ENCONTRO NACIONAL DAS INDÚSTRIAS DE COLCHÕES ABICOL

Reciclagem de Espuma Flexível

Evonik

Celso Toyoshima

Next Generation Evonik:

Sustainability fully integrated into all three strategic levels

Three major strategic levers… | **… with sustainability fully integrated …** | **… delivering on ambitious targets**

Next Generation Portfolio

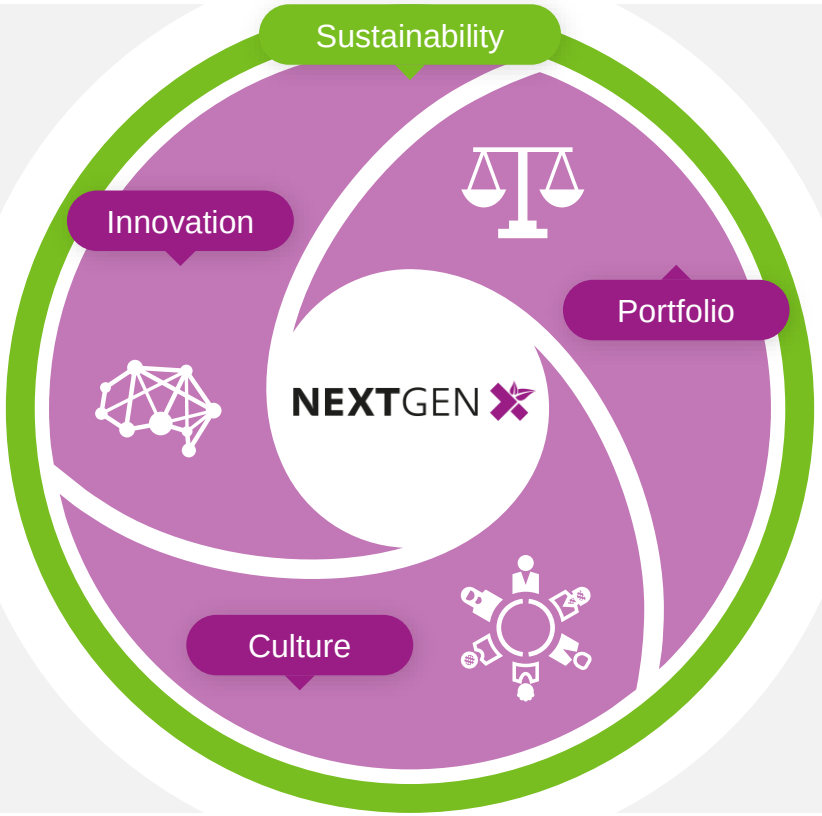
+ Exit Performance Materials
+ Full focus on three attractive growth divisions

Next Generation Innovation

+ €1 bn new sales well on track
+ Growth areas beyond 2025 already launched

Next Generation Culture

+ Diversity as key to successful strategy execution
+ ESG targets integrated into mgmt. compensation



ESG Targets

+ >50% sales share of NEXTGEN Solutions
+ -25% CO_2 emission reduction, e.g. via NEXTGEN Technologies

Financial Targets

+ Organic growth >4%
+ EBITDA margin 18-20%
+ ROCE ~11%
+ FCF Conversion >40%

Enabler of Sustainable Change

Sustainability Focus Areas

ENSURE HEALTH & WELL-BEING

DRUG DELIVERY SYSTEMS

- Advanced oral & parenteral drug delivery systems (e.g. mRNA LNP)

SPECIALTY ADDITIVES

- for environmentally-friendly solutions, e.g. water-based artificial leather

FIGHT CLIMATE CHANGE

FUTURE MOBILITY

- Lightweight solutions
- Solutions for hybrid & full battery cars

ECO-SOLUTIONS

- Specialty peroxides solutions
- Membranes for gas separation

Leading Beyond Chemistry

DRIVE CIRCULARITY

CIRCULAR ECONOMY

- Circular plastic & circular polyurethanes additive solutions

BIO-BASED SOLUTIONS

- Bio-based & fully bio-degradable surfactants
- Natural active cosmetics ingredients

SUSTAINABLE NUTRITION

- Omega-3 fatty acids from natural marine algae
- Gut health solutions

SAFEGUARD ECOSYSTEMS

Facts on Polyurethane Waste

In the EU, up to 40 million mattresses are discarded every year, most of them end up in landfills

In Europe, more than 1 million tons of flexible PU foam waste are generated every year – most of it ending up in the municipal waste streams

40.000.000
colchões x 20 cm
= 8.000 km

If they were stacked up,
the pile would be
8,000 km
high.

