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

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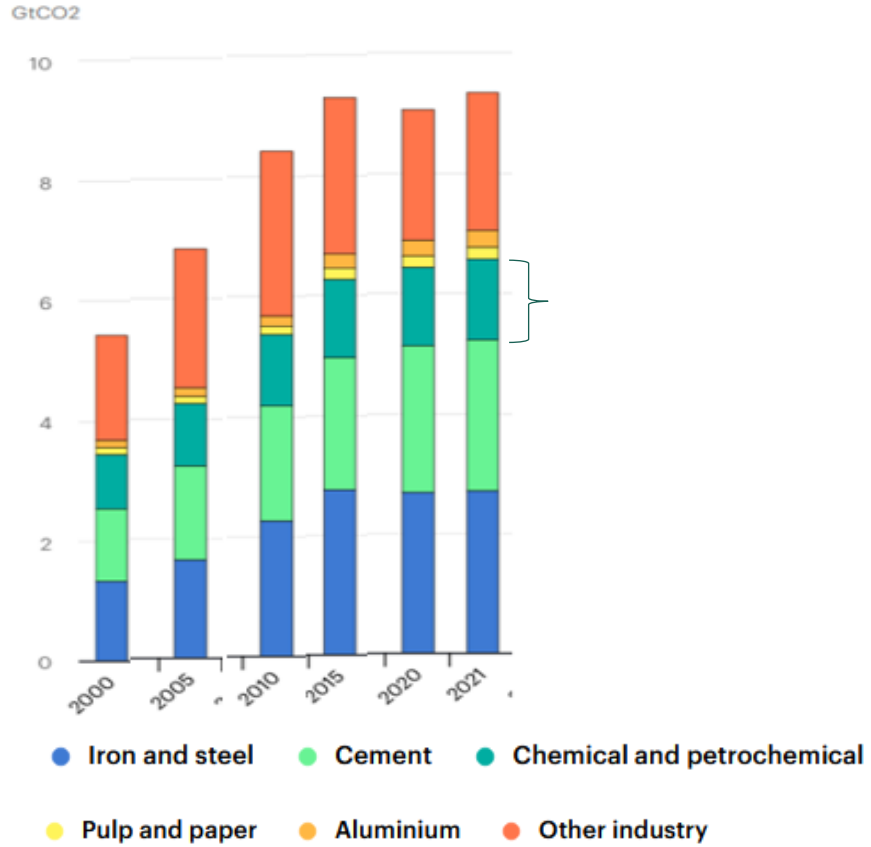
Industry: Chemicals Sector

