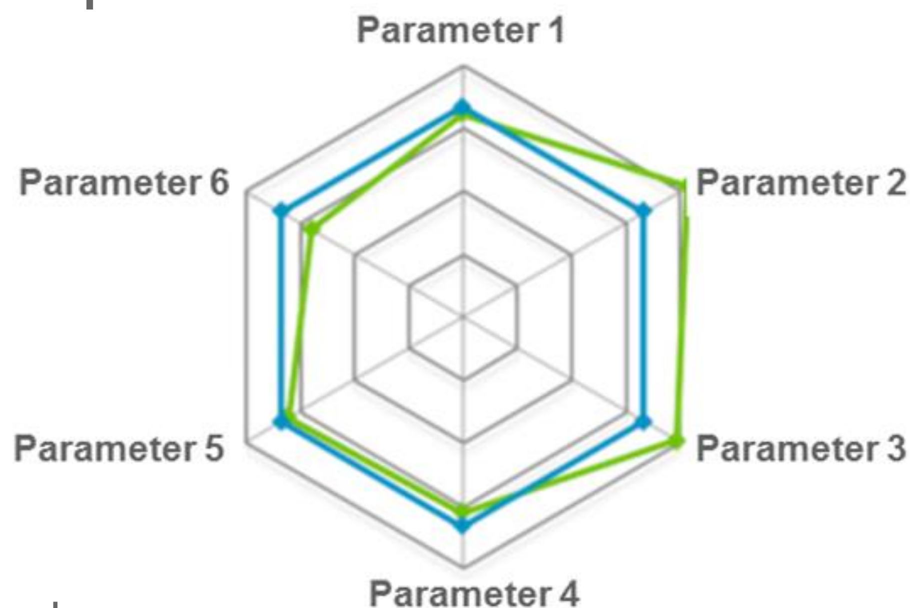
Foam quality evaluation results

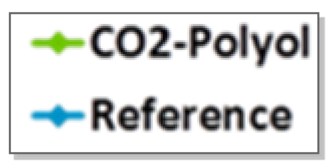
Very good foam properties achievable

Machine Trial Product



Properties





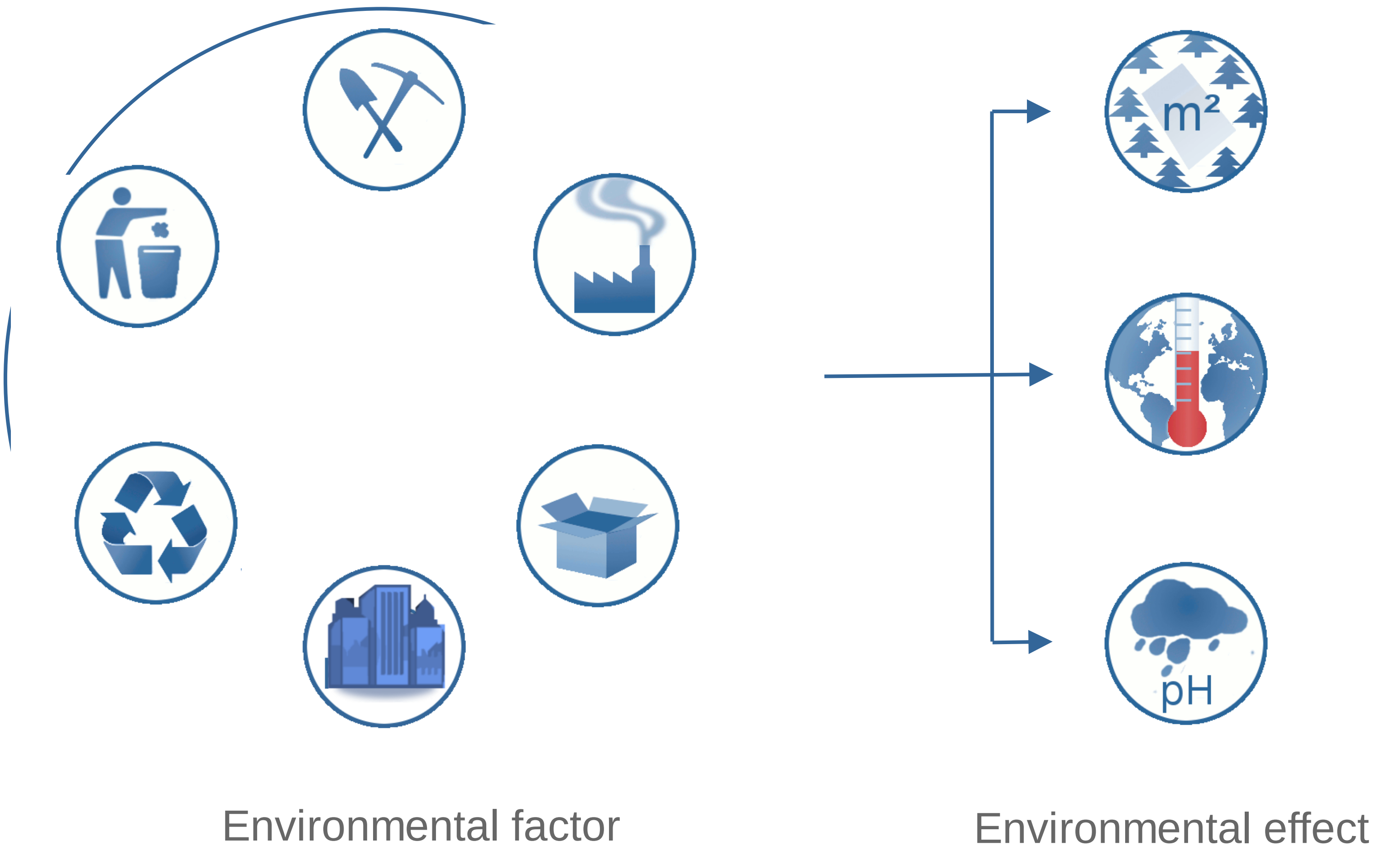
- CO_2 based polyurethanes can be used for many applications
- Properties on the same level or even better than conventional polyurethanes

