Sustainable Chemistry: Contributions to a Low-Carbon Economy

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Mainstreaming sustainable chemistry internationally

Life-cycle of products, Resource Sustainability, Circular Economy
Impact of decoupling human well-being from resource consumption (UNEP)
Aspects of Sustainable Chemistry

- Substance(s) used less (eco)toxic
- Substance(s) used better degradable
- Less use of non-renewable resources
- Less use of resources in the product‘s life cycle
- Less energy consumption in the product‘s life cycle
- Use of secondary resources
- Use of regional renewable resources (spec. cond.)
- Recycling of used substances/products possible
- More occupational safety
- Value-creating products/services
- Longevity of product
- …
- Contributing to the SDGs
Low carbon technologies: CO₂ utilisation

- Methanation ($+ \text{H}_2$) → Methane → SNG
- Methanol ($+ \text{H}_2$) → MTG → Gasoline
- Syngas → FT + Hydro-cracking → Syn. Diesel
- Ethanol ($\text{FT} \rightarrow \text{Reduction} + \text{H}_2$) → Jetfuels
- CRI, Iceland
- LanzaTech - Virgin Atlantic
- Audi e-gas, Werlte
- sunfire, Dresden

TRL 6-7: CO₂ utilisation
TRL 6-8: FT + Hydro-cracking
TRL 7-8: Methanation, Methanol, FT, Syngas
TRL 5-7: Ethanol, Reduction, Fermentation
Impact during the lifecycle

Low-carbon routes
- Capture \( \text{CO}_2 \uparrow \)
- Recycled carbon built into product
- Biogenic carbon built into product
- Photosynthesis
  - Cultivation, harvesting
- Energy supply
  - \( \text{CO}_2 \uparrow \)
- Process related emissions
  - \( \text{CO}_2 \uparrow \)
- Biomass supply
  - \( \text{CO}_2 \uparrow \)
- Process related emissions
  - \( \text{CO}_2 \uparrow \)

Fossil routes
- Feedstock supply
  - \( \text{CO}_2 \uparrow \)
- Process related emissions
  - \( \text{CO}_2 \uparrow \)
- Process related emissions
  - \( \text{CO}_2 \uparrow \)

Back to feedstock
- \( \text{CO}_2 \downarrow \)

Back to energy
- \( \text{CO}_2 \downarrow \)

Back to use
- \( \text{CO}_2 \uparrow \)
Life cycle aspects of products

- Low carbon production route
- Efficient products
- Recyclability
Life cycle aspects of products

- Limited resources
- Competing pathways
- High energy demand
- High biomass demand
- High metal dependency
- Economic gap factor >2

Low carbon production route

- CO₂ emission reductions (Mt)
  - 490 TWh (Maximum)
  - 140% of anticipated capacities
  - Available in 2050: 3400 TWh (IEA)
  - 210 Mt (Maximum) 175% of BAU emissions

- Low-carbon power demand (TWh)
  - 1900 TWh (Intermediate) 55% of anticipated capacities
  - 960 TWh (Intermediate) 30% of anticipated capacities

- Alternative feedstock demand
  - 300 Mt (Maximum) 80% of large source emissions
  - 250 Mt (Maximum) (30% of sustainable non-food biomass)

- CO₂ (Mt) Biomass (Mt)
  - 27 bill. €/y (Maximum)
  - 19 bill. €/y (Ambitious)
  - 17 bill. €/y (Intermediate)

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

DEChemA 2017, Low carbon energy and feedstock for the chemical industry
Life cycle aspects of products

Low carbon production route
- Limited resources
- Competing pathways
- High energy demand
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- Economic gap factor >2

Efficient products
- Downstream energy/GHG savings to be considered
- Leverage factor: 2.1 to 2.6 tCO₂e savings per emitted t

ICCA/ McKinnsey, 2009: Innovations for Greenhouse Gas Reductions
A life cycle quantification of carbon abatement solutions enabled by the chemical industry
Life cycle aspects of products

- **Low carbon production route**
  - Limited resources
  - Competing pathways
  - High energy demand
  - High biomass demand
  - High metal dependency
  - Economic gap factor >2

- **Efficient products**
  - Downstream energy/GHG savings to be considered
  - Leverage factor: 2.1 to 2.6 tCO$_2$e savings per emitted t

- **Recyclability**
  - 54 Mt p.a. products
  - 44 Mtoe energy required
  - ~425 Mtoe of EU energy consumption could be reduced in a fully formed circular scenario

accenture, 2017: Taking the European Chemical Industry into the Circular Economy
Example: Precast concrete sandwich panel

**ECO-SANDWICH®**

- 50% secondary raw material
- 12 cm thick layer of recycled concrete
- 20 cm of mineral wool,
- 4 cm layer for ventilation purposes
- 6 cm external skin, crushed bricks from demolition material
Qualitative comparison of a conventional precast concrete sandwich board and the ECO-SANDWICH®

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Precast concrete sandwich board</th>
<th>ECO-SANDWICH®</th>
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</thead>
<tbody>
<tr>
<td>GHG emissions</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Energy input and intensity</td>
<td>++</td>
<td>+</td>
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<tr>
<td>Raw material input</td>
<td>Widely available mineral raw materials</td>
<td>Partly mineral secondary raw materials</td>
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<tr>
<td>Waste – Production</td>
<td>0</td>
<td>?</td>
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<tr>
<td>Processing</td>
<td>+</td>
<td>+</td>
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<tr>
<td>After use</td>
<td>Recyclability questionable</td>
<td>Presumably not recyclable</td>
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<tr>
<td>Raw material intensity</td>
<td>High</td>
<td>Average</td>
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<tr>
<td>Critical contents</td>
<td>Prefabricated element for the facades of large buildings</td>
<td>Phenol formaldehyde resins</td>
</tr>
<tr>
<td>Technical advantages/ disadvantages</td>
<td>Inexpensive, easy workability</td>
<td>Presumably also intended for residential buildings</td>
</tr>
<tr>
<td>Economic advantages, employment</td>
<td>High</td>
<td>Labour-intensive due to complex manufacture; presumably competitive in low-wage countries</td>
</tr>
<tr>
<td>Market presence</td>
<td>High</td>
<td>Not known</td>
</tr>
</tbody>
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Sustainable products: holistic thinking required

- **Current examples of bio-based chemicals and polymers unsustainable?**
  - Highly functionalized molecules are simplified (degraded) with high need of chemicals and energy!

- **Degradability of polymers, a prerequisite?**
  - Position 1: all down-stream and consumer products must fulfill the criterion of full and fast mineralization
  - Position 2: proper end-of-life solutions once the polymers cannot be sustainably recycled anymore; depolymerize or chemical recycle mixed plastics in an economical and environmental-friendly way

- **How should we generally deal with highly functional materials that often comprise material mixes and composites?**
Value Chain collaboration

- Sustainable chemistry provides solutions to combat climate change
- Chemical industry can’t deliver alone
  - Value chain partners
  - Energy sector
  - Other process industries (industrial symbiosis)
- Incentives and matching policy frameworks necessary
Conclusions

- Chemical industry provides important contributions/solutions to combat climate change
  - Value chain collaborations required to leverage full potential

- Sustainable innovations require holistic life-cycle thinking
  - Limited view on only manufacturing or use phase or recyclability can be misleading

- Higher energy /GHG efficient solutions have to be checked for other impacts
  - Contradicting sustainability goals possible
We shape transformation