- 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



Direct CO2 Emissions from Industry, IEA 2021

Industry: Chemicals Sector

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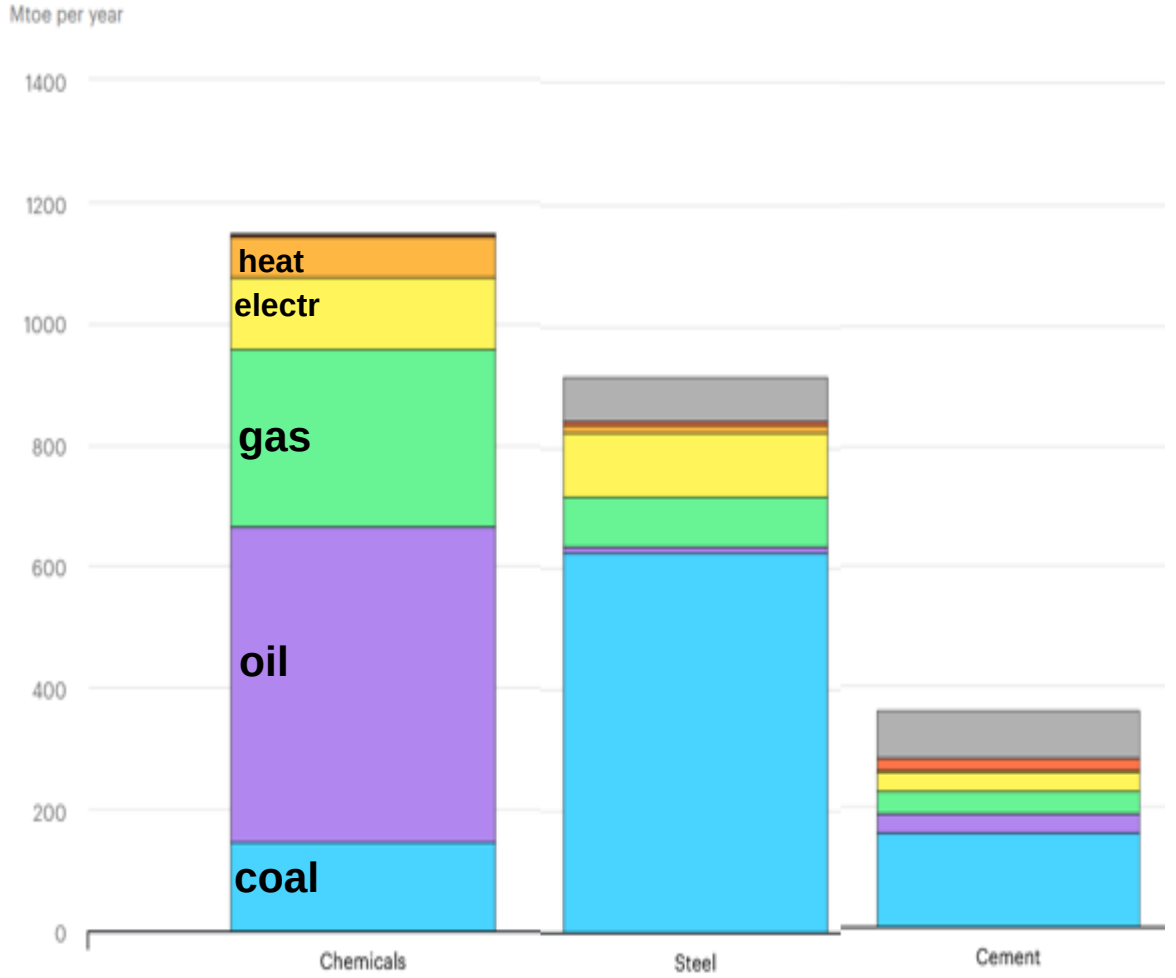
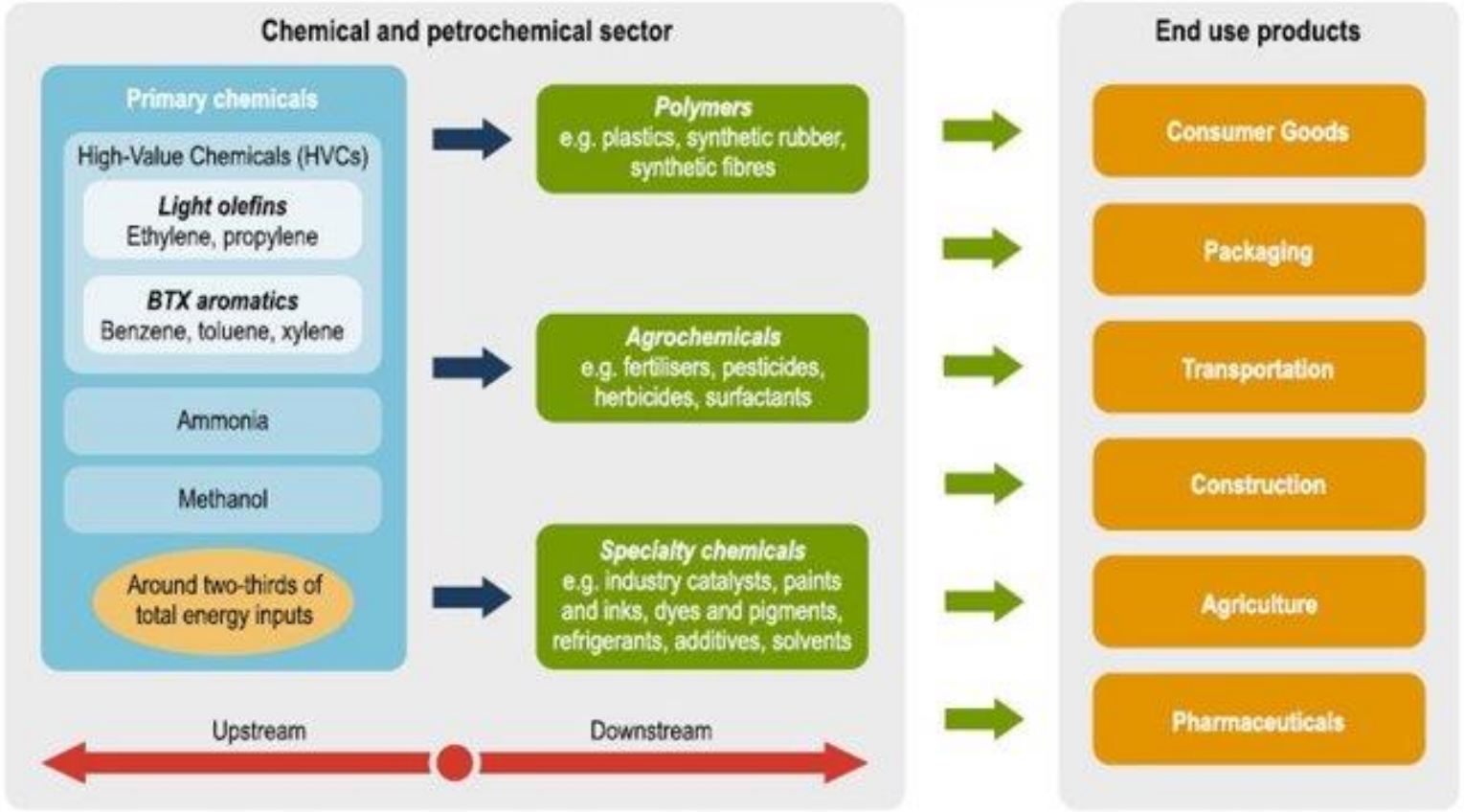


Final energy demand of selected heavy industry sectors by fuel 2019, IEA

Industry: Chemicals Sector

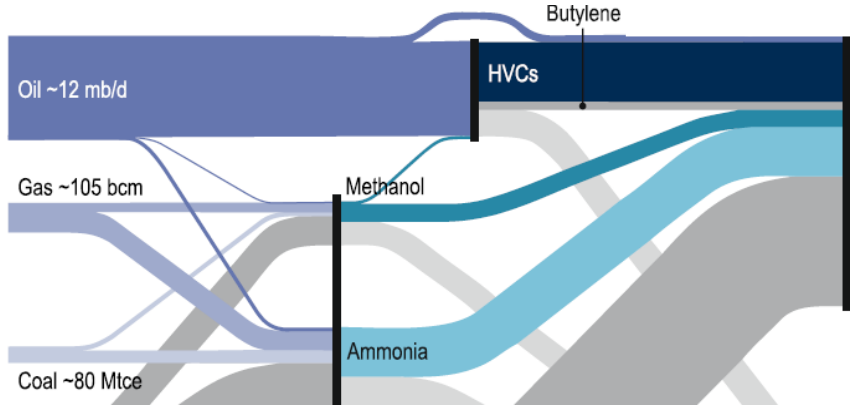
Figure 1.7 • Primary chemicals in context



Key message • While most energy consumption in the chemical sector takes place upstream, a host of transformations, intermediates, and end-use sectors lie downstream from primary chemicals.

Source: IEA, The Future of Petrochemicals

- Chemicals are fundamentally integrated into our daily lives with various end uses



