**Chemical industry tackles biggest transformation in its history**

*It is a mammoth undertaking: Most nations want to become climate-neutral by 2050 – and with them the companies in the chemical industry. Because on the one hand it produces energy-intensively, and on the other it cannot do without carbon, the chemical industry is having a particularly hard time decarbonising. But this only spurs the industry's researchers and engineers on even more.*

Time is pressing and the budget is limited. What applies to almost all areas of life also applies in particular to global greenhouse gas emissions. 196 nations had already agreed in Paris in 2015 to limit global warming to below 2 °C and, if possible, not to exceed even 1.5 °C. Climate researchers have calculated what is needed to achieve this – not only in percentage terms, but also in absolute figures: in 2018, the emissions budget for the greenhouse gas carbon dioxide was still 800 gigatonnes. According to estimates by the Potsdam Institute for Climate Impact Research, this was the maximum amount of CO2 that the global community was allowed to release into the Earth's atmosphere at that time without jeopardising the target of +1.8°C. But the clock is ticking: Because fossil fuels were also used between 2018 and 2022, the budget has been reduced by an average of 36.4 Gt per year since then - which means that 618 gigatonnes remain from 2023.

The largest emitters have therefore set concrete targets: China, with a share of 32.9 % of annual global CO2 emissions (2021), and Russia (5.1 %) want to become climate neutral by 2060, the USA (12.6 %) and Europe (7.3 %) already by 2050, India (7.0 %) only by 2070 and the chemical nations Japan (2.9 %) and South Korea (1.7 %) by 2050. But a simple rough calculation shows: Emissions must fall significantly sooner in order to meet the budget. With unabated carbon dioxide emissions, the emissions budget would already be exhausted by 2040.

**Chemical industry under decarbonisation pressure**

The chemical industry has an important role to play here: on the one hand, because it is responsible for around 5 % of CO2 emissions, and on the other hand, because the chemical industry, with its products, holds the key to most technologies for a climate-neutral economy. This is because the greenhouse gas emissions of the chemical industry have two causes: Energy production (approx. 60 %) and chemical reactions (40 %).

The climate goals that chemical companies have set for themselves are not only motivated by altruism. In the meantime, investors are putting a lot of pressure on them: more and more financial funds are only investing in companies that take measures to reduce their greenhouse gas emissions. And the fact that the largest chemical companies have chosen their own time target for climate neutrality in line with the national targets at their headquarters is no coincidence: If the target is missed, there is a threat of fines and bans on operations.

A look at the plans of the largest chemical companies shows that the industry is rising to the challenge. The large western corporations want to operate in a climate-neutral manner by 2050 at the latest and have set themselves milestones. The German chemical company BASF wants to replace all fossil fuels with electricity from renewable sources by 2030. The US company Dow is focusing on material cycles and plans to use plastic waste and alternative raw materials by 2030 to then produce 3 million tonnes of recyclable products annually. Exxonmobil Chemicals plans to emit about 20-30% less greenhouse gases by 2030 than in 2016. The plans of other major chemical companies are even more ambitious: the British petrochemical group Ineos wants to reduce its emissions by a third by 2030 compared to 2019, and Mitsubishi Chemical (Japan) and Sabic (Saudi Arabia) have set themselves similar targets with different reference years.

So far, the world's largest chemical company by far remains vague: Sinochem, which merged with Chemchina in 2021. Besides the general reference to the implementation of measures to improve energy efficiency, the company refers to the general goal of the Chinese government in its sustainability report for 2021. This aims for climate neutrality by 2060 and a maximum of annual CO2 emissions by 2030 at the latest.

Some chemical companies expect that rapid decarbonisation will also pay off economically. More and more customers are already paying attention to the carbon footprint of products when making purchases. And it is no longer only emissions from the combustion of fossil fuels (Scope 1) that are accounted for. Indirect greenhouse gas emissions from purchased energy (Scope 2) or in the upstream and downstream supply chain (Scope 3) are now also being considered. The plastics manufacturer Covestro, for example, is planning to become climate neutral with regard to Scope 1 and 2 as early as 2035 and then wants to close product cycles completely in order to achieve climate neutrality with regard to Scope 3 as well.

**The chemical industry must reinvent itself**

The example shows at the latest: Chemistry must reinvent itself. This requires new ways of producing and using energy, new forms of cooperation between chemical companies, raw material suppliers and buyers of the products and, last but not least, new processes. Although global chemistry synthesises thousands of compounds, the greatest potential for reducing emissions can be narrowed down to eight products: 75% of greenhouse gas emissions come from the production of ammonia, ethene, propene, nitric acid, carbon black, caprolactam, soda ash and fluorochemicals.