40.000.000 colchões de solteiro, D23

= 300.000+ ton de espuma

In 5 years
this stack would reach
geostationary orbit.

ENCONTRO NACIONAL DAS INDÚSTRIAS DE COLCHÕES ABICOL

Push from the Market: IKEA Approach

Our commitment

100% CIRCULAR PRODUCTS BY 2030

BY 2030 ALL MATERIALS USED ARE RENEWABLE OR RECYCLED

ENCONTRO NACIONAL DAS INDÚSTRIAS DE COLCHÕES ABICOL

Polyurethane Recycling
Methods and Definitions

The Biggest hurdles to viable Polyurethane Recycling are:

a) feasible technical solutions that preserve performance

b) suitable outlets for recyclates

Mechanical Recycling

Mechanical downcycling of polyurethane is the most common practice in NA. Predominant application is carpet underlays. The market is saturated and material can be sourced at low cost.

Chemolysis

Chemical process in which PU foams are reacted under acidic or alkaline/ basic conditions to obtain polyols and amines in order to reuse them as feedstock for new polyurethane materials

Pyrolysis

Mixed plastics are heated in an inert atmosphere and broken down to liquid and gaseous hydrocarbons and be further used in petrochemical processes, technology not ready for use at scale

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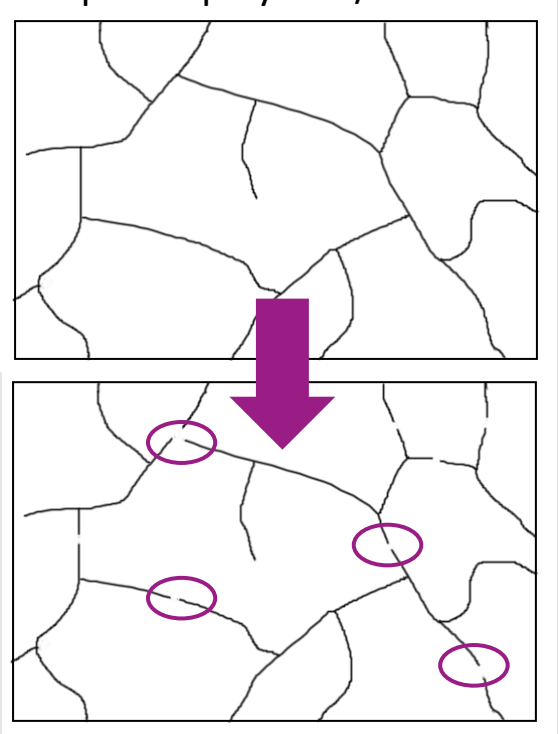
Thermoplasts vs. Duroplasts/Thermosets

Structural issue: duroplasts/thermosets are cross-linked: no melting or dissolving: network needs to be broken!