Source: Levi & Cullen, 2018

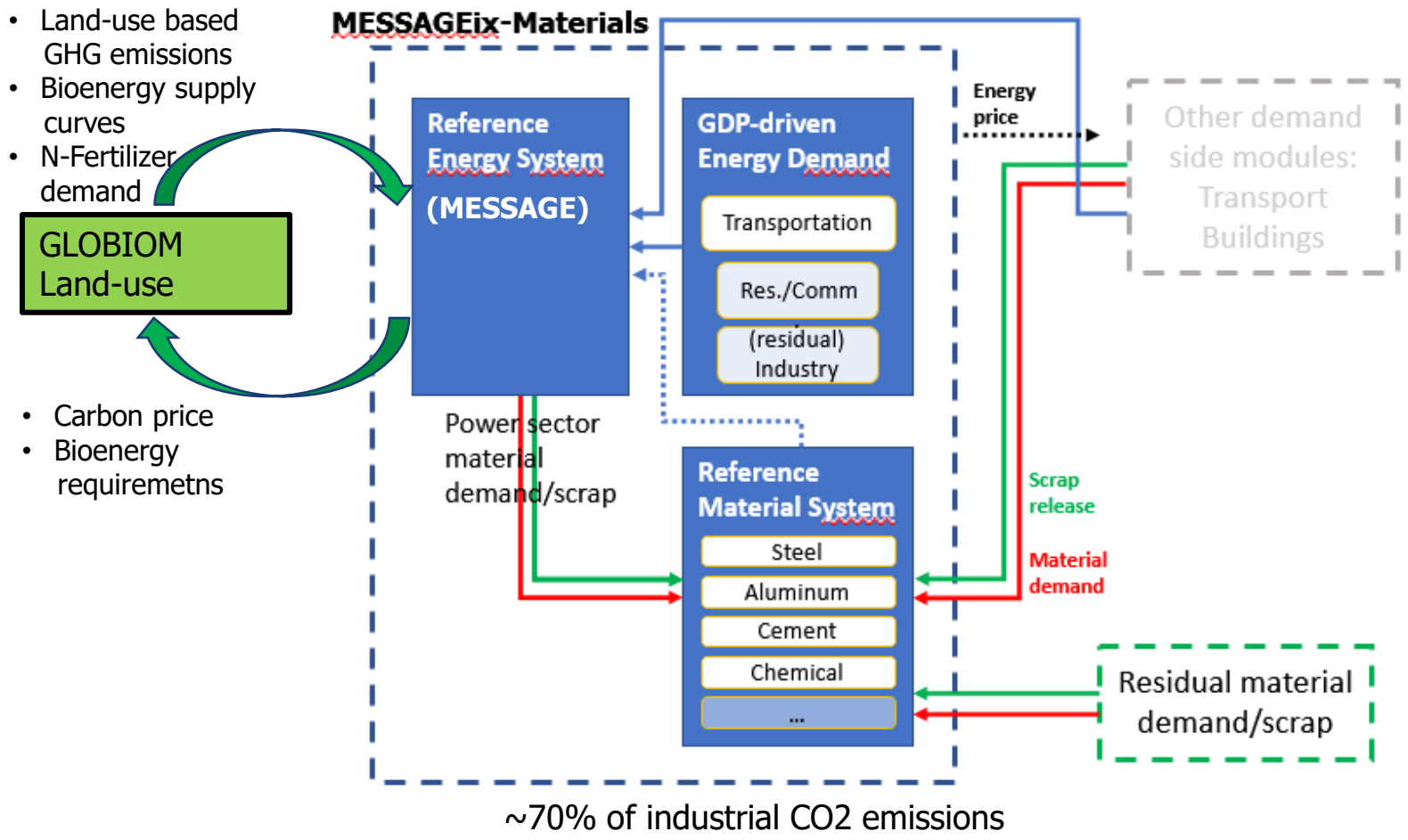
- Produced from all conventional fossil fuels
- Primary chemcials are responsible for ~60% of overall sector emissions

MESSAGEix-Materials

- A module that represents material flows from production to the end of life within **MESSAGEix-GLOBIOM Integrated Assesment 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



Scenario Implementation

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

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

Chemicals	**Circularity Measure** (Narrow-Reduce)	
	High-Demand	**Low-Demand**
Ammonia (NH3)	No Policy- high demand	No Policy- low demand
Nitrogen fertilizer		
Rest of Ammonia		
Methanol (CH3OH)		
Engineered Wood Products (EWP) in residential buildings	2 Degrees- high demand	2 Degrees- low demand
Rest of Methanol as feedstock		
High Value Chemicals		
High Value Chemicals		

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.

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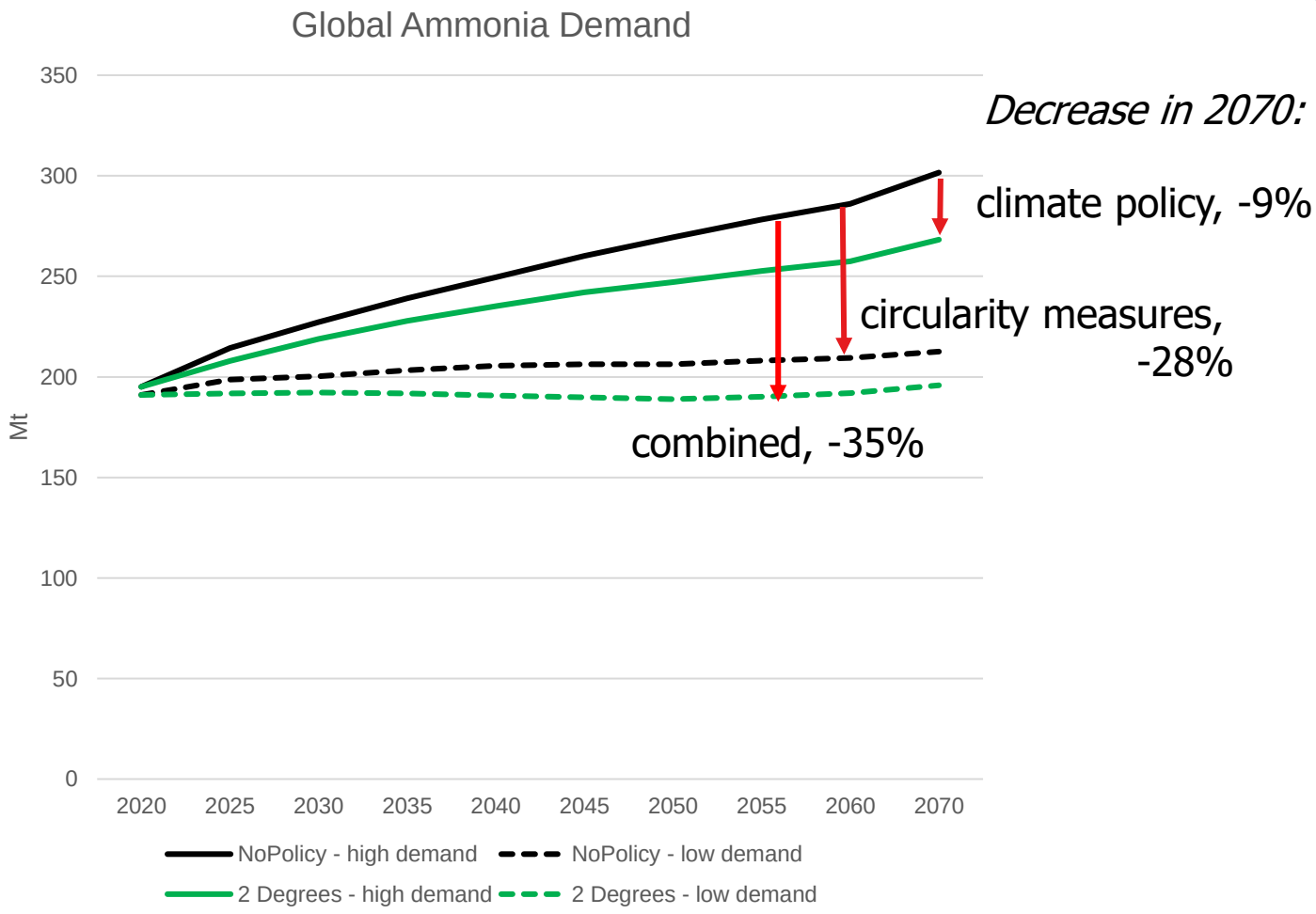
Ammonia

