Circular Economy at BASF

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Circular Economy at BASF

Dr. Martin Brudermüller
Chairman of the Board of Executive Directors
and Chief Technology Officer of BASF SE
Cautionary note regarding forward-looking statements

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The European Green Deal

“The Green Deal is Europe’s ‘Man on the Moon’ Moment”

Selected Green Deal objectives

- First climate-neutral continent by 2050
- Lead the way to a circular economy
- Move to a zero-pollution environment
- Accelerate to a sustainable food system
BASF’s Circular Economy Program: Targets

- 250,000 metric tons of circular feedstock by 2025
- Double circular sales to €17 billion by 2030
- Prioritize related capex, M&A, R&D
BASF’s Circular Economy Program: Today’s focus

New Feedstocks
New Material Cycles
New Business Models
Today’s recycling landscape for plastic waste
Fate of 30 million metric tons of plastic waste generated in EU28+2 in 2018

Only one third of all plastic waste is kept in the materials cycle in EU28+2.
The plastics value chain
New chemical recycling technology to increase the overall amount of plastic waste recycled

ChemCycling™ is complementary to mechanical recycling.

Chemical recycling
- Waste to chemicals
- Can handle mixed plastic waste
- Products are “virgin-grade”
The scale-up challenge: BASF collaborates with partners to supply its Verbund with pyrolysis oil

- World’s largest plastic pyrolysis plant\(^1\) of Quantafuel in Skive, Denmark is operating with first-generation catalysts
  - **Unique integrated process of pyrolysis** of mixed plastic waste and purification into a secondary raw material
  - Catalytic purification happens at ambient pressure
  - Flexibility in scale enables optimization of the supply chain setup

- Further cooperation partners with focus on pyrolysis of end-of-life tires:
  - Pyrum Innovations, Germany
  - New Energy, Hungary

\(^1\) Capacity of 16,000 metric tons per year
The purification challenge: Together with Quantafuel, BASF develops purification catalysts for their technology

- Waste plastic feedstock contains a variety of chemical structures and a significant amount of heteroatoms, e.g., chlorine, nitrogen and oxygen.
- These are undesirable in pyrolysis oil as they cause corrosion, create safety risks or poison process catalysts.
Chemical recycling broadens BASF’s feedstock base and leverages the Verbund concept

BASF can allocate new feedstocks to the most attractive applications combining its unique Verbund and Mass Balance concepts.
Next steps in BASF’s chemical recycling partnerships

**2020**

**Establishing partnerships**
- Start up of Quantafuel's plant in Skive, Denmark. Test second-generation approaches
- Investment into tire pyrolysis specialist Pyrum, Germany
- Agreement for a feasibility study with New Energy, Hungary

**2021**

**Further development of processes**
- Test second-generation approaches in pilot scale with Quantafuel
- Start of construction of two additional production lines in Pyrum's existing site in Dillingen
- Trials with mixed plastic waste in New Energy's plant in Dunaharszti

**Capacity building**
- Start construction of second-generation plant with Quantafuel
- Build-up of additional capacities with Pyrum and further partners

**2022**

ChemCycling™ is a key contributor to BASF’s commitment to use 250,000 metric tons of recycled feedstock annually by 2025.
Bio-based products across the portfolio further broaden BASF’s feedstock base

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Materials</th>
<th>Industrial Solutions</th>
<th>Surface Technologies</th>
<th>Nutrition &amp; Care</th>
<th>Agricultural Solutions</th>
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<tbody>
<tr>
<td>Bio PolyTHF®</td>
<td>ecovio® packaging</td>
<td>Sovermol® 830</td>
<td>Color Brite</td>
<td>Rambuvital®</td>
<td>Inscalis® insecticide</td>
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BASF’s Circular Economy Program: New Material Cycles
Established mechanical recycling loop for plastics

Mechanical recycling
- Polymer to polymer
- Clean single-stream waste needed
- Products are not “virgin-grade”
Mechanical recycling – a fast-growing market enabled by innovative additives

Mechanically recycled plastics globally
million metric tons

- 50 million metric tons collected for recycling in 2018
- 30 million metric tons mechanically recycled plastics in 2018
- 97 million metric tons projected in 2030 (growth at +10% p.a.)