Duroplastic polymer /thermosets

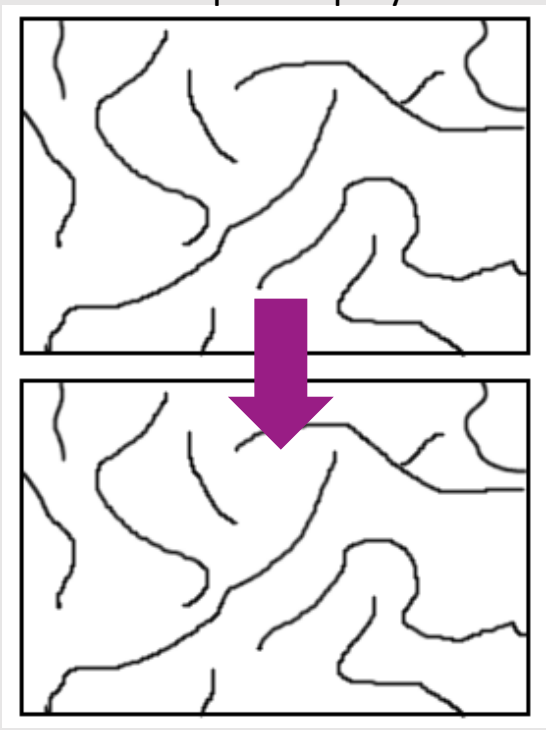


PU foam, rubber, epoxy resins

solid

liquid

Thermoplastic polymer



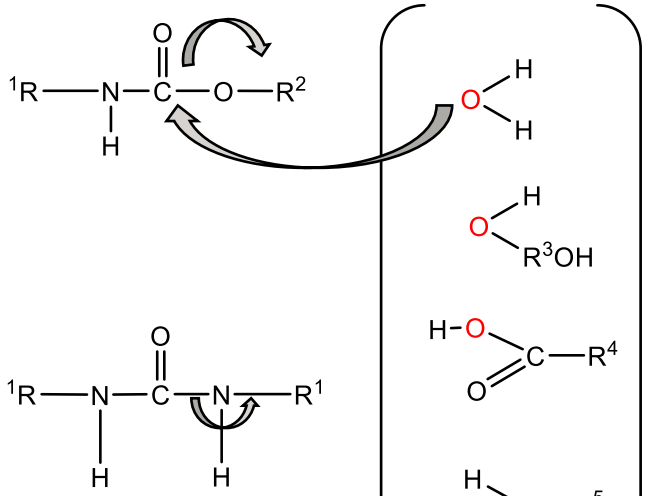
PE, PP, PS, TPU, PA, …

Chemolysis

- Polymers containing carbonyl functions can be cleaved back by nucleophilic substitution reactions
- Polyurethane foams contain various C=O functionalities, coming from the different reactions of isocyanate with various reaction partners

Urethane

Urea



Hydrolysis

Glycolysis

Acidolysis

Aminolysis

Recycling processes differ in

- the reagents used
- processing conditions
- steps involved
- quality of the end products

Combinations of different processes also commonly used.

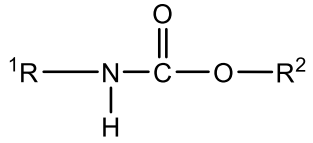
Chemolysis

Hydrolysis

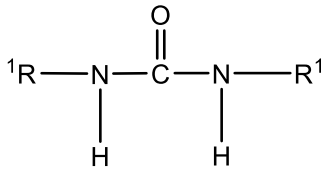
- Polymers containing carbonyl functions can be cleaved back by nucleophilic substitution reactions
- Polyurethane foams contain various C=O functionalities, coming from the different reactions of isocyanate with various reaction partners

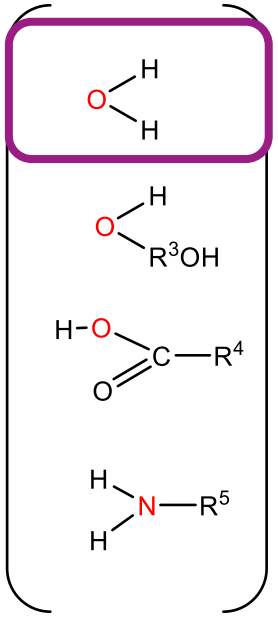
e.g.
T > 200°C, 16 bar

Urethane

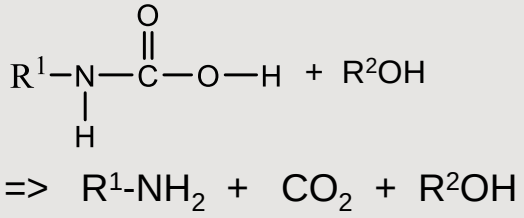


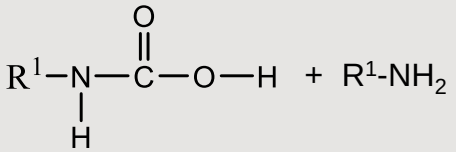
Urea





Hydrolysis





=> 2 R^1-NH_2 + CO_2

Advantage:

- Converting everything to the **diamine** plus the **polyol**.
- No oligomeric by-products, therefore higher quality & use levels possible

Disadvantage:

- **Separation** of amine and polyol needed before being reused

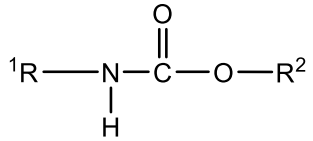
Chemolysis

Glycolysis

- Polymers containing carbonyl functions can be cleaved back by nucleophilic substitution reactions
- Polyurethane foams contain various C=O functionalities, coming from the different reactions of isocyanate with various reaction partners

T > 130°C reaction in heated glycols, “reaction pressure”