Circularity Measure (Narrow-Reduce)			
Chemicals	**High-Demand**	**Low-Demand**	
Ammonia (NH3)			
Nitrogen fertilizer	No Policy-high demand	No Policy-low demand	Climate Policy
Rest of Ammonia	2 Degrees-high demand	2 Degrees - low demand	



Ammonia production from MESSAGEix-Materials under different scenarios

Ammonia

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Ammonia (NH3)			
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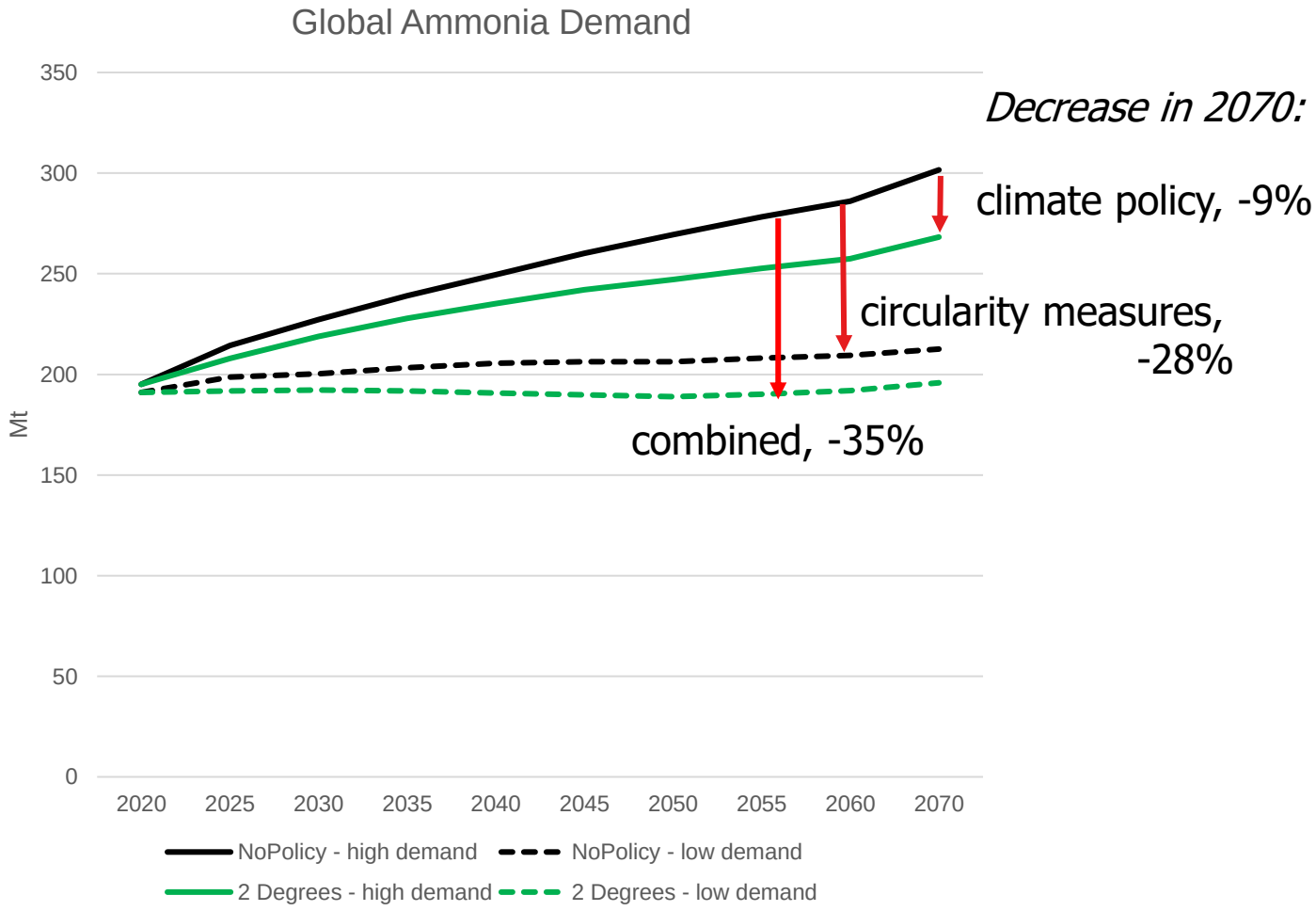

