BASF – We create chemistry

- Our chemistry is used in almost all industries
- We combine economic success, social responsibility and environmental protection
- Sales 2017: €64,457 million
- EBIT 2017: €8,522 million
- Employees (as of December 31, 2017): 115,490
- 6 Verbund sites and 347 other production sites

BASF Ludwigsafen
Chemical products contain carbon
„Decarbonization“ is not a usefull term
Reduction of greenhouse gas emissions with increased production

Development since 1990
Index 1990 = 100%, BASF Group excl. oil and gas business

- +104% volume of sales product
- −48.3% absolute greenhouse gas emissions
- −74.7% specific greenhouse gas emissions
Elements of Energy Management at BASF

**Energy Verbund**
Linkage of energy flows between production plants

**Energy Production**
High efficient combined heat and power plants (CHP) with combined cycle gas turbines (CCGT)

**Energy Efficiency**
Process optimization e.g. new catalysts in the acrylic acid plant, heat integration, ...

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**Annual savings**
Primary energy 18 mill. MWh
CO₂ emissions 3.9 mill. t CO₂

**Annual savings**
Primary energy 13 mill. MWh
CO₂ emissions 2.6 mill. t CO₂

**Several hundred measures per year**

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* BASF Group 2017
DECHENA Technology Study: Low carbon energy and feedstock for the European chemical industry

- **Scope: European chemical industry**
  Methanol, ethylene/propylene, benzene/toluene/xylene, ammonia/urea, chlorine
  > 50% of energy consumption and GHG-emissions of European Chemical Industry

- **Technology measures**
  Energy efficiency, biomass and waste, H₂+CO₂-based processes, H₂ only from water electrolysis

- **Four Scenario calculations** based on selected percentages of technology implementation

- **No carbon leakage**

- Additional impact of CO₂-based methanol and ethanol as fuel component
CCU: Using CO₂ as feedstock

Energy Content

- **Hydrocarbons**: Benzene, Ethylen, Polyethylen, Polypropylen...
- **Oxygene rich Chemicals**: Formaldehyde, Ethanol, Acrylic acid, Formic acid...

![Chemical structures and reactions involving CO₂ and H₂O]
DECHHEMA Technology Study: Results of scenario calculations (w/o fuels production)

- **210 Mt (Maximum)**: 175% of BAU emissions
  - Available in 2050: 3400 TWh (IEA)

- **101 Mt (Ambitious)**: 84% of BAU emissions
  - 70 Mt (Intermediate): 59% of BAU emissions

- **4900 TWh (Maximum)**: 140% of anticipated capacities
  - 1900 TWh (Ambitious): 55% of anticipated capacities
  - 960 TWh (Intermediate): 30% of anticipated capacities

- **300 Mt (Maximum)**: 80% of large source emissions
  - 100 Mt (Ambitious)

- **250 Mt (Maximum)**: (30% of sustainable non-food biomass)
  - 200 Mt (Intermediate): 24% of sustainable non-food biomass
  - 50 Mt (Intermediate)

- **215 Mt (Ambitious)**

- **27 bill. €/y (Maximum)**
  - 19 bill. €/y (Ambitious)
  - 17 bill. €/y (Intermediate)

- **Investment Requirements (bill. €/y)**: 2 (BAU)

BAU: business-as-usual
Emissions in the Chemical Value Chain

To produce

~20 Basic Chemicals

~20,000 Chemicals in the value chain

80% GHG Emissions

20% GHG Emissions

R & D focus on big emitters needed
Methane pyrolysis – a new source of $\text{H}_2$

Project outlook and financing aspects

R&D-Project
funded by the German Ministry of Education and Research

Pilot Unit
~€20-40 million investment
Start-up ≥2020,

Reference/demonstration unit on commercial scale
~€100 million investment
Start-up ≥2024,

Risks
• breakthrough process development
• carbon utilization in metallurgy
• industrial scale reference required
• CAPEX and OPEX support needed
More Hydrogen from the same amount of renewable Energy by Methane Pyrolysis

H₂ by **Water Electrolysis**

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

H₂O(l)

H₂ by **Methane Pyrolysis**

\[ \text{CH}_4(g) + \text{C}(s) + 2\text{H}_2(g) \rightarrow \Delta H^o = +37 \text{ kJ mol}^{-1} \text{ H}_2 \]

87% less energy
But: fossile feedstock
Alternative: Bio-Methane if available
Our contribution to fulfill the Paris agreement – Avoidance with highest contribution

- **Energy Efficiency**: High efforts to tackle remaining opportunities

  - **Sustainable Biomass as feedstock**: BASF Biomass Balance and dedicated Bio-based products
  - **Waste as feedstock**: Use waste in a reasonable way while limiting effects on climate
  - **Focus on products with high oxygen content and thus less energy needs**

- **Avoidance**

  - **CO₂ Avoidance by new production technologies**
  - **Research and Development of low CO₂ processes for chemicals with highest emissions**

- **Use of limited resources like biomass and renewable energy based on best value to society limit availability for chemistry**
Learnings

- Large-scale CO2-reductions can only be achieved through a significant electrification of industrial processes, leading to a huge increase of low-carbon electricity demand.

- Radically lowering the price of renewable electricity, including Government driven surcharges and levies, presents an indispensable prerequisite for a successful industrial transformation.

- R&D funding programs contribute to accelerate the development of new technologies.

- To turn these R&D activities into actual investments, we need a global (at least G20) CO2 price to allow for a business case. The economic constraints around zero-carbon transformation needs to be acknowledged.
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