New technology works

But is it sustainable?

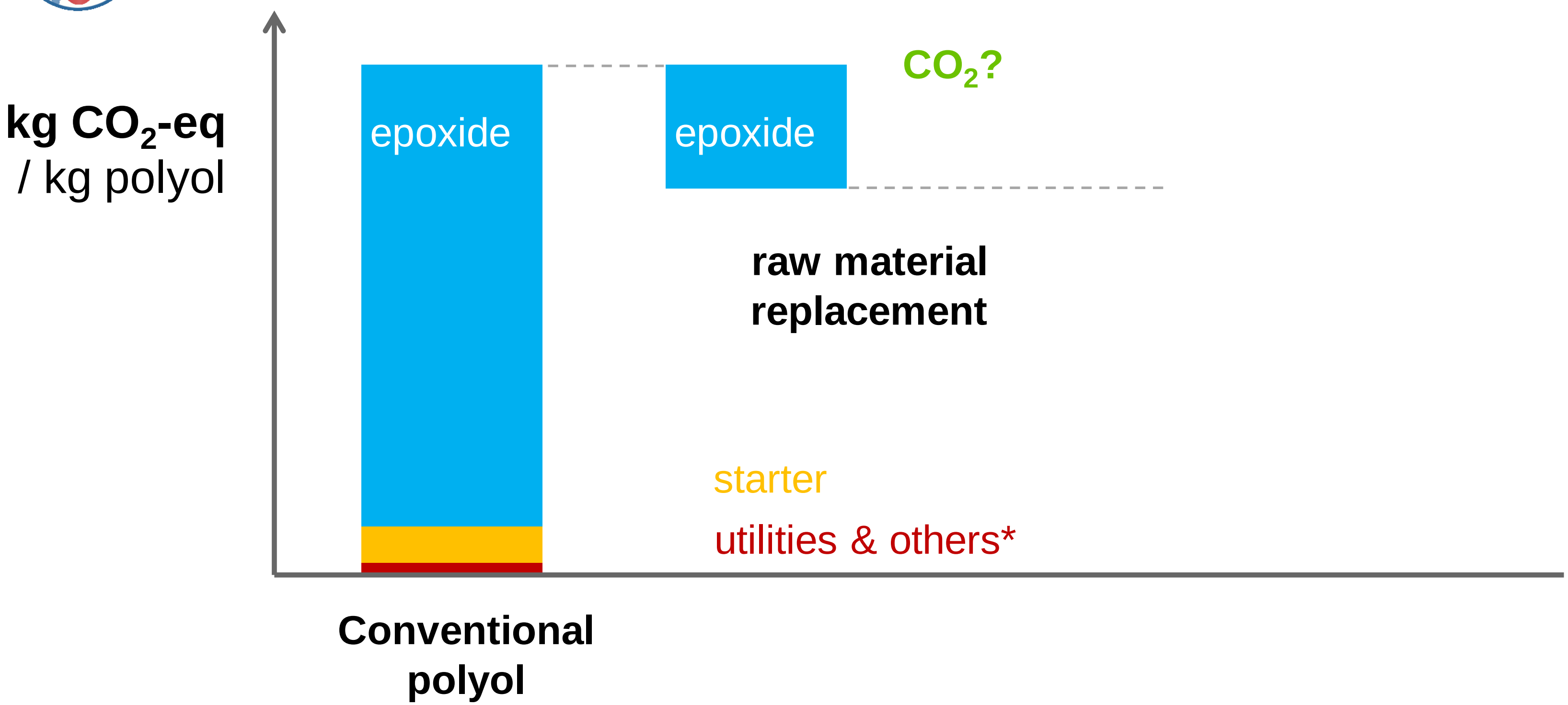
!?

