Climate-positive chemistry

Strategies for minimizing CO_2 emissions and maximizing carbon stocks in the chemical value chain.

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The chemical industry plays a central role on the pathway to climate neutrality. As an industry that evolved from the availability of fossil resources, it is still based on a linear value chain today. Fossil resources are processed into chemicals and at the end-of-life, final products based on these chemicals are incinerated or landfilled. At five percent of Germany's emissions, the production of chemicals alone is one of the largest sources of CO_2. The extraction of fossils and the end-of-life treatment of chemical-based products are responsible for additional emissions that are approximately three times the production-related emissions. As the world's largest exporter of chemicals and as the location of the headquarters of numerous global chemical companies, Germany needs to seize the opportunity to lead the global transformation of chemicals. In the past, the chemical industry has already proven that it can be innovative and set new standards: Since 1990, production has increased by 63 percent while energy demand has decreased by 19 percent and greenhouse gas emissions by 54 percent. For the transition to net-zero in the remaining 22 years, further efficiency gains will not be sufficient. Instead, the linear value chain must be replaced by a circular economy based on renewable energies and resources.

Germany is currently confronted with multiple crises:
1) The energy crisis: The chemical industry is the largest industrial consumer of fossil resources in Germany. The loss of vast amounts of cheap energy from Russia fundamentally questions the future of economic production in this country. The risk of an unplanned relocation of production would have fatal consequences for our economy and climate protection.
2) The climate crisis: The temporal window to meet the 1.5 degrees Celsius limit is closing, requiring radical CO_2 mitigation in this decade. Even more, all major climate pathway studies predict that we will need to form large amounts of CO_2-sinks to protect our climate.

The chemical industry, together with all other branches along the value chain, is a key player to tackle these multiple crises. A common objective, that is shared with the energy sector, the supply of renewable feedstocks, product design and with the waste industry, can enable the chemical industry to become the driver of cross-industry carbon management. Through the production and long-term use of biogenic plastics, as well as through the combination with Carbon Capture and Utilization and Storage (CCUS) technologies for inevitable emissions, necessary CO_2-sinks can be generated.

Previous studies that addressed the reduction of chemicals-related emissions in Germany mainly targeted the direct emissions from the production of plastics while not addressing the "shadow" emissions from the feedstock supply and from the end-of-life treatment. Other studies mainly focused on circularity and end-of-life treatment while not addressing the primary production. However, it is a cross-sectoral view that shows that a consistent transformation to renewables and circularity can be climate positive.

A new approach for the transition of the chemical value chain needs to consider all life-cycle emissions and the most efficient allocation of available energy sources and resources, also with respect to other sectors and branches. From the cross-sector perspective, there are three central strategies to transition chemicals to climate positivity:

1. **Direct electrification** of process energy to reduce production emissions and the amount of fossil fuels needed and making the most efficient use of limited available renewable energies.

2. Establishing a **circular economy** that reduces end-of-life emissions of chemical products as well as fossil feedstock demand. Designing plastic products for long-term use, reuse, repair, and recycling reduces the amount of needed material while maintaining the same service. Mobilizing the potential of mechanical recycling and introducing chemical recycling technologies turns waste into a regional source of value creation and reduces the dependency on fossil imports.

3. Replacing fossil with **renewable feedstocks**. Since carbon is the main building block of most chemicals, the remaining fossil feedstocks will need to be replaced by renewable sources. Apart from electricity-based hydrogen and its derivatives, biomass, consisting mainly of carbon and hydrogen, is a promising regional feedstock that can replace fossil feedstock imports. Applying the principle of cascading use of biomass, sustainable biomass should be redistributed from energy to feedstock use. In principle, a wide variety of different types of biomasses can be used to produce chemicals. This characteristic makes it possible to conceive the industrial use of biomass as an integral part of climate-positive landscape management - a bioeconomy that aims at transforming land use towards prioritizing biodiversity, climate resilience, and CO_2 uptake while still enabling revenues from industrial biomass use. This approach too enables regional value creation and reduces dependencies on fossil imports.

