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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

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Cautionary note regarding forward-looking statements

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The European Green Deal

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

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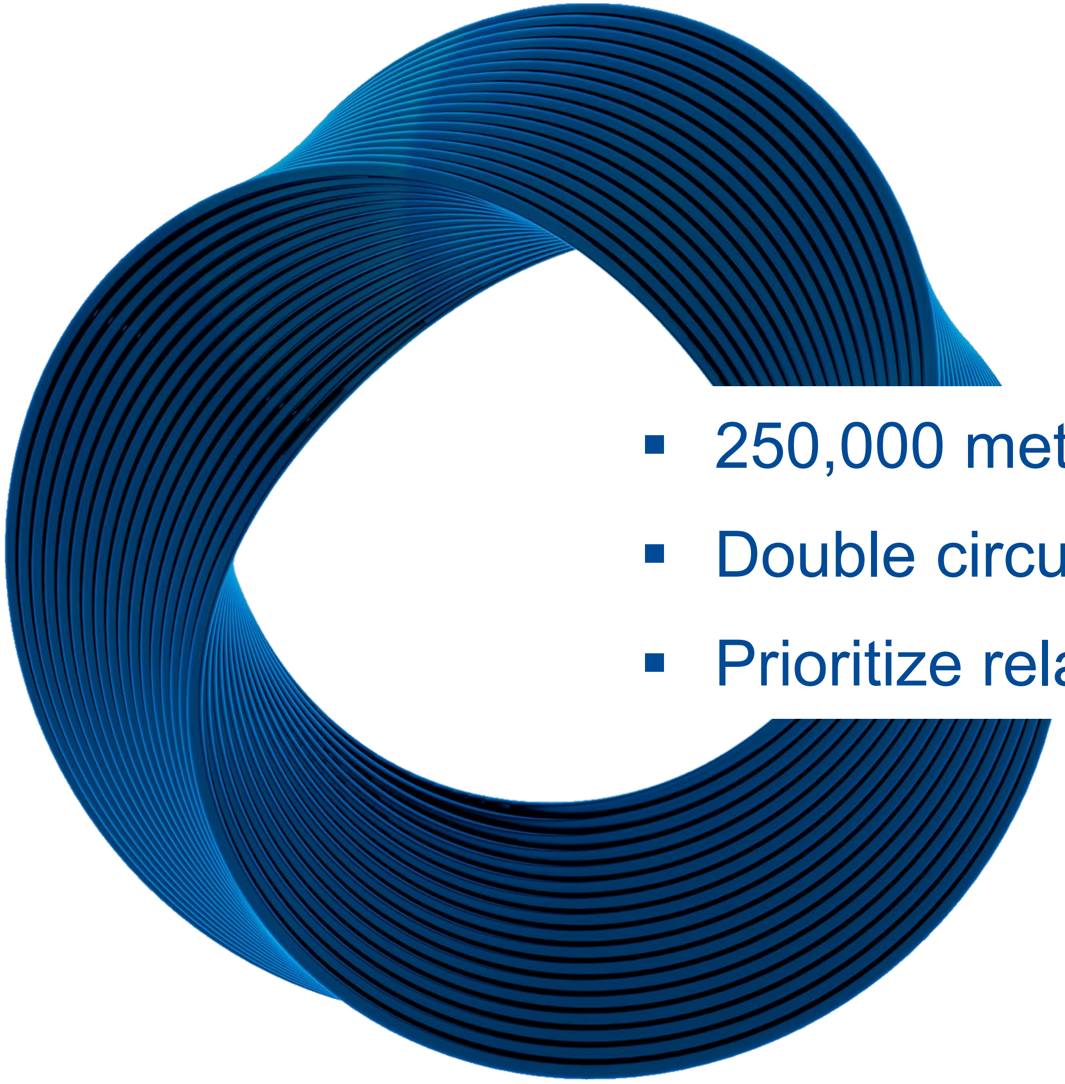
BASF’s Circular Economy Program: Targets



- 250,000 metric tons of circular feedstock by 2025
- Double circular sales to €17 billion by 2030
- Prioritize related capex, M&A, R&D

