The role of chemicals in the transition towards a low-carbon and circular society: an integrated assessment modeling approach

Gamze Ünlü, Florian Maczek, Jihoon Min, Volker Krey & Stefan Frank
Industry: Chemicals Sector

- 3rd biggest emitter in industry amounting to 1.37 GtCO2, which is 15% of all industrial-sector direct CO2 emissions in 2021, ~5% of all GHG emissions 2019 (IPCC, 2022)
- Biggest energy consumer among all industrial sectors (if feedstock included) ~ 46 EJ
- Heavily depending on oil and gas, amounting to approximately 14% and 8% of the world’s oil and gas use respectively
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*Final energy demand of selected heavy industry sectors by fuel 2019, IEA*
Industry: Chemicals Sector

- Chemicals are fundamentally integrated into our daily lives with various end uses
- Produced from all conventional fossil fuels
- Primary chemicals are responsible for ~60% of overall sector emissions

*Source: IEA, The Future of Petrochemicals*
MESSAGEix-Materials

- A module that represents material flows from production to the end of life within MESSAGEix-GLOBIOM Integrated Assessment Modeling framework

- Implications of material cycles on energy demand and GHG emissions

- Broaden the climate mitigation options that can be evaluated in our modeling framework such as the circular economy related ones

\[ \sim 70\% \text{ of industrial CO2 emissions} \]
## Scenario Implementation

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>High-Demand</th>
<th>Low-Demand</th>
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<tbody>
<tr>
<td>Ammonia (NH3)</td>
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<tr>
<td>Nitrogen fertilizer</td>
<td>No SDGs (*)</td>
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<tr>
<td>Rest of Ammonia</td>
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<td>Methanol (CH3OH)</td>
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<tr>
<td>Engineered Wood Products (EWP) in residential buildings</td>
<td>WOOD (***)(higher methanol demand)</td>
<td>REF (***)(lower methanol demand)</td>
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<td>Rest of Methanol as feedstock</td>
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<td>High Value Chemicals</td>
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**Circularity Measure (Narrow-Reduce)**

### Climate Policy
- **No Policy**
- **2 Degrees**

(*) Different dietary assumptions in SDGs: Low growth in food consumption, low-meat diets, halving food waste, fertilizer best management practices.

(**) Function of GDP with income elasticity coefficients derived from IEA demand scenarios. Two different coefficients are used leading to „high“ and „low“ demand.

(***) WOOD: increased wood utilization, material substitution
REF: historical material use
Material demands from STURM building stock-turn over model.
## Scenario Implementation

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Ammonia production from MESSAGEix-Materials under different scenarios.

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**Global Ammonia Demand**

- **Decrease in 2070:**
  - Climate policy, -9%
  - Circularity measures, -28%
  - Combined, -35%

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*Ammonia production from MESSAGEix-Materials under different scenarios*
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Global Ammonia Demand

Ammonia production from MESSAGEix-Materials under different scenarios
Ammonia circularity measures, -37% CO2 Emissions, NH3 Production

Climate policy: Fossil fuels remain in the system (coal, gas) but with CCS.

As the supply side is already low in CO2 emissions in 2 degrees scenario, the effect of demand reduction is less in 2 degrees scenarios.

Final Energy, NH3 Production

- NoPolicy - high demand
- NoPolicy - low demand
- 2 Degrees - high demand
- 2 Degrees - low demand
Methanol

- Formaldehyde resins produced from methanol are mostly used as adhesives in engineered wood products (EWP)
- Material substitution: cement vs. wood in residential buildings
- New products like CLT (Cross laminated timber) and Glue laminated timber (GLULAM)
  - made from solid wood parts
  - can replace structural cement and steel

Mjøstårnet-Norway, certified as the world's tallest timber building, 18 storey
Methanol

Is there a trade-off in emission reductions caused by the increased chemicals production as a result of the increased wood demand?

Substitution with wood reduces overall material intensity of residential buildings

WOOD: increased wood utilization

REF: historical material use
Methanol: Buildings

Additional emissions from resins needed for wood products

Carbon stored in biomass
Methanol: Buildings

Additional emissions from resins needed for wood products

What happens if the cement production becomes greener in a 2 degree scenario?

Avoided emissions from wood-cement substitution
Without climate policy, the demand side changes manage to decrease emissions (40% in 2070). → not enough to reach the climate targets.

With the 2 Degrees scenarios, we see there is a faster and higher decrease in the emissions and less dependency on the CCS technologies in low demand variation.
Conclusions

• Emission mitigation in petrochemical industry does not mean defossilization – dependency on fossil resources will remain at least in the next decades, especially in HVCs and ammonia.

• Climate policy is more effective to decarbonize ammonia production on the supply side with the deployment of CCS. In the absence of climate policy, decreased consumption in line with SDGs is also effective in decreasing the emissions from production.

• In construction sector, wood can be an effective storage possibility of biogenic carbon already before 2050, increased chemicals sector emissions not being an obstacle.

• Demand focused policies with circular practices are equally as important as supply side transformation.
Thank you for your attention!

Questions?