Complex LCA by RWTH University – All aspects covered



Dream Production LCA – Climate Change

Impacts on Climate Change



* includes process steam, electricity, cooling water, catalyst etc.

N.von der Assen and A.Bardow (**2013**). Oral presentation, ICCDU XII, Alexandria, VA, USA

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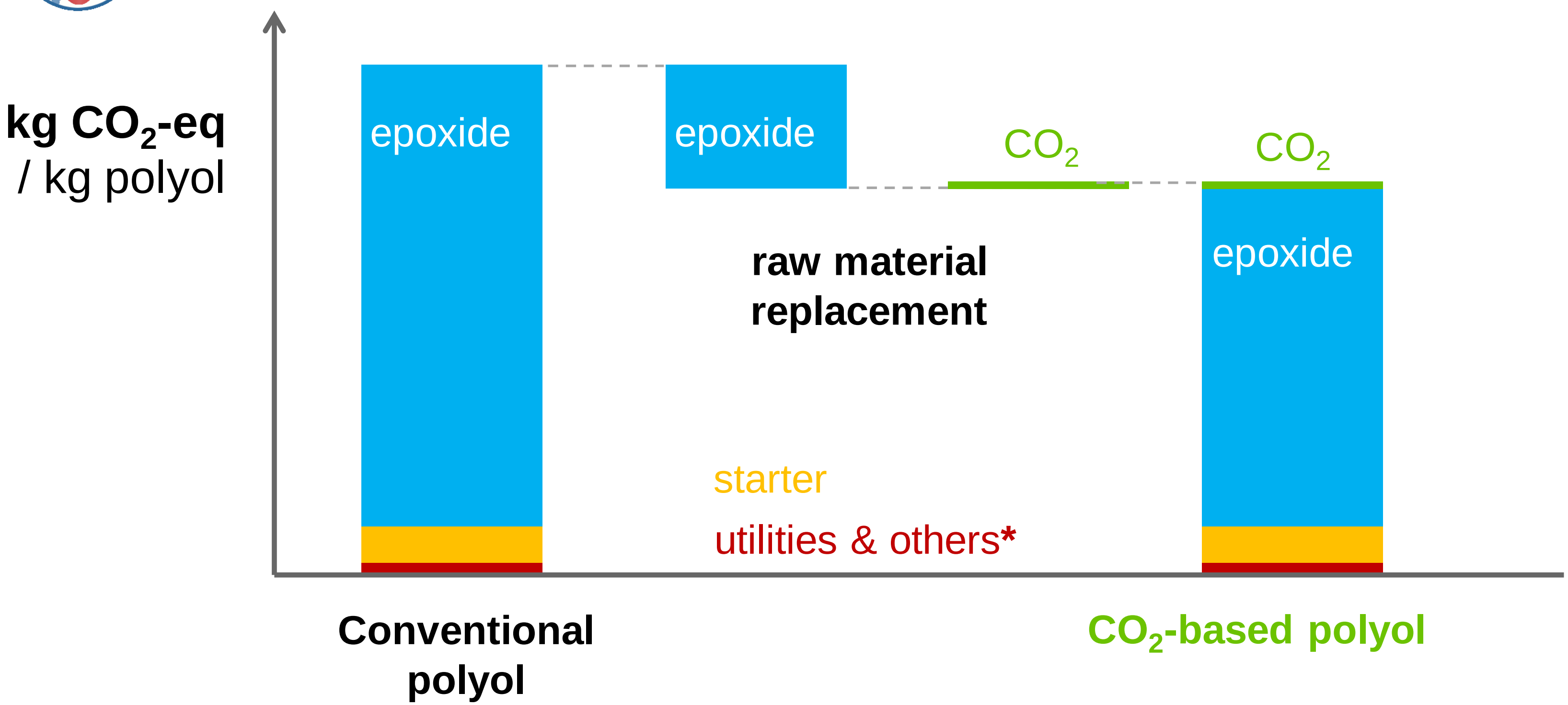