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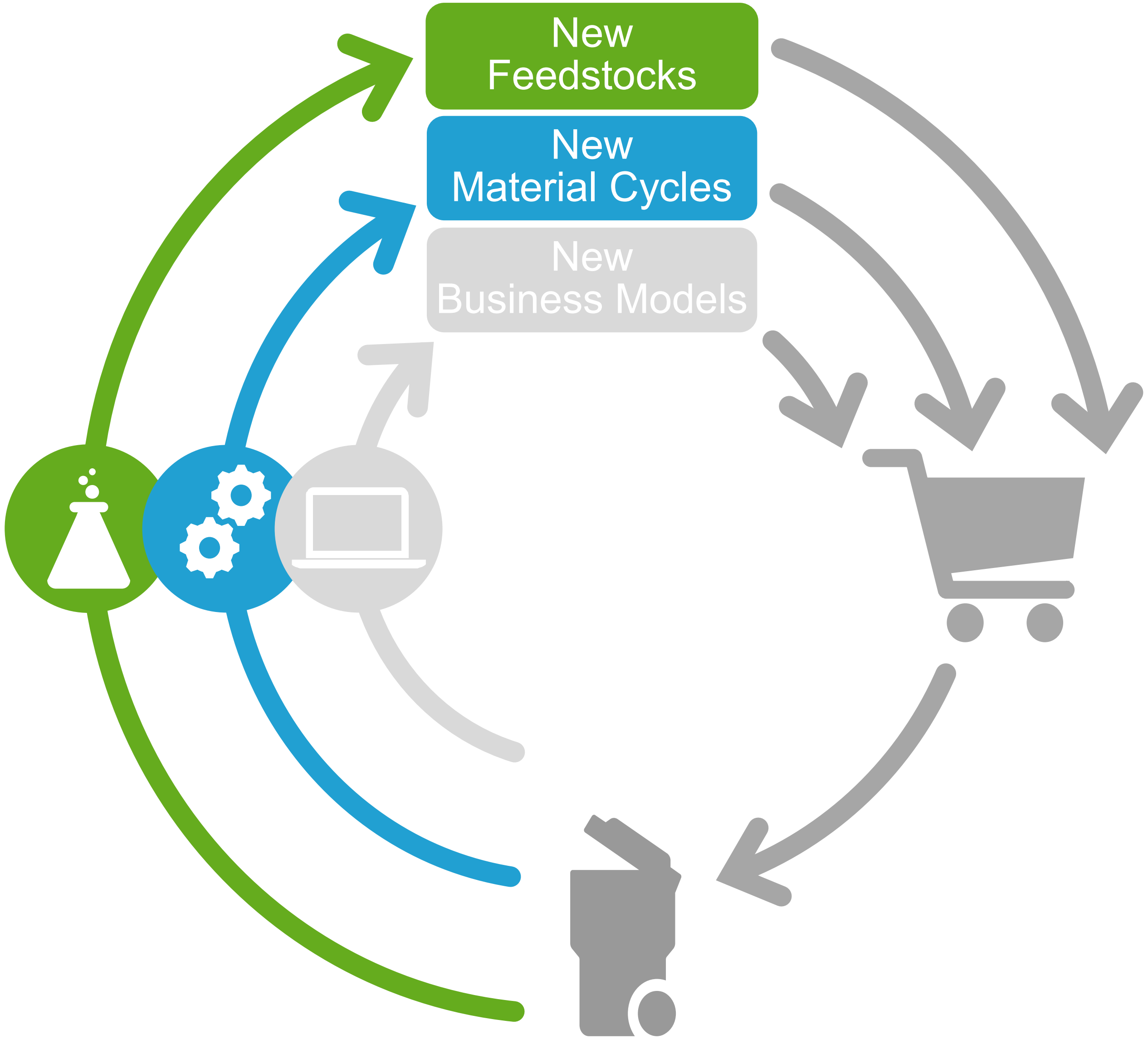
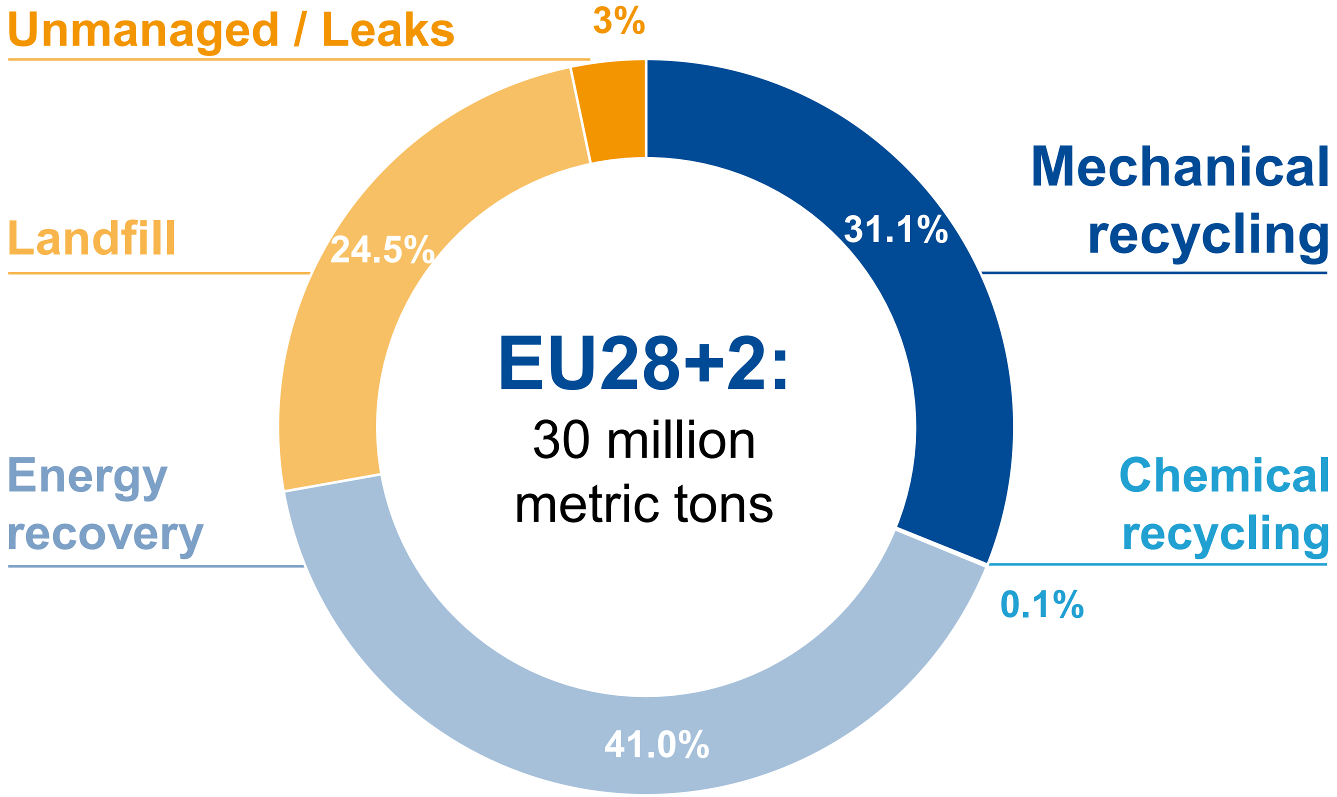
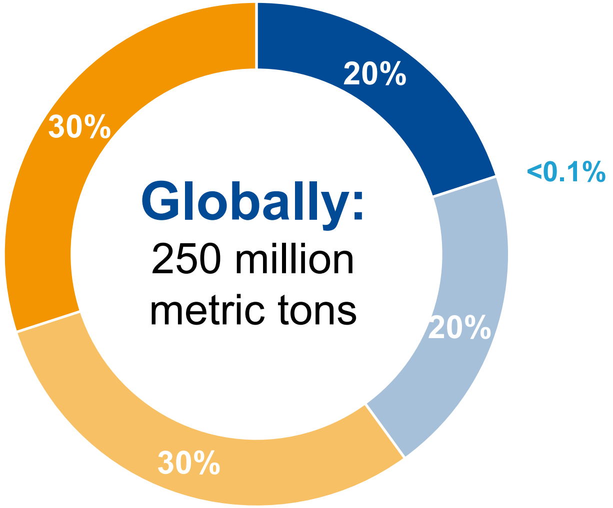
BASF's Circular Economy Program: Today's focus



