Abstract

Headwind or tailwind?

Defossilization in the chemicals industry

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Summary

1. The chemicals industry is an industry built on carbon – approximately 450 mn tons in feedstock, 330 mn tons in energy consumption, and 100 mn tons in unavoidable process emission[1]
2. From material aspect, recycled, bio-based, waste-based, and CO2-based gain significant trajectory; however, the majority (>75%) will be served by fossil sources by 2030
3. From energy perspective, optimized reaction engineering, efficiency improvement, waste heat recovery, and sustainable alternative energy sources will make major contribution
4. Unavoidable emission through production processes and energy consumption should be captured for utilization or permanent storage
5. Despite clear guiding principles, defossilization of the chemicals industry is facing significant challenges, especially in scalability and costs
6. With proper (regulatory) incentives and maturing technology, certain solutions show attractive economic viability
7. Cross-industry collaboration and openness to technology are required to build up a sustainable and financially viable new ecosystem at scale

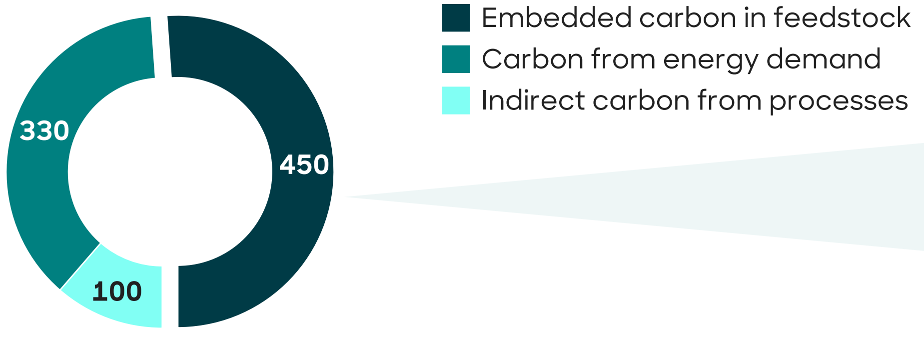
1) 2022 data

Source: IEA, OECD, desk research, Roland Berger

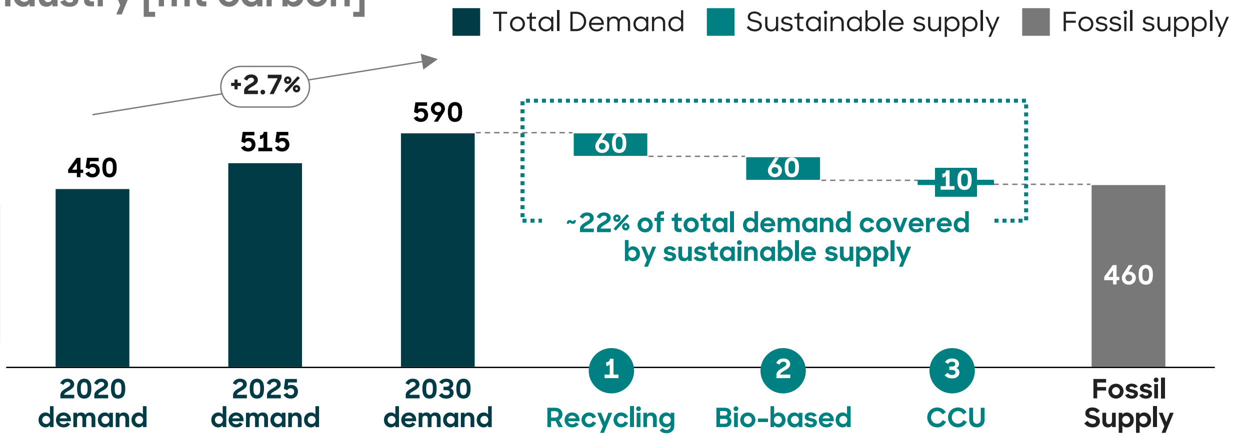
2

Carbon feedstock demand of the chemical industry is to reach approximately 590 mt by 2030; only minor part will be covered by sustainable carbon sources

Carbon demand of the global chemicals industry, 2022 [mt carbon]



Demand and supply of feedstock carbon in the chemicals industry [mt carbon]



1 Recycled carbon

- Recycling with highest technological readiness
- Significant shortcomings in global waste supply and quality as key limiting factors

2 Biobased carbon

- Direct competition to food and feed in 1st generation processes
- 2nd generation for commodities as bioethanol commercialized
- Moderate tech. readiness and high cost of 3rd generation (algae) processes
- Drop-in solution with lower capex requirement