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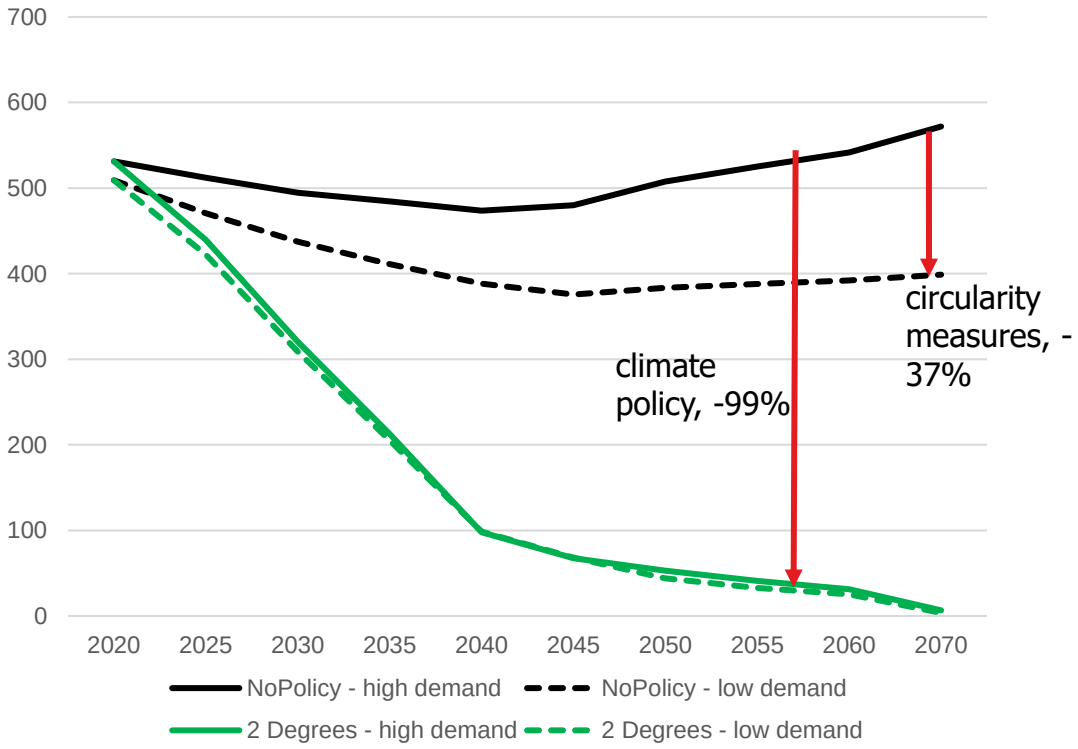
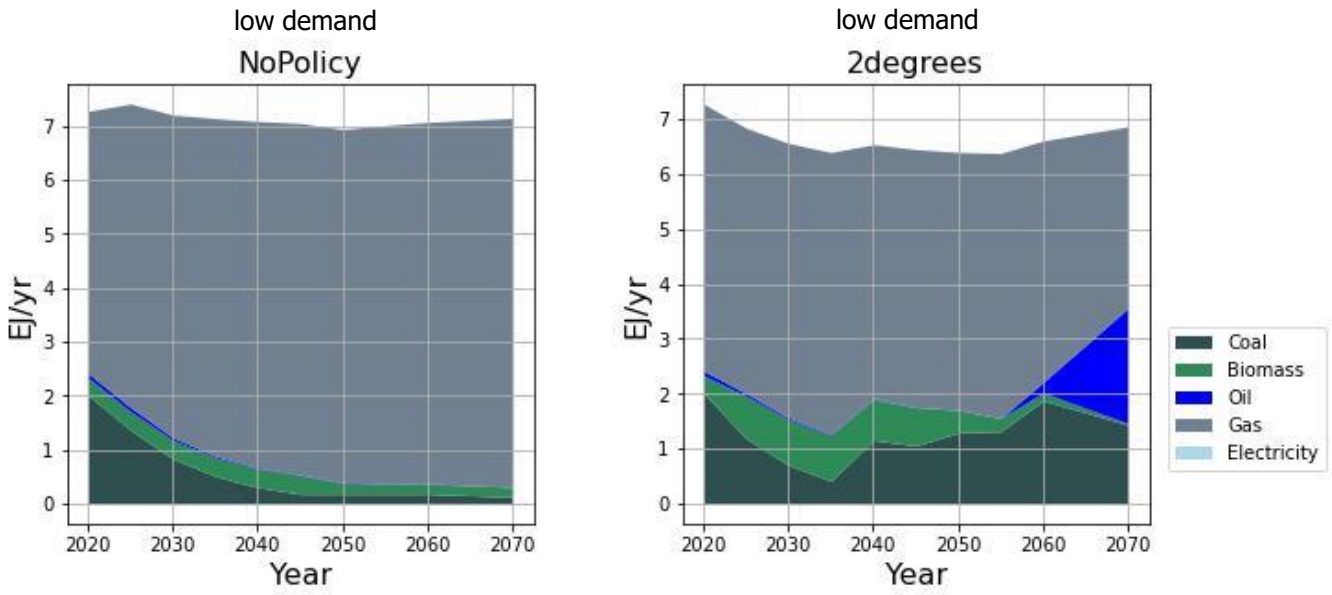
Ammonia



CO2 Emissions, NH3 Production

Supply side



Final Energy, 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.

Methanol

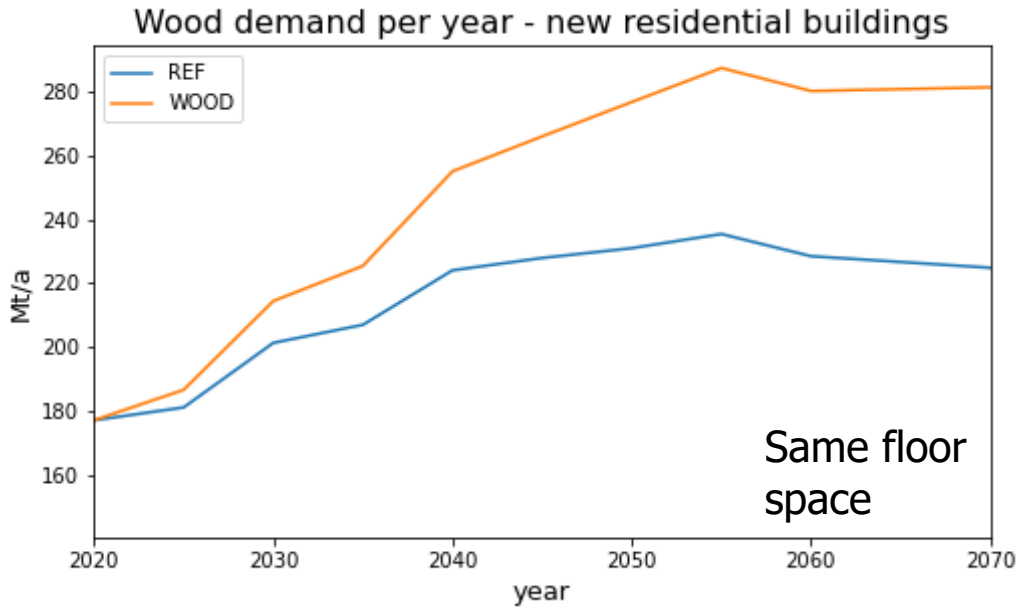
- Formaldehyde resins produced from methanol are mostly used as adhesives in engineered wood products (EWP)
- Material substitution: cement vs. wood in residential buildings
- New products like CLT (Cross laminated timber) and Glue laminated timber (GLULAM)
  - made from solid wood parts
  - can replace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