Today's recycling landscape for plastic waste

Fate of 30 million metric tons of plastic waste generated in EU28+2 in 2018

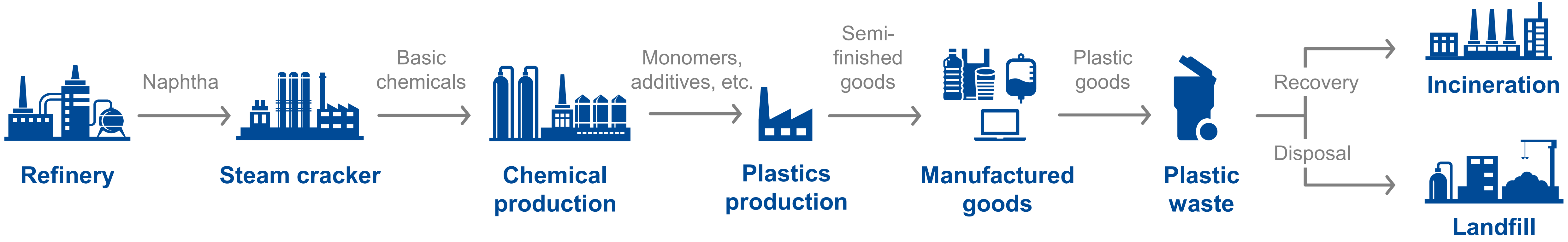




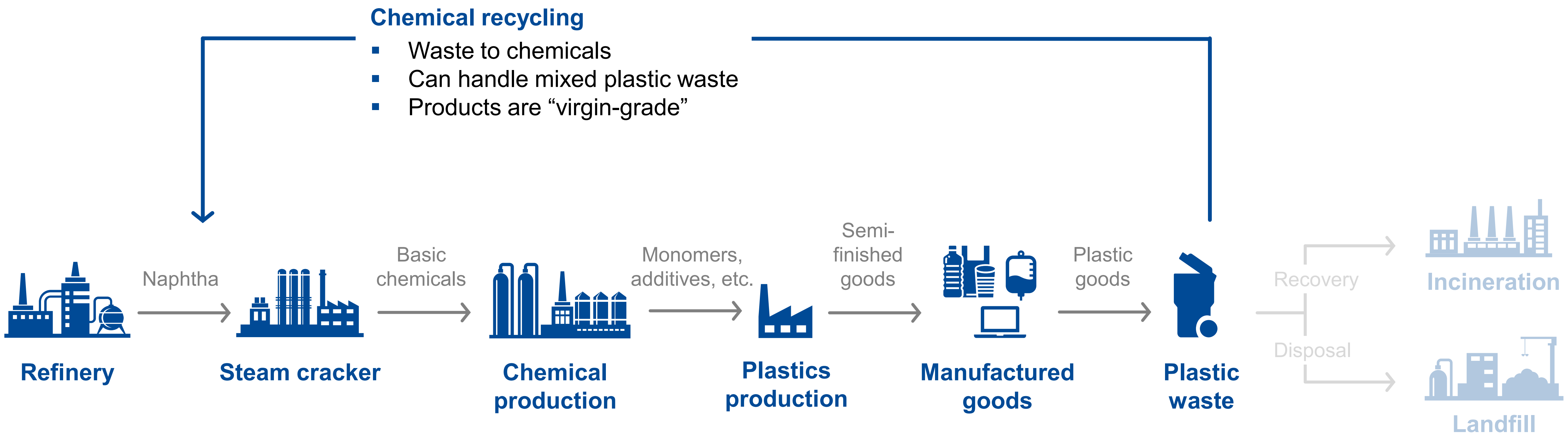
Only one third of all plastic waste is kept in the materials cycle in EU28+2.

 Source: Conversio, Circular Economy of Plastics 2018 EU28+2, September 2019; Conversio, Global Plastics Flow 2018, February 2020

The plastics value chain



New chemical recycling technology to increase the overall amount of plastic waste recycled



ChemCycling™ is complementary to mechanical recycling.

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

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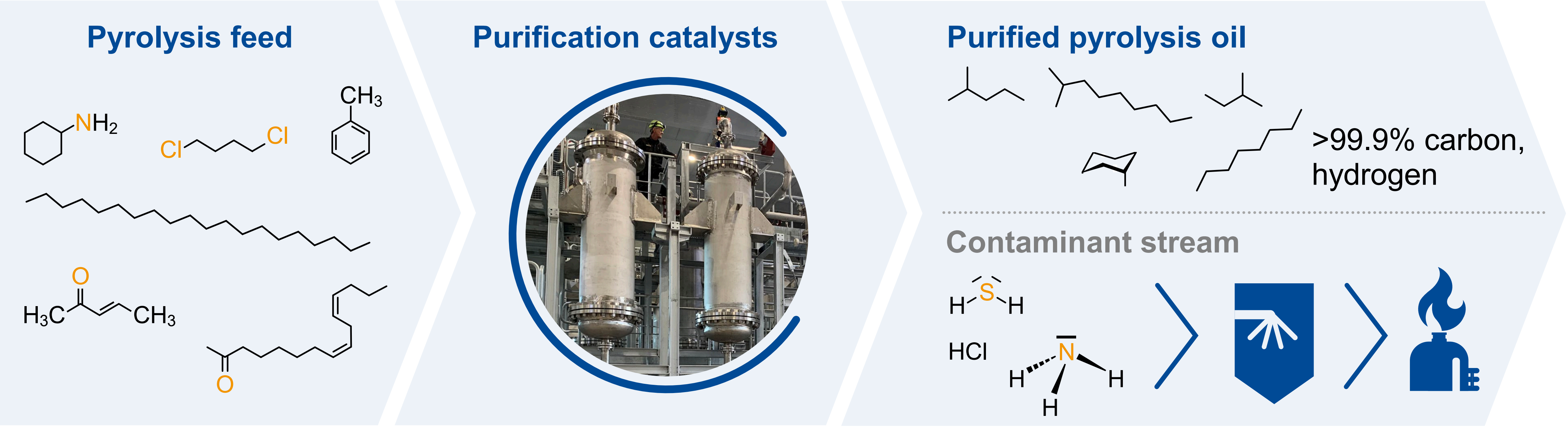
The purification challenge: Together with Quantafuel, BASF develops purification catalysts for their technology