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Niklas von der Assen and André Bardow
Green Chem., 2014, **16**, 3272-3280

Dream Production

From research to commercial use

- Following successful research phase, commercial use of the new process and the production of the first CO_2-based polyols for sale.
- Construction of a production line at the Dormagen site with an annual capacity of 5,000 metric tons.
- Investment volume of EUR 15 million
- Planned start of production early 2016

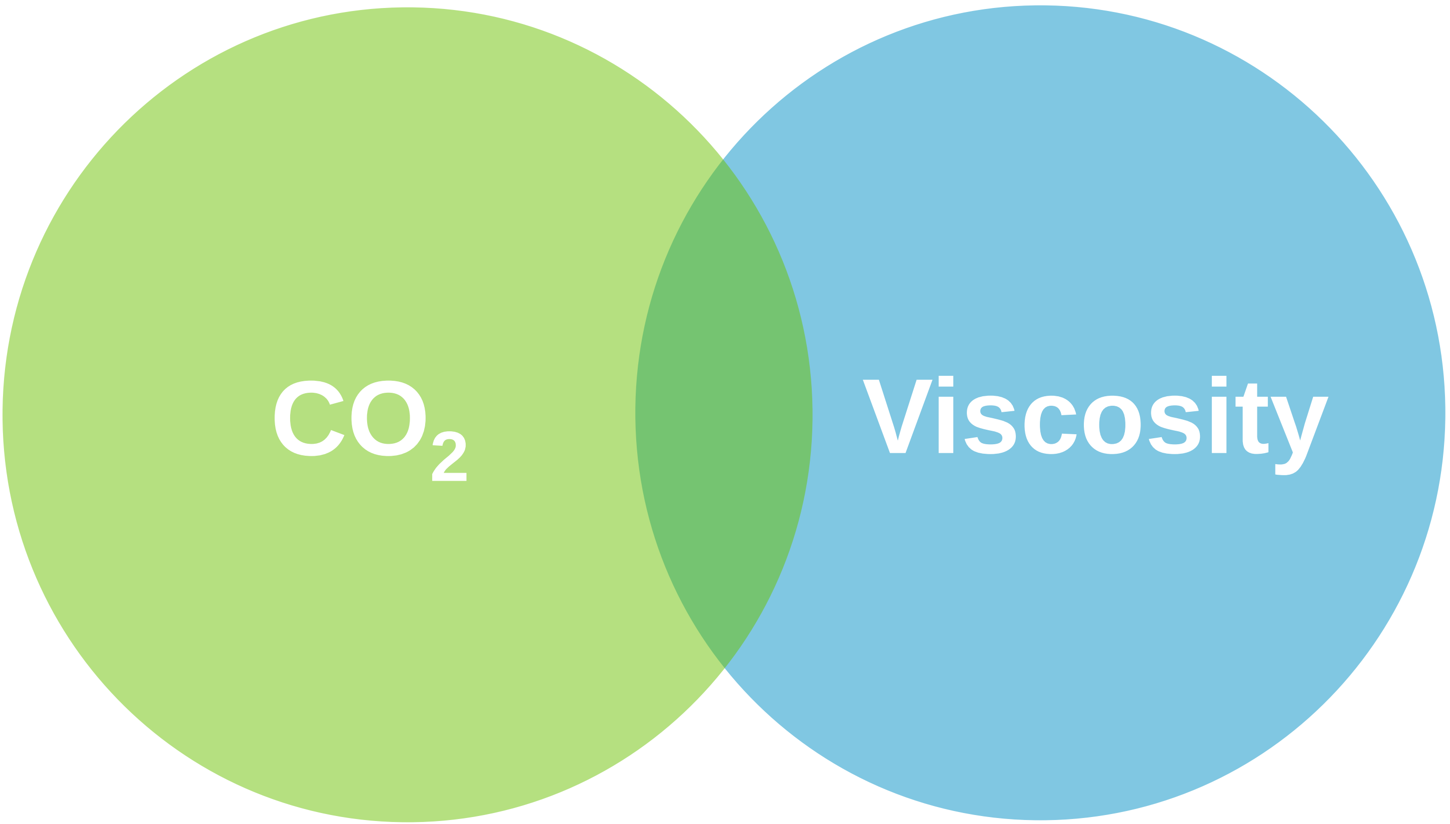
Thank you for your attention!