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

Methanol

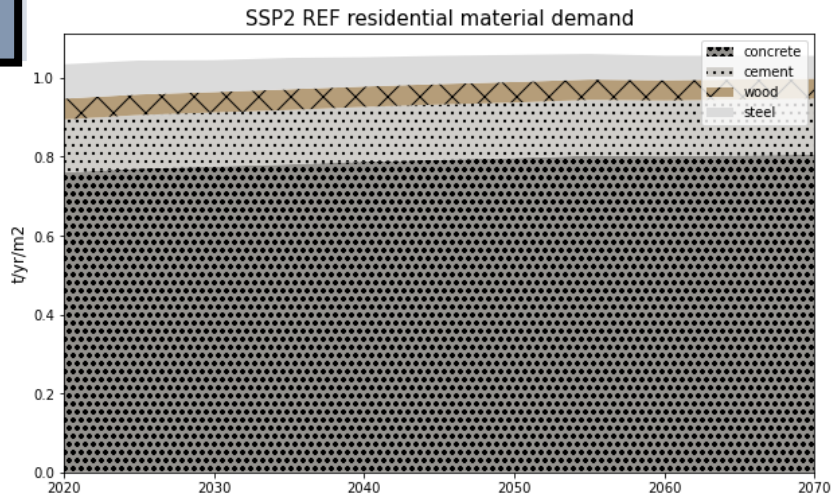
Chemicals	High-Demand	Low-Demand
Methanol (CH3OH)		
Engineered Wood Products (EWP) in residential buildings	No Policy-(WOOD)	No Policy-(REF)
Rest of Methanol as feedstock	2Degrees-(WOOD)	2Degrees-(WOOD)

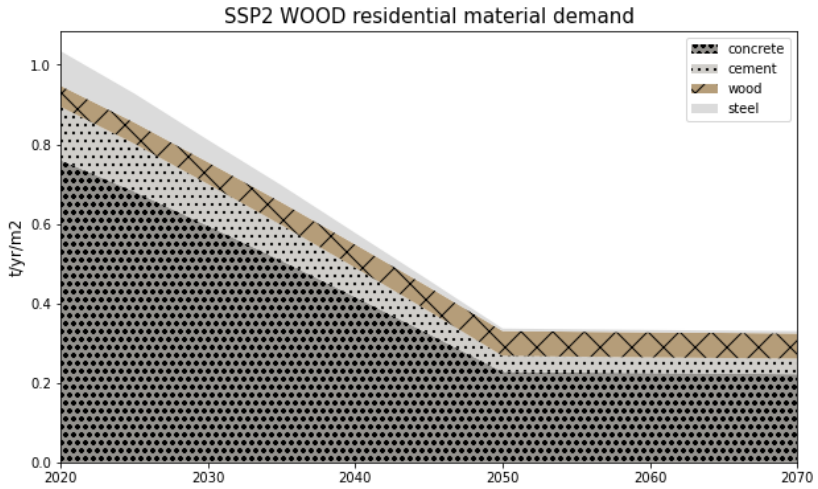
Is there a trade-off in emission reductions caused by the increased chemicals production as a result of the increased wood demand?