- 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.

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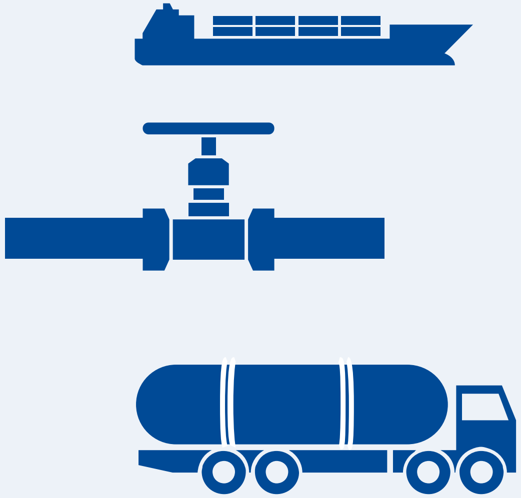
Chemical recycling broadens BASF's feedstock base and leverages the Verbund concept

Flexible feedstocks



Verbund concept

Mass Balance 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 Dunaharaszti

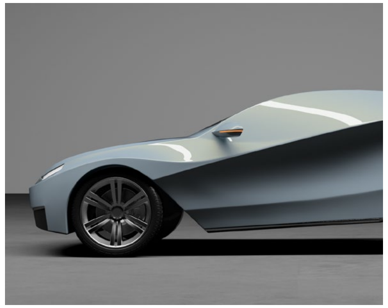
2022

Capacity building

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

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

Chemicals	Materials	Industrial Solutions	Surface Technologies	Nutrition & Care	Agricultural Solutions
					
Bio PolyTHF®	ecovio® packaging	Sovermol® 830	Color Brite	Rambuvital®	Inscalis® insecticide

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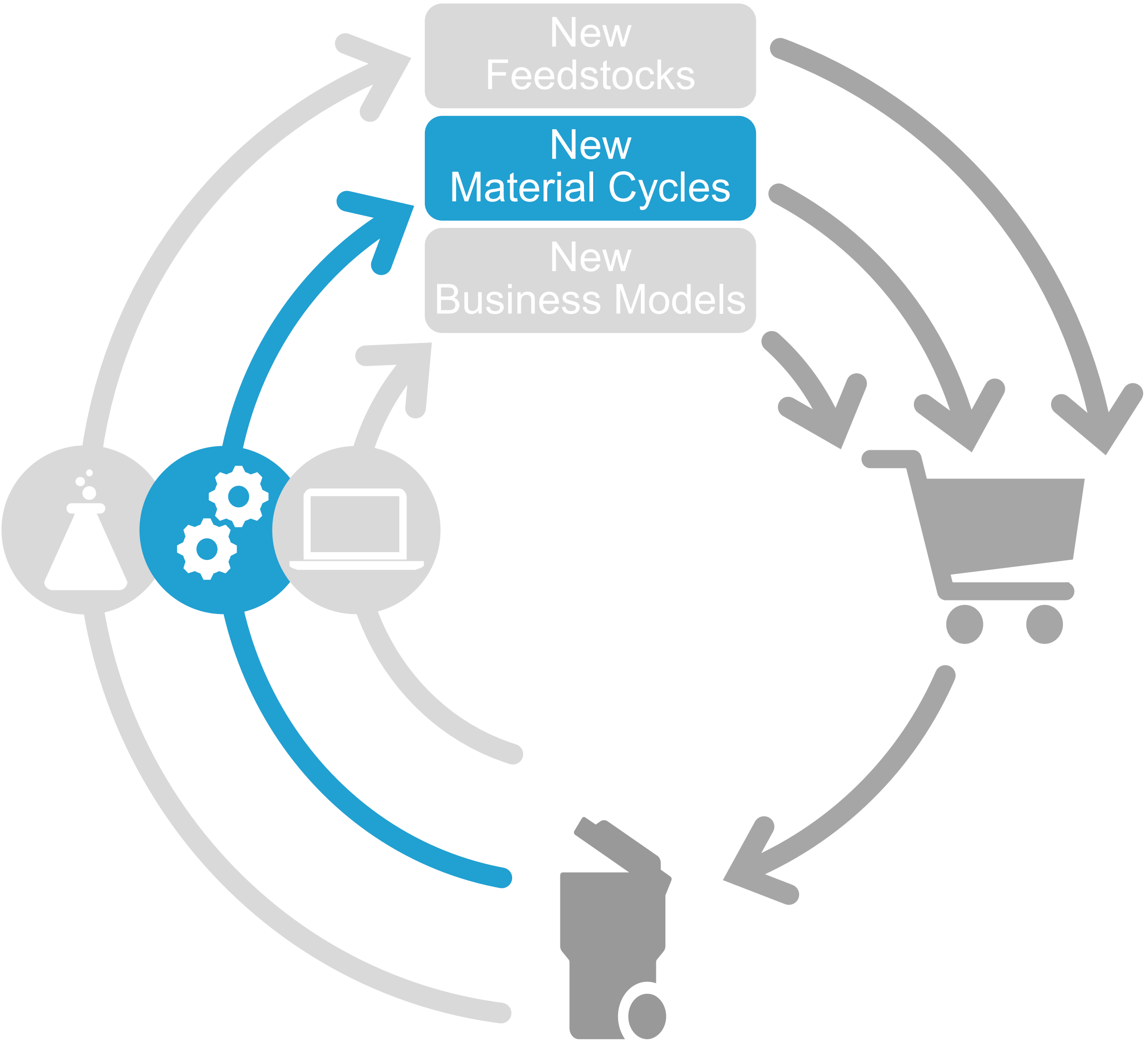
BASF’s Circular Economy Program: New Material Cycles