- ✓ It works
- ✓ Very good foam properties achieved
- ✓ Improved CO_2 footprint

Science For A Better Life

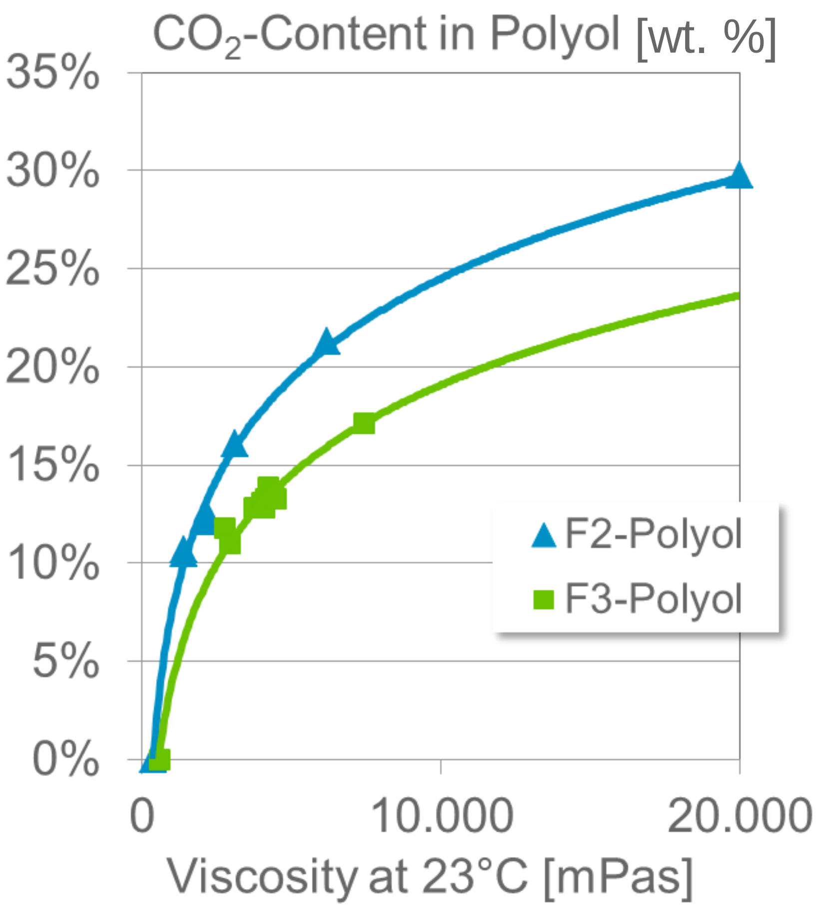
CO_2-based polyols:

Balance between value creation and market acceptance



Effect of CO_2 in polyols

Carbonate groups contribute to increased viscosity



- Viscosity strongly depends on functionality and CO_2 content
- Polyols can be designed according to application requirements
- CO_2-based polyols show viscosity properties in the range between polyether and polyester grades