WOOD: increased wood utilization

REF: historical material use

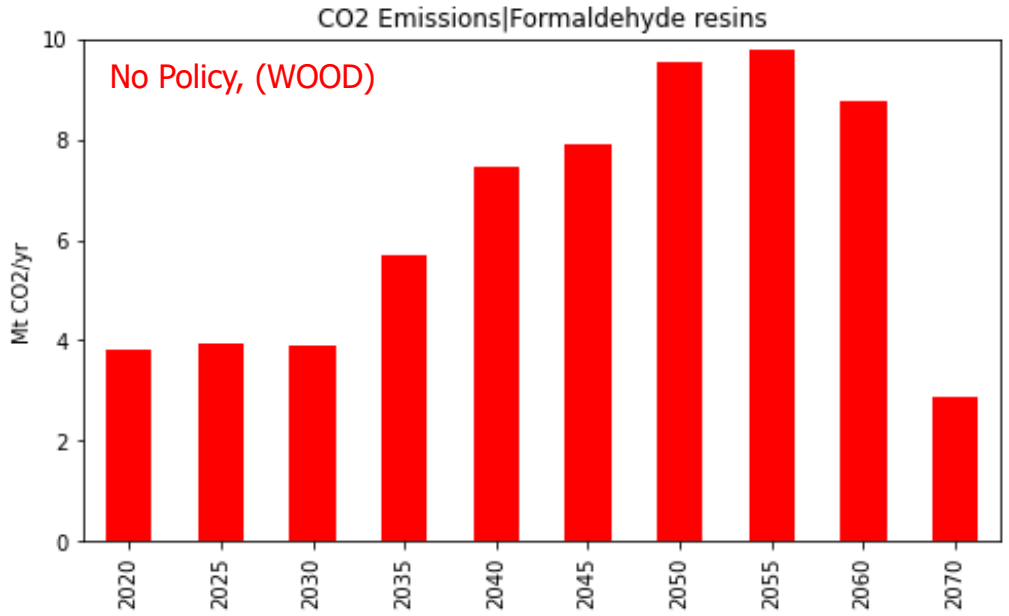


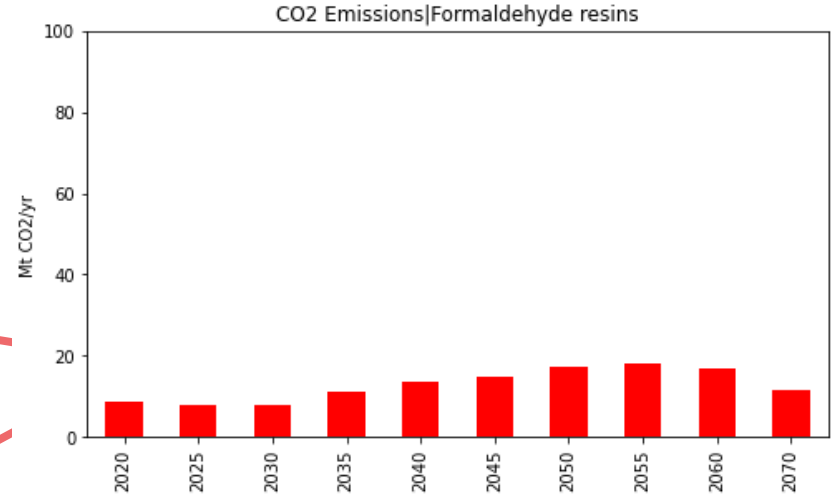


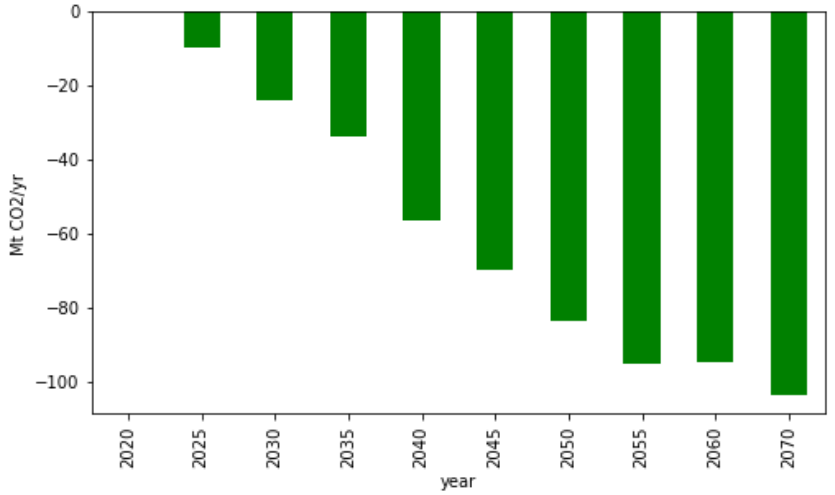
Substitution with wood reduces overall material intensity of residential buildings

Methanol: Buildings

Additional emissions from resins needed for wood products



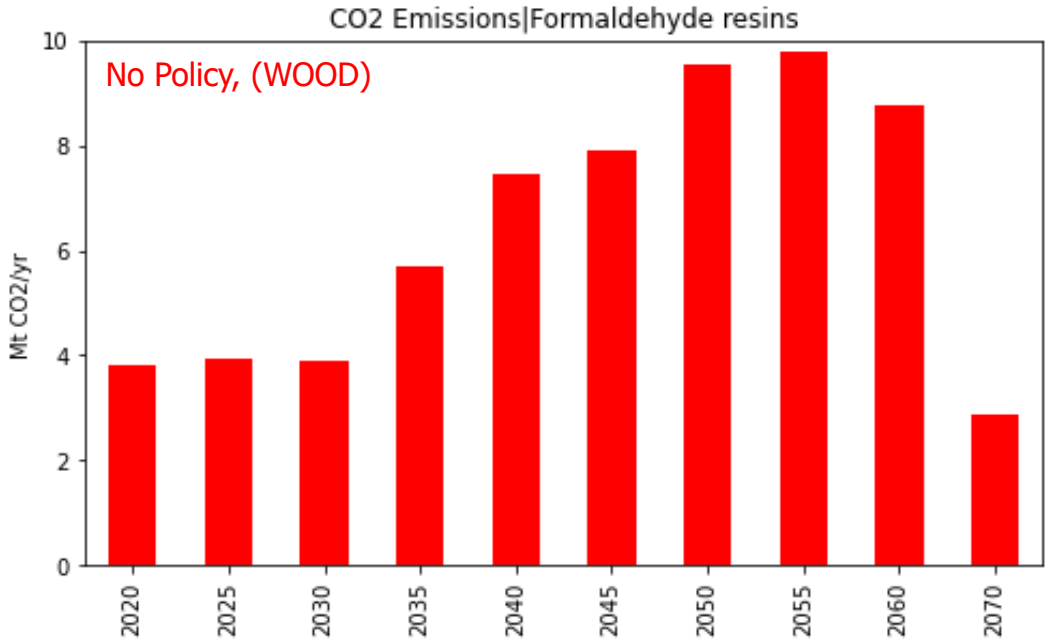


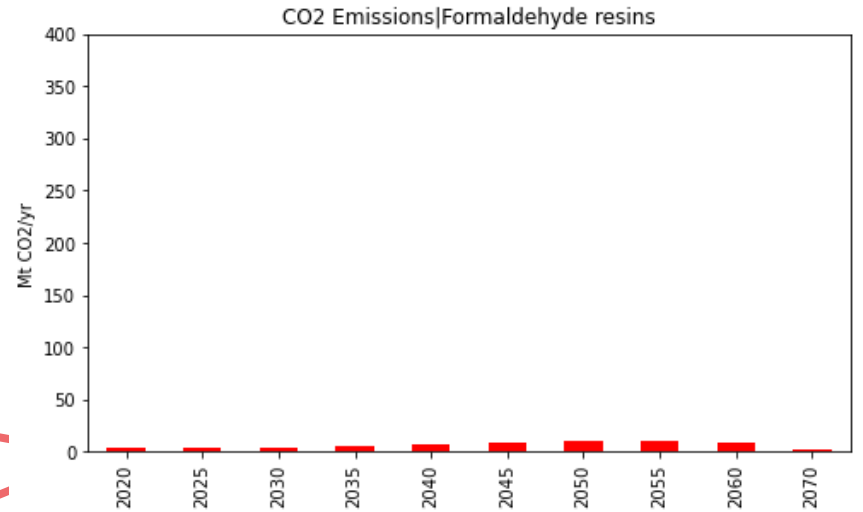


Carbon stored in biomass

Methanol: Buildings

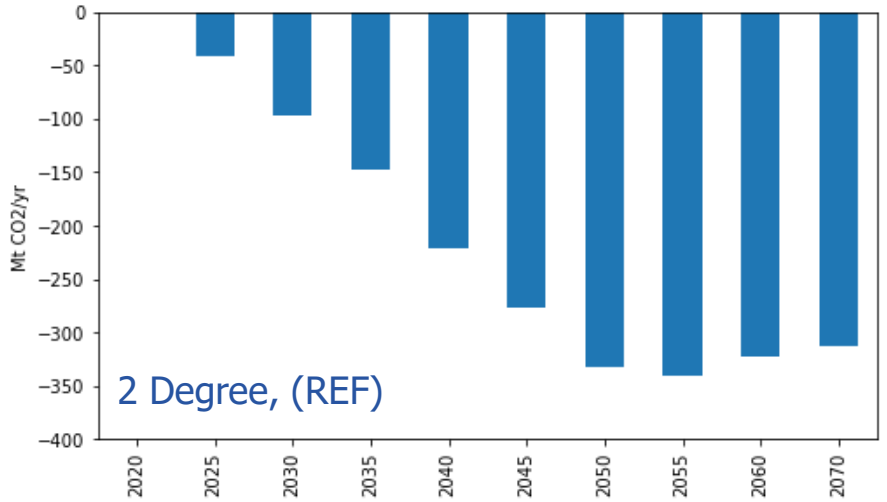
Additional emissions from resins needed for wood products