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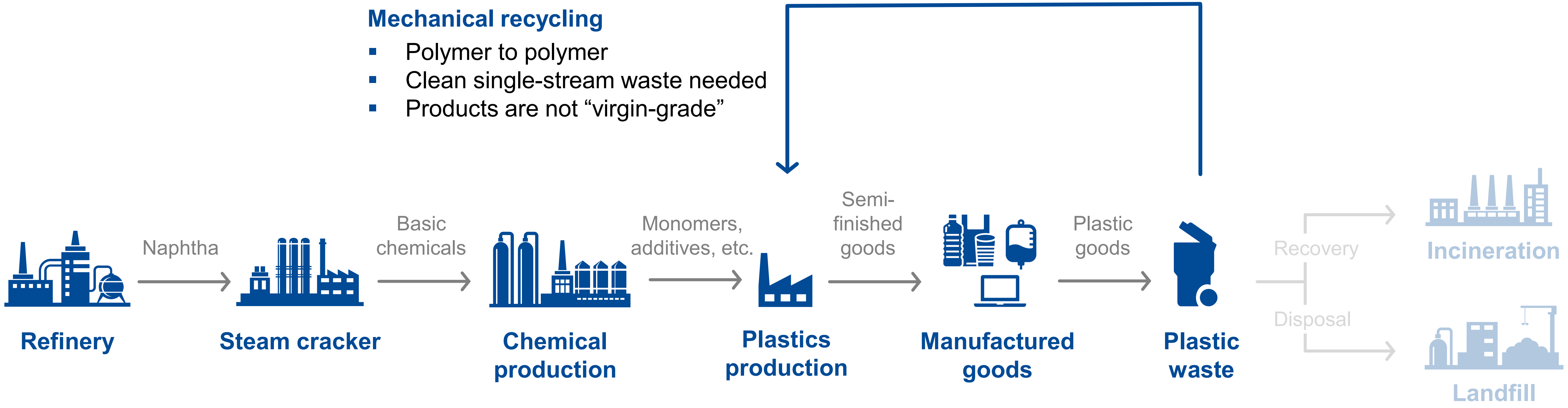
Established mechanical recycling loop for plastics