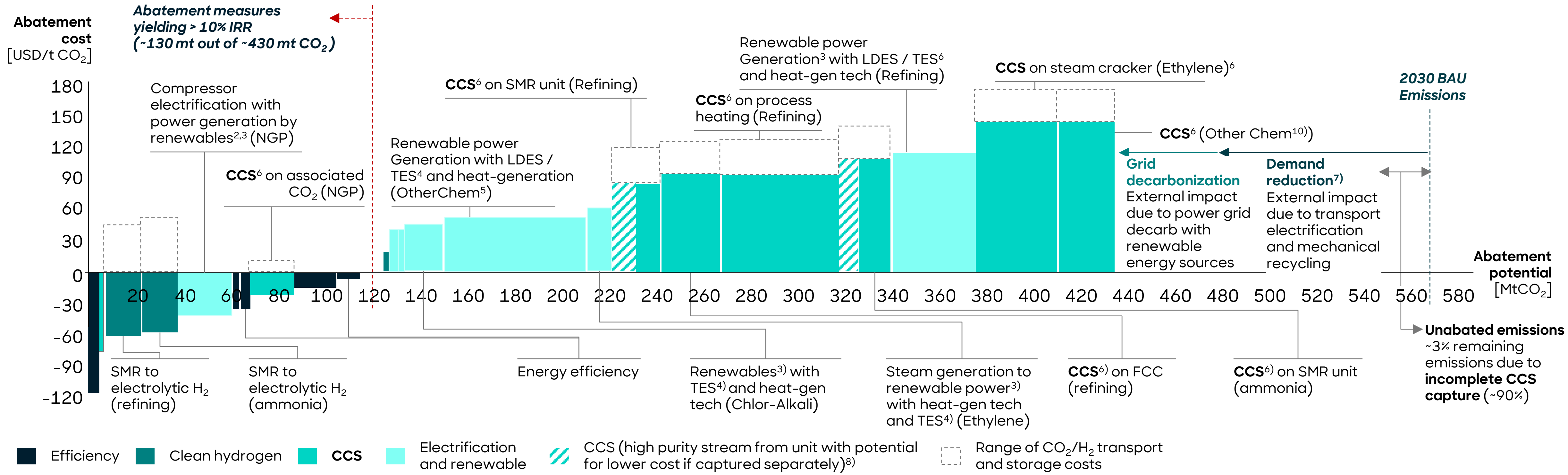
3 Utilized carbon

- CCU technology least advanced and high capex requirement
- For most products 10-20 years required to become large-scale commercialization
- While direct air capture being least economic, many high concentration CO_2 emitters exist

Source: IEA, Nova Institute, OECE, Desk research, Roland Berger

Under favorable regulation conditions, CCS can be economically viable, e.g., within the IRA, ~30% of emission can be abated under attractive financial viability

2030 marginal abatement cost curve for Chemicals & Refining industry, with IRA in the US [USD/t CO_2]



1) Heat electrification analysis include IRA 48E incentive assuming the projects meet the prevailing wage and apprenticeship requirements, and half of projects meets qualify for the domestic content adder. ITC incentives are included. Other policies are not considered in this analysis due to unclear economic impact (E.g., downstream impact of policies) and local impact (e.g., state and local policies. Asset and geography specific consideration of policies could significantly impact choice of technology and resulting abatement cost
2) Electrification of compressor results in significant efficiency improvements over steam turbines (95% versus 35% efficiency)
3) Renewable cost assumes Class 5 onshore wind production from NREL Annual technology Baseline for 2030 and excludes the costs associated with transmission and delivery of electricity. IRA-inclusive scenarios include investment tax credit of 35%, 30% from a base construction that meets the prevailing wage and apprenticeship requirements and an additional 5% due to an assumption that half of projects will claim the 10% domestic content adder. No adders included for low-income communities and energy communities. Net capex cost assumed is $621/kW and opex is $39/kW
4) Heat generation technology assumes the costs associated with charging and TES as an archetypical setup; however, asset specific heat generation can be achieved with other technologies such as heat pumps and resistive heaters. Technology development and asset specific considerations could significantly impact the choice of heat generation technology.
5) Ethylene process assumptions used to model propylene and BTX processes (e.g., propane and naphtha cracking)
6) Displayed CCS cost estimates based on EFI foundation capture costs with transport (GCCSI, 2019) and storage (BNEF, 2022) costs ~$10-40 tonne (representing the lower and upper bounds of the displayed range) except where noted. All in 2022 dollars. All CCS figures represent retrofits, not new-build facilities. The inflation variance on each cost estimate represents the range of cost increases on a generic chemical processing plant due to inflation from 2018 using the Chemical Engineering Plant Cost Index (CEPCI)
The range of 2030 electrolytic hydrogen costs for refining is estimated at $.22-1.22 / kg H2. The range of 2030 electrolytic hydrogen for ammonia is estimated at $.28-1.28 / kg H2. All hydrogen cost assumptions for this modeled scenario are based on DOE's Clean Hydrogen Lift-off, which relief on the 2022 McKinsey Hydrogen Model. The impact of the 45V tax credit is modeled as a $1.80 / kg H2 reduction in OpEx cost, based on assumptions of 10% WACC, 10 years of tax credit, and a 20-year project lifetime. It is important to note that the assumptions underlying this analysis are uncertain, and the Clean Hydrogen Lift-off report is continually being updated. DoE electrolyser cost estimates have already increased since the value published in this report due to variable such as supply chain constraints and inflation. Additionally, the impacts of tax incentives on cost will be subject to guidance from the US Department of Treasury.
8) Demand reduction consists of primarily transport sector electrification as well as the impact of a mechanical recycling rate of 25% of all plastics
9) Split of emission streams assumed to be ~60% concentrated and ~40% dilute in SMR unit. Portion of SMR concentrated streams assumed to be smaller for ammonia due to captive usage of concentrated CO2 streams for urea production
10) Assumes CCS implementation on other chemicals high temperature heat sources with costs based on ethylene steam cracker capture costs

NGP: next generation geothermal power; **SMR**: steam methane reforming; **LDES**: long distance energy storage; **TES**: thermal energy storage; FCC: fluid catalytic cracking.

Source: GREET 2022, NREL, DOE Hydrogen Liftoff Report, EFI CCS report - "Turning CCS projects in heavy industry & power into blue chip financial investments", Inflation Reduction Act, LDES Council, Expert interviews, Danish Energy Agency, Netherlands Enterprise Agency, GHG Protocol, White House net-zero targets, McKinsey Global Energy Perspective, EFI Foundation, "Turning CCS Projects in Heavy Industry & Power into Blue Chip Financial Investments", Roland Berger

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