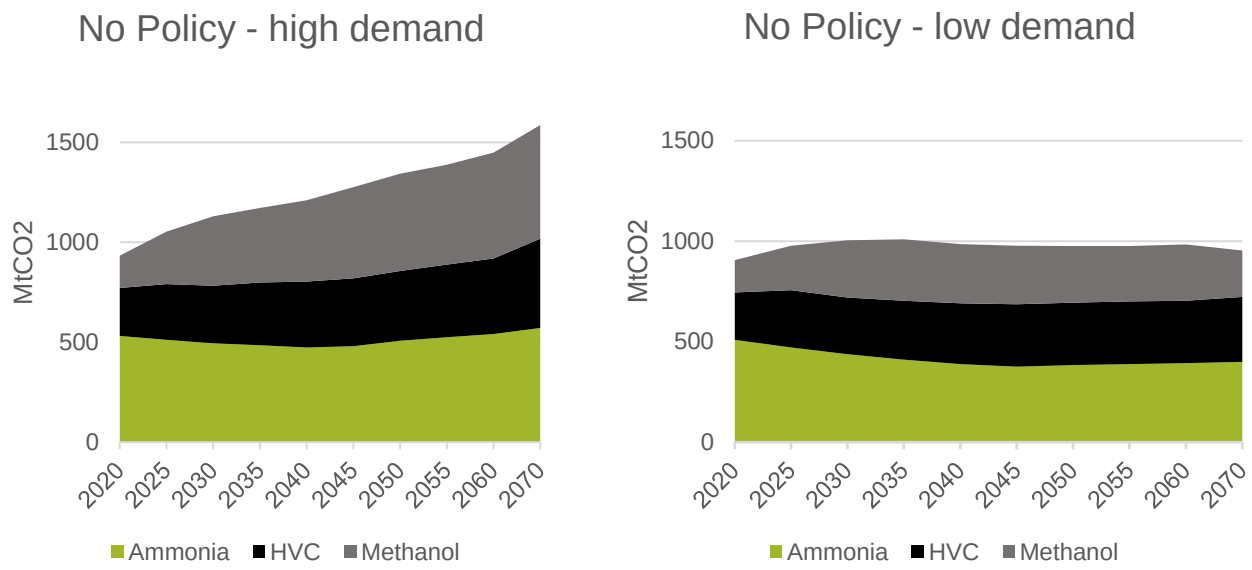


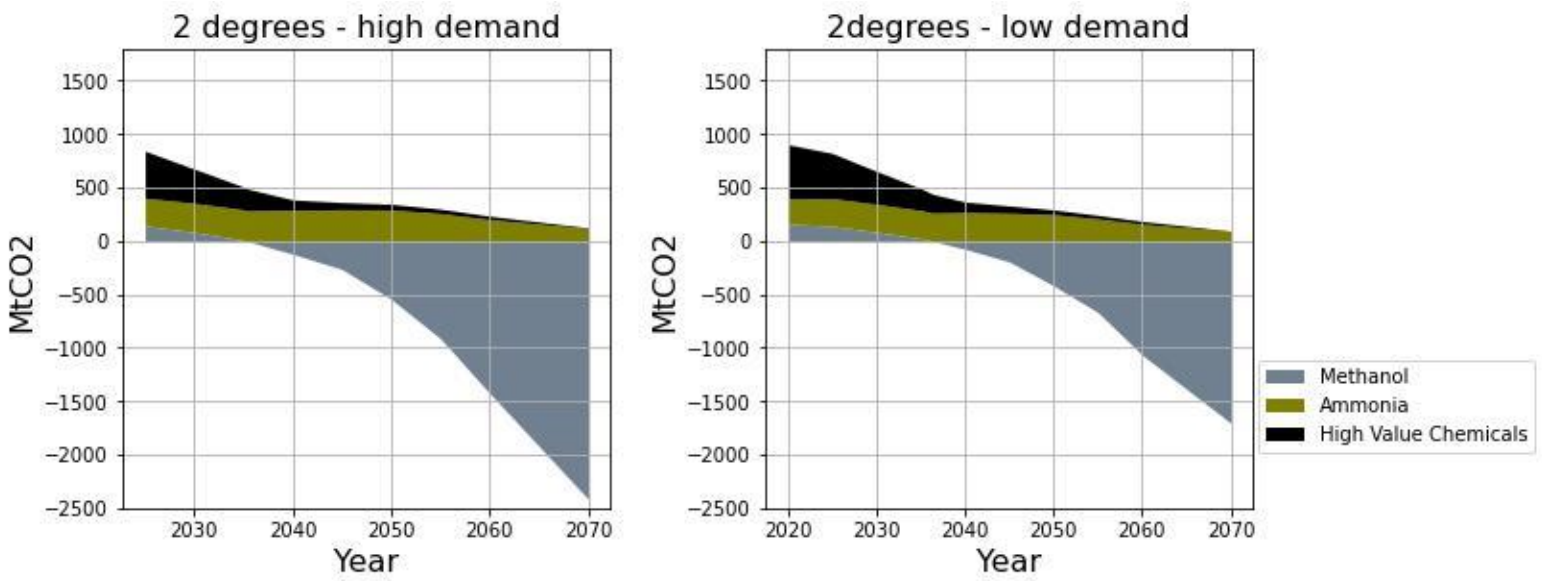
What happens if the cement production becomes greener in a 2 degree scenario?

Avoided emissions from wood-cement substitution



Chemicals Total CO2 Emissions





- 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 ressources 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?