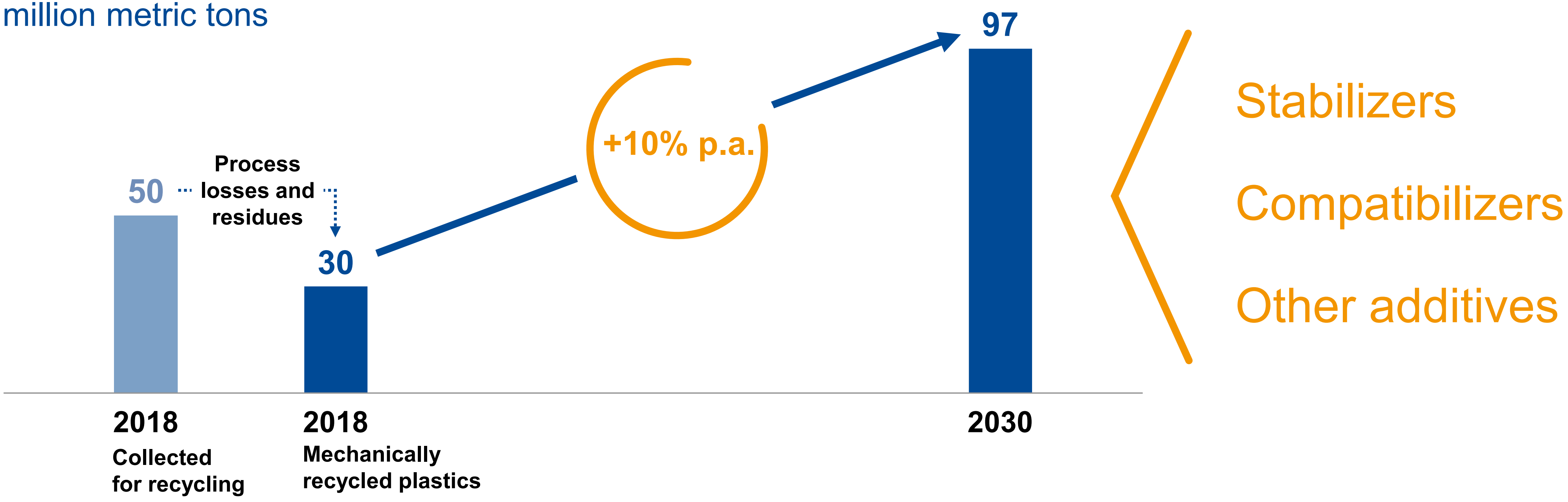
Mechanical recycling

- 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



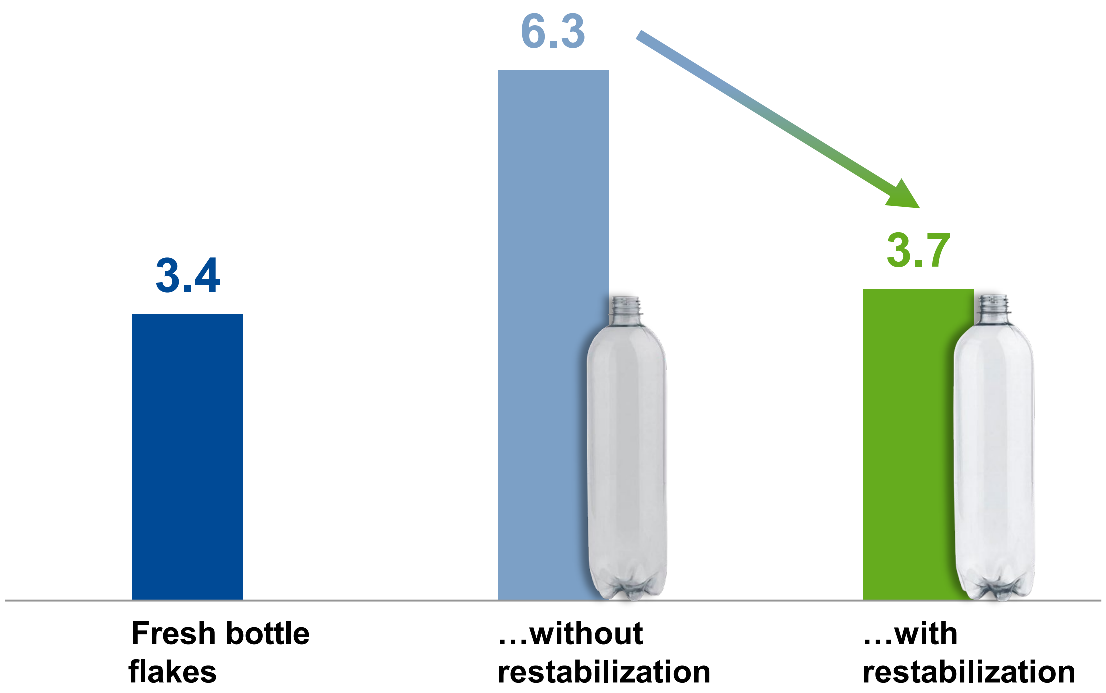
BASF is expanding its broad plastic additives portfolio with offerings specific to the mechanical recycling of common types of plastic.

 Sources: Mc Kinsey, No time to waste: What plastics recycling could offer, September 2018; Conversio, Global Plastics Flow 2018, February 2020

Innovative stabilizers enable mechanical recycling

Example: Recycled PET bottles – color shift

Discoloration
yellowing index



Challenge:

- Discoloration of recycled PET bottles

Solution:

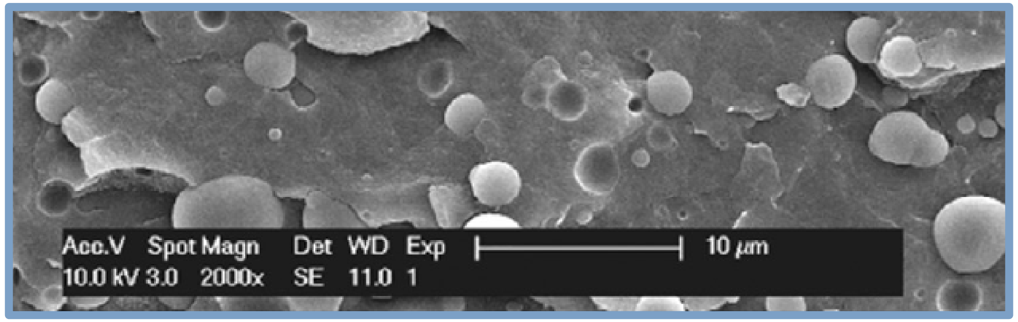
- Yellowing and greying is inhibited by adequate additization during recycling
- Reuse in applications of equal or higher value are made possible

Source: BASF internal analysis at Polymer Additves Lab in Kaisten, Switzerland

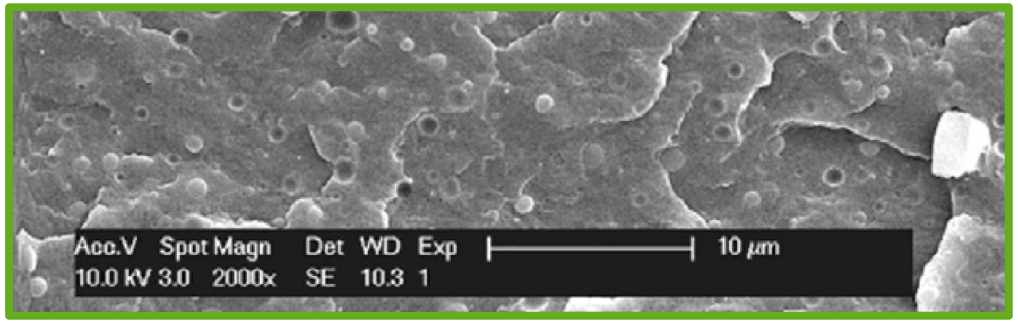
Innovative compatibilizers enable higher recycling rates

Example: Polymer mixtures – inhomogeneities

Without compatibilizer



With compatibilizer



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

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 Source: K. Ragaert et al, Waste Management 2017, 35.