Thermal foam stability
CO_2-based foam show good performance

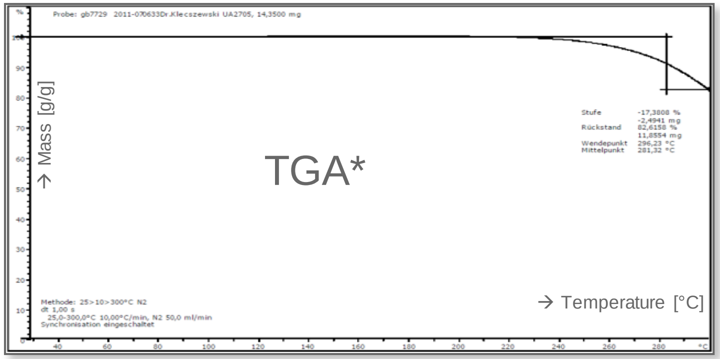
Thermal stability test* for PUR slabstock:

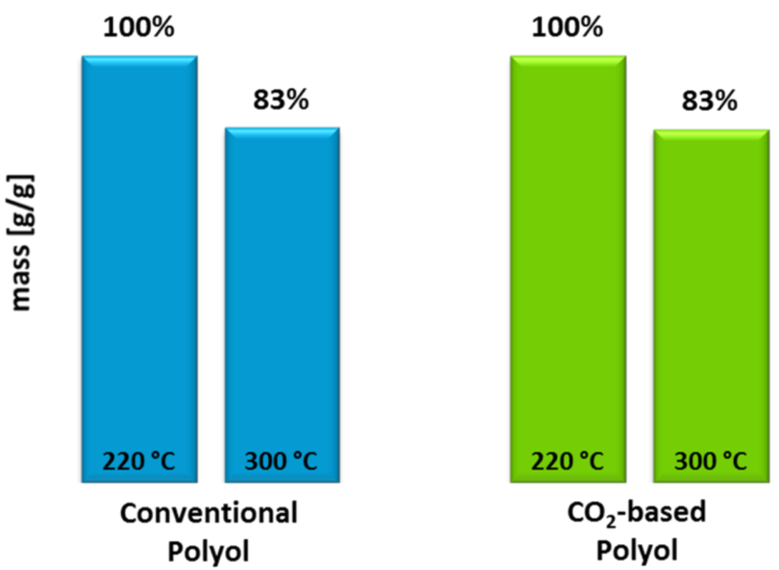
- Identical onset temperature and mass loss
- No difference in thermal sensitivity

Conclusion:

- CO_2 is chemically fixed inside the polyurethane backbone
- Thermal foam stability matches that of conventional polyols

* TGA: Thermo-Gravimetric Analysis (heating rate: 10 K/min)

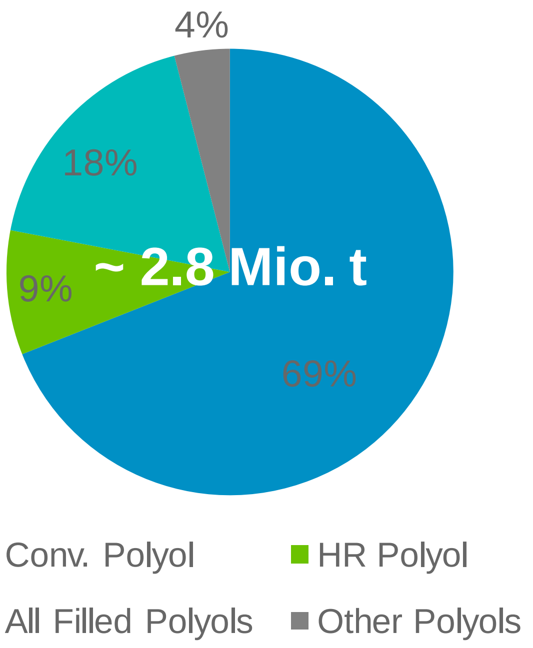




New CO_2-based polyols for flex-foam

Comfort materials count for ~36% of the PU market

Global slabstock polyol market 2012*



* Estimate based on IAL studies