Urethane



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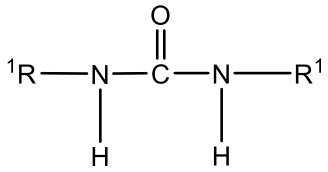
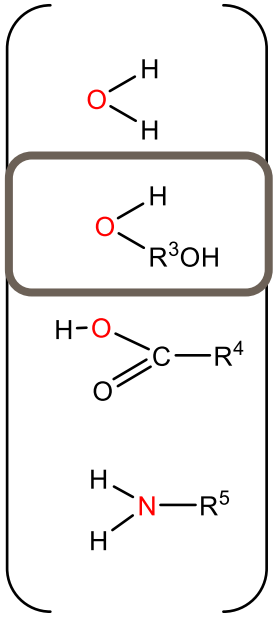
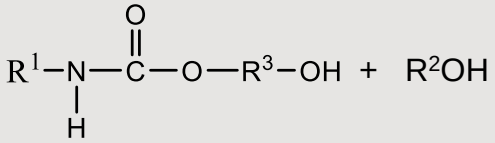
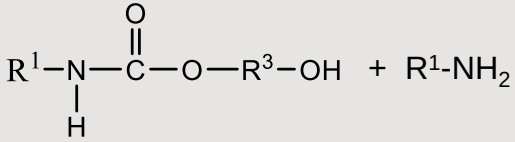




Glycolysis





- Mix of **hydroxy-carbamates**, **alcohols**, different **oligomers** and aromatic **amines**
- Generally <u>high OHN</u>
- Is normally used without further separation after the reaction
- Typically used in **rigid foam** applications

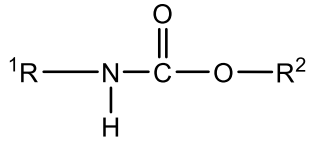
Chemolysis

Acidolysis

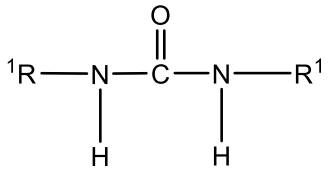
- Polymers containing carbonyl functions can be cleaved back by nucleophilic substitution reactions
- Polyurethane foams contain various C=O functionalities, coming from the different reactions of isocyanate with various reaction partners

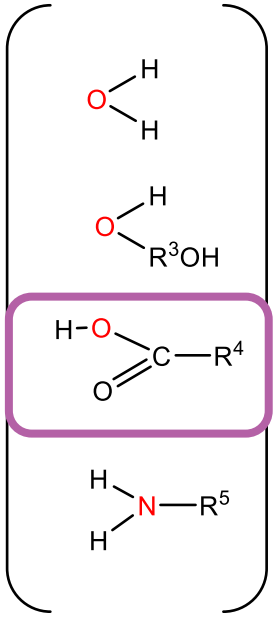
e.g. T > 130°C & reaction in molten organic acids

Urethane

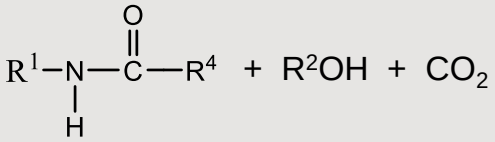


Urea

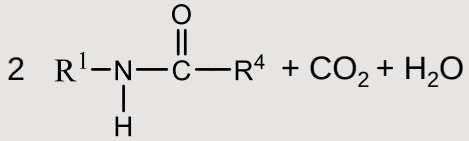




Acidolysis



R^2-OH + R^3COOH => R^3**COO**R^2 + H_2O



- Mix of **amides** with **alcohols** & **esters**
- Often oligomeric structures, intermediates present as well
- Reaction mixture is normally **neutralized** and **filtered** before use
- Allow for **lower OHN**

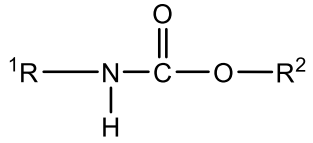
Chemolysis

Aminolysis

- Polymers containing carbonyl functions can be cleaved back by nucleophilic substitution reactions
- Polyurethane foams contain various C=O functionalities, coming from the different reactions of isocyanate with various reaction partners