Footprint of key battery materials

1 kg nickel class 1 with >99% purity

7.9 kg
CO_2

3.6 kg
oil

106 kg
blue water

1 kg lithiumhydroxide-monohydrate

271 kg
blue water

7.4 kg
CO_2

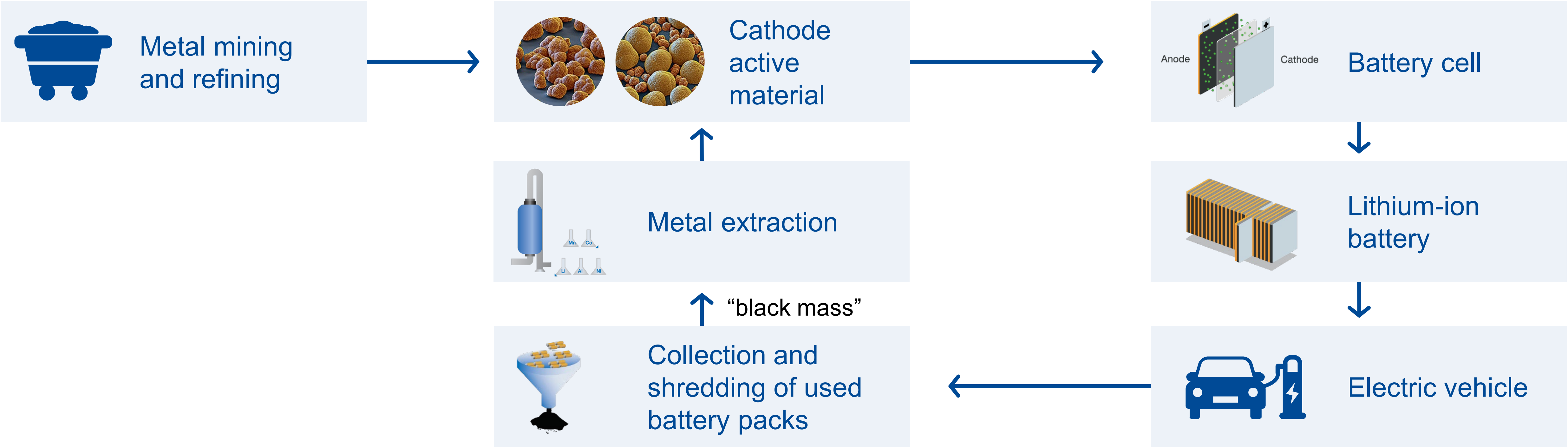
2.6 kg
oil

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

Note: "CO_2" means CO_2-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 CO_2 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.

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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

1 kt Li in form of $LiOH*H_2O$

Step 2: Extraction of Ni, Co

H_2SO_4, H_2O_2 → Leaching → Carbon (removal via filtration)

H_2SO_4, CaO → Purification → $CuSO_4$, $Al(OH)_3$, $Fe(OH)_3$, $Zn(OH)_2$, $CuSO_4$

NaOH, solvent → Ni, Co solvent extraction → **10 kt NCM** in form of Ni, Co, (Mn) sulfate

Benefits of LiOH first:

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

The new BASF process reduces CO_2 footprint and is flexible.

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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

eit RawMaterials
Connecting matters

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Ministerium für Wirtschaft, Arbeit und Energie

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

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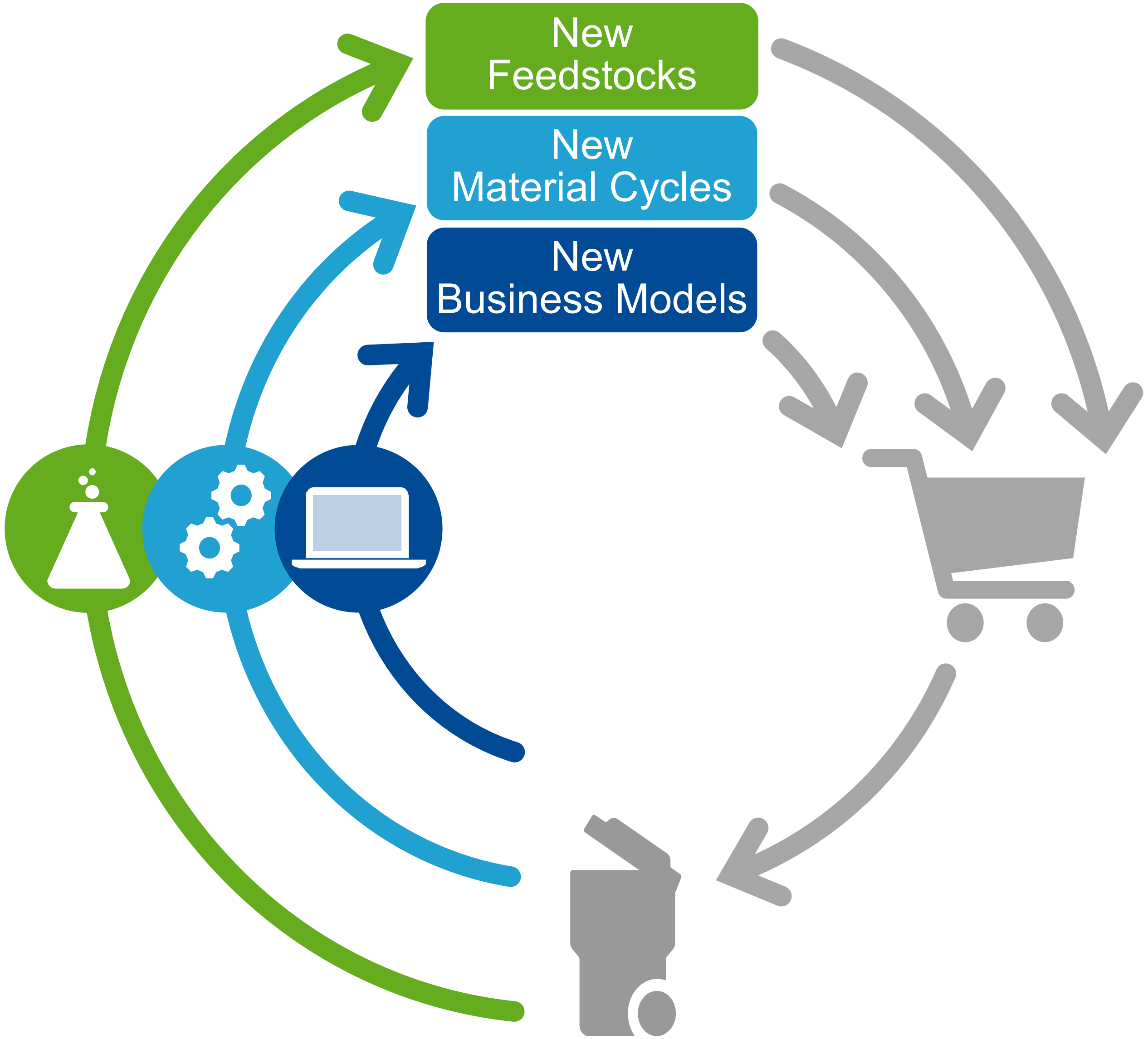
BASF's Circular Economy Program