BASF is expanding its broad plastic additives portfolio with offerings specific to the mechanical recycling of common types of plastic.
Innovative stabilizers enable mechanical recycling
Example: Recycled PET bottles – color shift

**Challenge:**
- Discoloration of recycled PET bottles

**Solution:**
- Yellowing and greying is inhibited by adequate additization during recycling
- Reuse in applications of equal or higher value are made possible

**Discoloration**
**yellowing index**

<table>
<thead>
<tr>
<th></th>
<th>Fresh bottle flakes</th>
<th>…without restabilization</th>
<th>…with restabilization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Discoloration</strong></td>
<td>3.4</td>
<td>6.3</td>
<td>3.7</td>
</tr>
</tbody>
</table>

Source: BASF internal analysis at Polymer Additives Lab in Kaisten, Switzerland
Innovative compatibilizers enable higher recycling rates
Example: Polymer mixtures – inhomogeneities

**Challenge:**
- Mixtures of chemically different polymers show inferior performance profiles for reuse due to de-mixing

**Solution:**
- Innovative block copolymers can connect different polymer phases
- Compatibilization avoids defects and ruptures in recycled plastics

Without compatibilizer

With compatibilizer

Footprint of key battery materials

1 kg nickel class 1 with >99% purity

7.9 kg CO₂

3.6 kg oil

106 kg blue water

1 kg lithium hydroxide-monohydrate

271 kg blue water

7.4 kg CO₂

2.6 kg oil

The considerable footprint of virgin nickel and lithium can be reduced with recycling loops.

Note: "CO₂" means CO₂-equivalents, "oil" means energy demand in oil-equivalents
Sources: H₂O: Minirvo Ltd, Lithium Hydroxide Monohydrate Life Cycle Assessment Study, 2020, ex Salar del Hombre Muerto
Nickel: Nickel Institute, Life Cycle Analysis 2017 for class 1 Nickel (100%), ex Nickel sulfate
The new value chain for electric vehicles – recycling closes the loop

Creating a circular economy for battery materials

We aim to recycle used batteries as well as waste streams from all process steps and to create a “zero-waste” value chain.
Processing “black mass” – comparison of main technologies

Pyrometallurgy

- High recovery rates for nickel, cobalt and copper
- Graphite and solvents burned, providing much of the process energy
- Mature technology

- High energy intensity (around 1,500°C) and CO₂ footprint
- Loss of lithium in slag – recovery from slag is expensive

Hydrometallurgy

- High recovery rates for cobalt, nickel and copper
- Lithium is recycled
- Option for manganese and graphite recycling
- Moderate temperature range

- High investment required
- Inflexible process
- High amounts of by-products, waste

Both technologies have potential for improvement with regard to lithium yield, by-products or investment cost.
New BASF process scheme avoids waste

Step 1: Removal of lithium from “black mass”

“black mass”
30 kt

Smart lithium release ➔ Selective Li-leaching and purification

Benefits of LiOH first:

✓ avoids sodium sulfate by-product
✓ allows direct access to lithium hydroxide
✓ cuts investment cost in the value chain

Step 2: Extraction of Ni, Co

Leaching
H₂SO₄, H₂O₂

Purification
H₂SO₄, CaO

Ni, Co solvent extraction
NaOH, solvent

1 kt Li in form of LiOH*H₂O

10 kt NCM in form of Ni, Co, (Mn) sulfate

The new BASF process reduces CO₂ footprint and is flexible.
Next steps in closing the loop in battery materials

2020

- Pilot trials
- Flowsheet development

2021

- Start of pilot plant construction
- Process fine tuning

2022

- Start up pilot plant
- First battery-grade LiOH from pilot plant

BASF innovations will enable a new circular value chain in Europe.

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation.

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BASF’s Circular Economy Program

- New Feedstocks
- New Material Cycles
- New Business Models
Product Carbon Footprints create transparency for customers
Digital application to calculate greenhouse gas emissions of 45,000 sales products

20,000 raw materials
Scope 3

10 TWh/a energy
Scope 2

700 production plants
Scope 1

10 TWh/a

Product Carbon Footprints of
~45,000 sales products

Cradle-to-gate Product Carbon Footprints for BASF’s portfolio available by end of 2021 based on process emissions, energy demand and upstream emissions.
Profitable growth with transformation – based on resource efficiency of the Verbund and the Mass Balance concept

CO₂ emissions – illustrative example
per 1 kg product

We are creating a toolbox to offer differentiated carbon footprints for our sales products.
Circular Economy and Carbon Management Programs – BASF’s way to drive sustainability

We are providing drop-in products with new sustainability characteristics for customers in all industries.
- BASF

We create chemistry