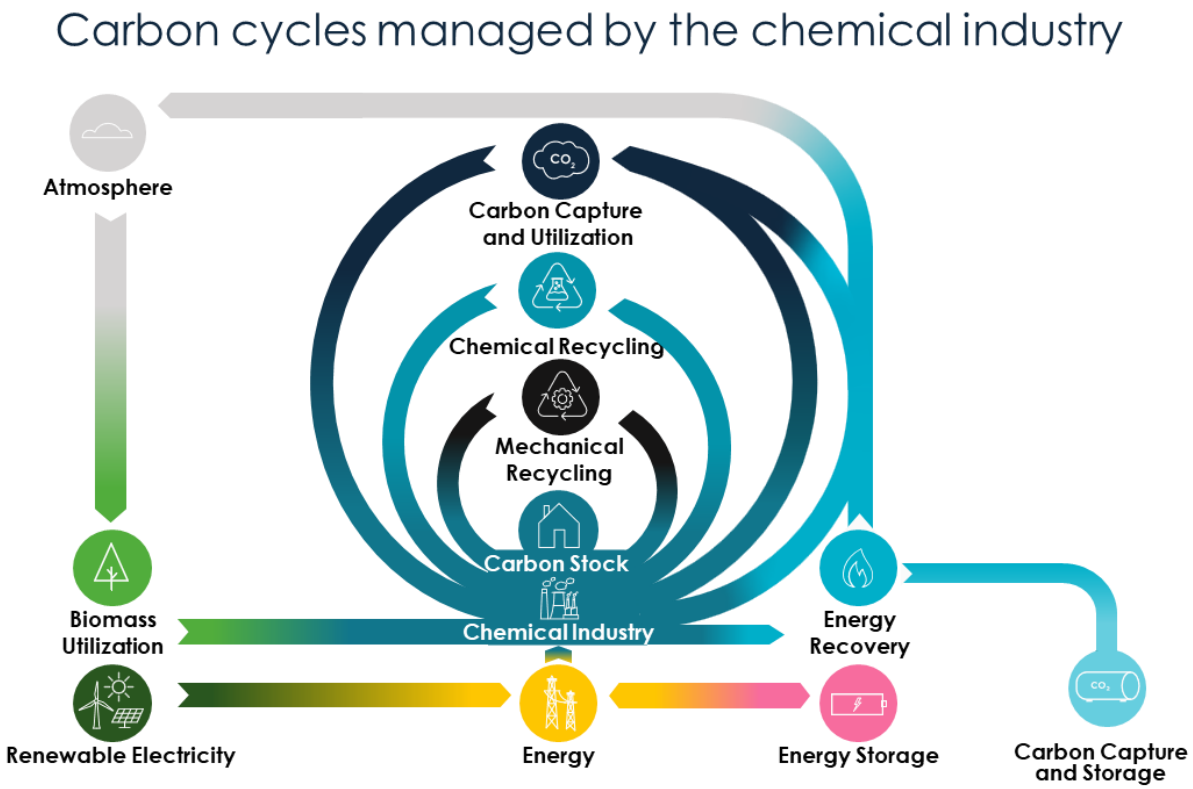

Figure 1: Objective for a climate-positive chemistry: Cross-industry carbon cycles managed by the chemical industry.

These three core strategies reduce the fossil energy and resource requirements of the chemical sector while enabling the same production output (Figure 1). The production of biobased chemicals with a long lifetime in combination with recycling creates a net CO_2-sink. Non-recyclable biobased chemicals can, in the sense of a cascading use, be incinerated and used energetically. The combination of incineration of biobased chemicals with CCUS preserves the CO_2-sink and contributes to achieve the climate targets.

In the current times of multiple crises, new investments need to be understood as a solution for long-term sustainability and reduction of structural dependencies. Making these investment decisions and enabling the transition requires a clear long-term objective between the different sectors and an appropriate regulatory framework that provides the basis for successful change. Climate-positive chemistry provides the basis for a clear objective and for the development of an appropriate regulatory framework in concert with industry. In the next step, the target setting with the three core strategies will be calculated model-based for Germany to show investment decisions, impacts of different regulatory frameworks and climate targets.