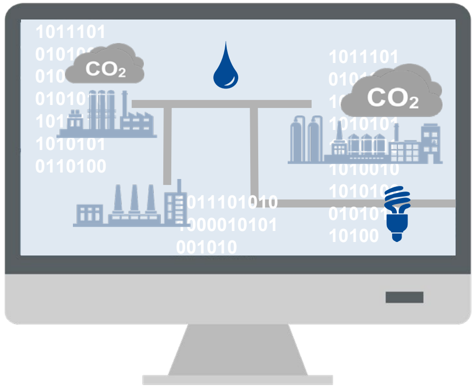
Product Carbon Footprints create transparency for customers

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



CO_2

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.

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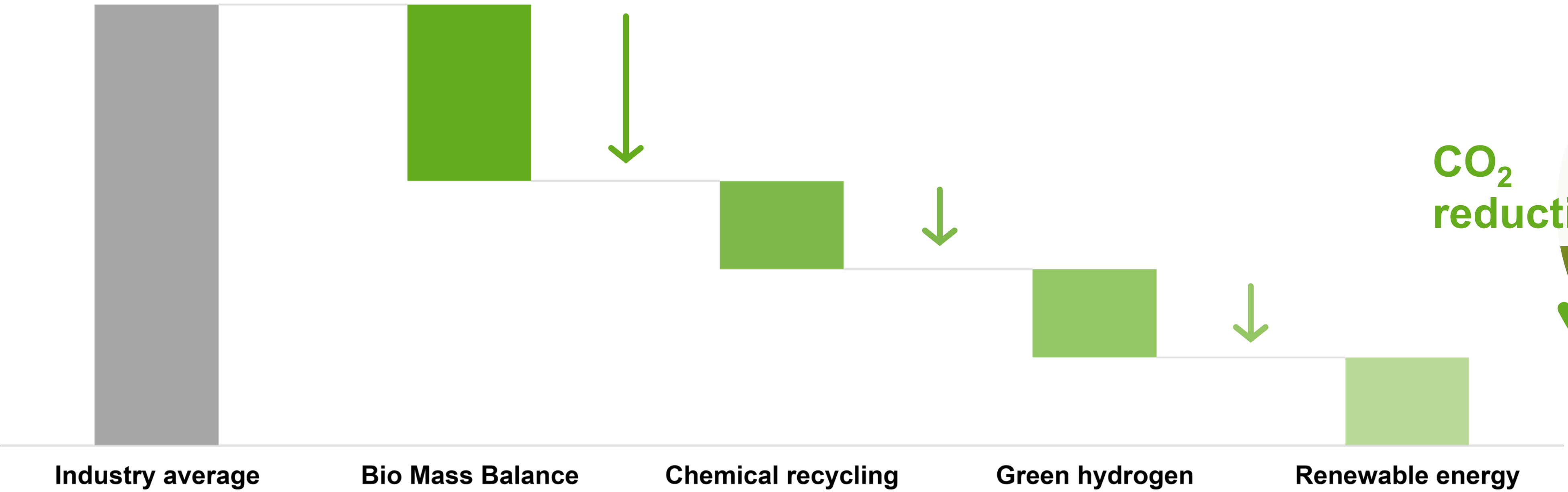
Profitable growth with transformation – based on resource efficiency of the Verbund and the Mass Balance concept

CO_2 emissions – illustrative example
per 1 kg product



We are creating a toolbox to offer differentiated carbon footprints for our sales products.

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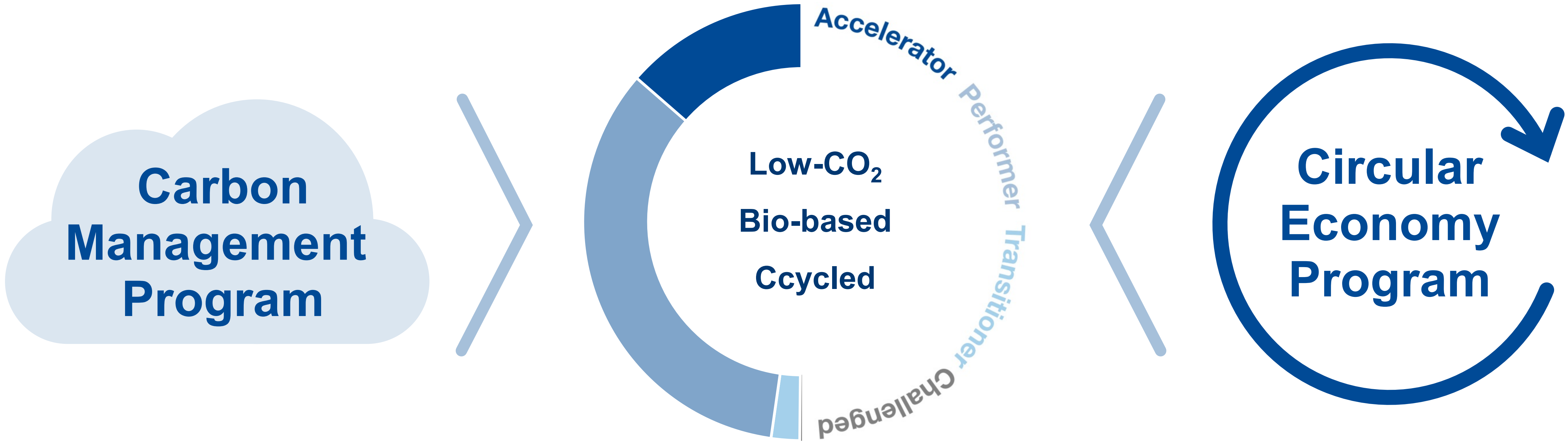
Circular Economy and Carbon Management Programs – BASF’s way to drive sustainability



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

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