R&D Webcast for Investors and Analysts
on January 10, 2019

Carbon Management at BASF –
R&D strategies to reduce CO₂

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Cautionary note regarding forward-looking statements

This presentation contains forward-looking statements. These statements are based on current estimates and projections of the Board of Executive Directors and currently available information. Forward-looking statements are not guarantees of the future developments and results outlined therein. These are dependent on a number of factors; they involve various risks and uncertainties; and they are based on assumptions that may not prove to be accurate. Such risk factors include those discussed in the Opportunities and Risks Report from page 111 to 118 of the BASF Report 2017. BASF does not assume any obligation to update the forward-looking statements contained in this presentation above and beyond the legal requirements.
BASF as a pioneer in developing tools for sustainability performance measurement

Systematic application of sustainability measurement since 1996

1996
Eco-Efficiency Analysis

2004
SEEBALANCE®

2007
Corporate Carbon Footprint

2011
AgBalance™

2012
Investment evaluation

2013
Biomass Balance Certification

2015
Sustainable Solution Steering®

2017
Advanced IT solutions for customers

2018
Carbon Management Value-to-Society

New SEEBALANCE®

Products in the value chain

Corporate
Portfolio and digital solutions
The Carbon Dioxide Challenge

BASF’s Carbon Management

Outlook
The Carbon Dioxide Challenge

BASF’s Carbon Management

Outlook
R&D Webcast on January 10, 2019

Global greenhouse gas (GHG) emission scenarios

GHG emissions in % (Reference 1990)

Global GHG emissions 1990: 36.4 metric gigatons

Global GHG emissions

Reference

Currently intended policy*

Policy for 2°C scenario

Source of global GHG emissions and future scenarios: JRC Global Energy and Climate Outlook 2016

* Implementation of Nationally Determined Contributions as expressed in Paris Agreement

Risk of 3.8 – 4.7°C

Around 3°C

2°C
BASF’s successful greenhouse gas reduction

Since 1990, BASF has halved its emissions and doubled its sales volume

**BASF’s output in 1990**

- **40 mt CO₂**
- **2.2 tons per ton**

**BASF’s output in 2018**

- **22 mt CO₂**
- **0.6 tons per ton**

“mt” = million metric tons, “tons per ton” = metric tons CO₂ equivalents per metric ton sales product
**BASF’s carbon footprint 2017 and established measures**

Established measures:
- Biomass balance
- Bio-based products and materials
- Verbund concept and process optimization
- CO$_2$ as a feedstock
- CO$_2$-saving BASF products and solutions
- Biodegradable BASF products and materials

BASF commits to CO$_2$-neutral growth in its new corporate strategy. This requires a new approach to Carbon Management.

*mt* = million metric tons  * thereof 36 mt from BASF’s oil and gas business
BASF’s Carbon Management aims to decouple growth from CO₂ emissions

**Established measures**
- Biomass balance
- Bio-based products and materials

**New measures**
- ChemCycling
- Renewable energy

**Source**

**Make**
- Verbund concept and process optimization
- CO₂ as a feedstock

**Use**
- CO₂-saving BASF products and solutions

**End-of-life**
- Biodegradable BASF products and materials

**Carbon Management Program**
- New CO₂-saving BASF products and solutions
- Close-the-loop solutions
- ChemCycling
The Carbon Dioxide Challenge

BASF’s Carbon Management

Avoid CO₂ on site
Use CO₂ as a feedstock
Help customers avoid CO₂ (Accelerator products)

Outlook
BASF’s sales products in a nutshell

Chemical formula: \((\text{C} H_{3.1} \text{O}_{0.3} \text{N}_{0.2} X)_n\)

Composition:

- Carbon
- Hydrogen
- Oxygen
- Nitrogen
- Others

Raw materials:

- Naphtha, natural gas, renewables, recycled waste, CO\(_2\)
- Air
- Others

Chemistry is based on carbon and cannot be “decarbonized.”
BASF’s Carbon Management targets fugitive carbon

A Verbund is the ideal setup for Carbon Management.
BASF’s Verbund avoids CO₂
The full picture – for ethylene
BASF’s Verbund avoids CO₂
Synergies among selected value chains

A Verbund optimizes the use of products and utilities.
In total, BASF’s Verbund in Ludwigshafen avoids around 6 mt of CO₂ emissions.
BASF’s Carbon Management Measures at a glance

CO₂ emitters:
- Power plants
- Steam cracker
- Ammonia/hydrogen
- N₂O
- Others

Measures:
- Process optimization, energy management, N₂O decomposition
- Clean hydrogen research, E-Furnace research, clean olefins research
- Purchase of renewable energy

BASF’s Carbon Management includes process optimization, technology research and the supply of renewable energy.
The Carbon Dioxide Challenge

BASF’s Carbon Management

Avoid CO$_2$ on site
Use CO$_2$ as a feedstock
Help customers avoid CO$_2$ (Accelerator products)