e.g. room temperature,
atmospheric pressure

Urethane



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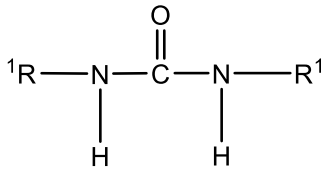
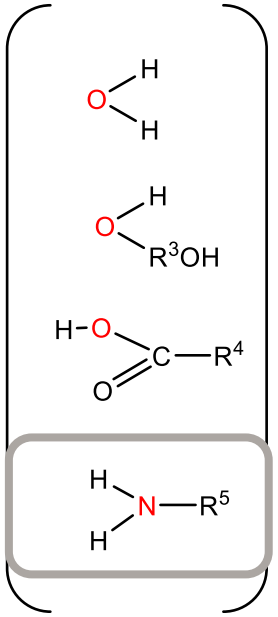
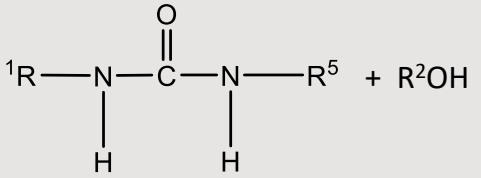
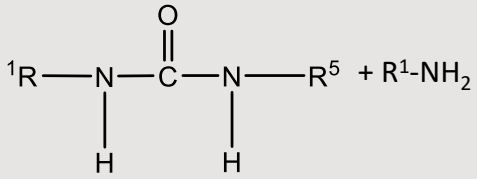




Aminolysis





- Mix of
  urea compounds,
  polyol and
  aromatic amines

Chemolysis

Challenges

- C**olour** of the recycling polyol is gray / brown due to oxidation processes
- The **degradation of the network is often not complete enough**. The **viscosity** of the recycling polyol is often high.
- Depending on the process **further processing steps** after the reaction might be necessary, like neutralization, filtration, removal of water, distillation of solvents, deactivation of catalysts, adding of antioxidants.
- Depending on the process and the used PU material the recycling material can be a mixture with various species present.
  Often **break-down products** of various chemicals are contained. Odor of new foam might be influenced.
- Iron content concern.. Overall, recycling polyol needs to be treated with care in terms of **scorch and self-ignition** of new produced foam.
- From a **legal point of view** the recycling polyol is a) waste a b) newly produced chemical mixture? Does REACH apply? How to register the varying composition?
- The **OH number** of the recycling polyol
- **Up to 30 % use level** in normal flexible foam formulations. Much less in sensitive formulations.

Landscape in Chemical PU Recycling

Ikano/Ikea

Chemical Recycling

- Follows H+S acidolysis process

Dow/Renuva

Chemical Recycling

- Collaboration with H+S based on acidolysis process (since 2017) under Renuva project name
- Recently added Eco Mobilier, Orrion and Vita to Renuva program

BASF

Chemical Recycling

- New process development

Pyrolysis

- For all types of plastic waste
- High caloric intake through PU might pose an issue

Rampf Eco Solutions

Chemical Recycling

- Glycolysis/Acidolysis

Tempur/RePURpose

Chemical Recycling

- Danish consortium incl. Tinby research Institute
- Not published which type of chemolysis

Covestro/PUReSmart

Chemical Recycling

- Development of new and easier to recycle polyols through „PUReSmart consortium
- New chemolysis process development

Evonik is also helping to

solve this threat

to the industry.

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Post-Consumer Mattresses

Circular Supply Chain

1. PU Foam Product reaches EoL
2. Material disposal to collector
3. Material Sorting, Dissembly, Separation & Shredding
4. Depolymerization
5. Foaming with re-Feedstock
6. Distribution of recycled PU Foam Product

Amine Phosgenation

EVONIK Leading Beyond Chemistry **Additives** allow for high use level of recycled PU components and reduction of scrap

EVONIK Leading Beyond Chemistry **Various business model options**

Enables mattress recycling via hydrolysis of PU

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Final details

Evonik Flexible PU Foam Recycling

- IP for the process is already in place to protect our know-how.
- Hydrolysis reaction to break-down the polyurethane flexible foam.
- Both main components of flexible PU foams can be recovered.
- Currently, we are focusing on the recovered polyol. The use of the recovered TDA will be considered at a later date.
- High-quality recycled polyol on lab scale. Increased use level compared to other processes.
- Vita partnership not exclusive. Evonik is open to work with other companies later in the project. At the moment, we are not able to work with other foam producers as the process is still at an early stage.
- Ongoing upscaling of the process. Extra time to create the most environmentally friendly process – process with least energy consumption and highest recovery rate of the main components of PU flexible foam as well as producing recycled materials that are easy to process.
- Samples will be available once scale-up is completed.


EVONIK
Leading Beyond Chemistry