Outlook
**Chemistry is energy**

**Thermodynamics of water electrolysis**

\[
\text{H}_2\text{(g)} + 0.5 \text{O}_2\text{(g)} \rightarrow \text{H}_2\text{O}^{(l)} \quad \Delta H^\circ_{\text{r}} = +286 \text{ kJ mol}^{-1} \text{H}_2
\]

**Thermodynamics of CO}_2 \text{ formation**}

\[
\text{CH}_4\text{(g)} + 2 \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)} + 2 \text{H}_2\text{O}^{(g)} \quad \Delta H^\circ_{\text{r}} = -803 \text{ kJ mol}^{-1} \text{CH}_4
\]

Water and carbon dioxide are very stable molecules. Using them as chemical raw materials is very energy-intensive.
Using CO$_2$ as a feedstock is energy-intensive
Viable options are therefore limited

BASF is exploring new processes to make specialty chemicals from CO$_2$.

- Hydrocarbons
- Industrial chemicals
- Carbohydrates
- Urea
- Synfuels
- Photosynthesis

E.g., acrylic acid
→ BASF invests in R&D

Global CO$_2$ consumption: 115 mt p.a.
→ BASF produces AdBlue®

"mt" = million metric tons
Limited potential to use CO₂ as a feedstock in the chemical industry

CO₂ emissions in Germany 2017

905 mt CO₂

Chemical production in Germany 2017

48 mt CO₂eq

We need new breakthrough technologies to significantly reduce the CO₂ footprint.

"mt" = million metric tons
The Carbon Dioxide Challenge

BASF’s Carbon Management

Avoid $CO_2$ on site
Use $CO_2$ as a feedstock
Help customers avoid $CO_2$ (Accelerator products)

Outlook
CO$_2$-saving innovative solutions

Mineral-based in-situ foam: Cavipor$^\text{®}$

Enabling e-mobility: Cathode active materials
The Carbon Dioxide Challenge

BASF’s Carbon Management

Avoid CO₂ on-site
Use CO₂ as a feedstock
Help customers avoid CO₂ (Accelerator products)

Outlook
BASF’s new CO$_2$ emission target

Baseline 2018

+50% sales products

-33% specific emissions

Our target 2030:

CO$_2$-neutral growth
BASF’s new CO$_2$ emission target

Until 2030, BASF aims to grow its output by 50% without increasing its CO$_2$ emissions.

25 *mt* = million metric tons, *tons per ton* = metric tons CO$_2$ equivalents per metric ton sales product  * forecast
BASF’s Carbon Management – our focus today

Potential CO₂ reduction

- Shift power supply towards renewable energies
- Further improve process and energy efficiency
- Develop CO₂-reduced breakthrough technologies
- Costs and risks

powered by BASF’s unique catalyst platform
BASF aims to develop the world’s first electrical heating concept for steam crackers (1,000°C) within the next five years. This requires the redesign of the entire furnace from the alloy composition to electric connectors and transformers.*

**Approach:**
- Switch cracker coil heating from natural gas to electrical resistance heating, combining high current with low voltage
- Integrate an E-Furnace – to be newly engineered – into the steam cracker in Ludwigshafen

**Next milestone:**
- Proof of material for steam cracker coils, i.e., study interaction of coil alloy with applied electric power

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* Government funding will be necessary due to high technological and commercial risk
BASF is developing a completely new reactor design for the pyrolysis of methane into hydrogen and solid carbon* and is evaluating options to utilize the byproduct solid carbon.

**Approach:**
- Decompose methane (CH₄) into hydrogen and solid carbon via thermal pyrolysis avoiding CO₂ as byproduct
- Design a moving carbon bed reactor that combines chemical reaction and heat integration

**Next milestone:**
- Proof of the heating concept, i.e., overcome carbon deposition, inhomogeneous flow and pulsations inside the reactor

* Government funding will be necessary due to high technological and commercial risk
Dry reforming of methane and direct conversion of syngas to DME: New catalysts for clean olefins

Approach:

- Switch feedstock for olefins from naphtha to methane
- Produce CO-rich syngas via dry reforming of methane and convert the syngas into dimethyl ether (DME), an established precursor for olefins

Next milestone:

- Production trial for CO-rich syngas and completion of DME upscaling

BASF will commercialize its new generation of catalysts for the dry reforming of methane (planned for 2020) and the direct conversion of CO-rich syngas to DME (planned for 2022) in collaboration with Linde.
CO₂ as feedstock for superabsorbents: New chemistry for using CO₂

Approach:
- Evaluate the thermodynamically favored reaction of CO₂ with ethylene to sodium acrylate, which is the main raw material for superabsorbents
- Switch feedstock for superabsorbents from C3 (propylene → acrylic acid) to C2 + CO₂ (ethylene + CO₂ → sodium acrylate)

Next milestone:
- Catalyst activity and lifetime as well as energy demand for the base regeneration in target range

BASF is developing an industrial process for the catalytic formation of sodium acrylate based on CO₂ and ethylene.