One approach in the production of ethene and propene is the development of electrically heated steam crackers. This is currently being promoted by numerous chemical companies. This is because the cracking furnaces, in which the basic materials for the production of plastics and basic chemicals are produced from naphtha, ethane, propane and butane, have a miserable energy balance: almost 700 kilograms of carbon dioxide are produced per tonne of ethene produced. The total CO2 emissions of the globally operated steam crackers are estimated at 300 million tonnes per year.

90 % of this is accounted for by the heating of the cracking furnace – and that is the good news. If the furnaces can be heated with renewable electricity, this would be an important step towards climate-neutral chemistry. BASF, Sabic and Linde are currently working together on an electrically heated steam cracker. In parallel, Dow and Shell are driving development forward together. While these processes are initially to be tested on a pilot scale, Ineos has already announced the construction of a large-scale plant in the port of Antwerp, although the technology for this is still open: the new cracker is to use ethane as a raw material and could in future be heated exclusively with climate-neutral hydrogen. In addition, options for CO2 capture and storage (CCS) and electrically powered furnaces are to be considered during construction.

**Electrification and the circular economy**

In general, electrification is an essential lever with regard to climate-neutral chemistry. If the required process steam is no longer produced from the combustion of fossil fuels in the future, but with sustainably generated electricity, large savings in carbon dioxide emissions can be achieved. Heat pumps can also play a role in this: Powered by renewable electricity, they make it possible to generate steam from previously unused residual heat. Together with MAN Energy, BASF is currently investigating the use of a large heat pump with a thermal output of 120 megawatts at the Ludwigshafen site.

More and more chemical companies are now even securing electricity supplies from wind farms for the electrification of their processes - even from those that have not even been built yet. But the renewable electricity capacities needed for electricity-based chemistry are enormous. According to a DECHEMA study, almost 50 percent more electricity would be needed in Europe for this than is currently available in Europe. Without the import of green or blue hydrogen, ammonia or methanol from regions with large capacities for renewable electricity, most chemical nations will not be able to achieve the goal of climate neutrality.

In addition, the complete abandonment of fossil raw materials will require the synthesis of chemicals from hydrogen and carbon dioxide in the future. The process for this – the Fischer-Tropsch synthesis – is available. Waste gas flows from the cement industry (sector coupling), for example, come into question as a carbon dioxide source.

Hydrogen also plays a central role in the production of the largest basic chemical in terms of volume: ammonia synthesis. No other chemical manufacturing process emits as much climate-damaging CO2 . Until now, ammonia has mainly been produced from natural gas by steam reforming, but in future it will require enormous quantities of climate-neutral hydrogen. This can be produced either by water electrolysis with renewable electricity, or by steam reforming with subsequent CO2 capture and storage (blue hydrogen). A new approach is methane pyrolysis, which is currently being developed by several companies and research institutions.

Another basic chemical is also based on natural gas: the alcohol methanol. In the future, this could be produced from hydrogen and carbon dioxide generated from biomass or other industrial processes (sector coupling). Another source of raw materials in the future can be provided by the circular economy: for example, plastics manufacturers are working on new processes with which plastic waste can be turned into the starting material for the production of basic chemicals through mechanical and chemical recycling. Solvolysis, depolymerisation or - in the case of mixed waste - pyrolysis provide new monomers or synthesis gas that can be used for the production of new plastics and chemicals.

**New business models and flexible processes in demand**

However, a chemistry based on green electricity and green hydrogen will not only require new processes, but also new business models: The current approach of continuous production 24 hours a day, seven days a week cannot easily be transferred to a world with fluctuating electricity volumes and prices. Flexible processes are needed, but also processes in which hydrogen will play a major role as energy storage, energy carrier and raw material. Electrification is supported by current developments in electrochemistry: this enables chemical conversions at lower temperatures and pressures.

Efficient reaction technology, especially with new catalytic processes, will make a further contribution to climate-neutral chemistry: Linde and Shell, for example, are investigating a new process that could completely replace steam crackers: Ethene synthesis based on catalytic dehydrogenation of ethane. Because the process, known as Edhox, takes place at 400 °C instead of 850 °C, the energy requirement is significantly reduced.

In general, it is worth taking a look at the high-temperature processes because they often cannot be electrified at all. These include, in particular, rotary kilns and blast furnace processes that have to be converted to biogenic or carbon-free fuels.

However, it will be some time before the new processes based on renewable electricity or bio-based raw materials are mature enough to produce a significant positive climate effect in global chemistry . Decarbonisation by capturing and storing the resulting carbon dioxide (CCS, CCUS) therefore offers itself as a bridge technology. This could decarbonise the production of (blue) hydrogen and the basic chemicals ammonia and methanol, as well as higher-value chemicals such as ethene, propene or aromatics. The limiting factor here so far has been the availability of CO2 deposits and the lack of capture capacities. The United Nations IPCC estimates that at least 4 gigatonnes of CO2 will have to be saved annually by 2050 via carbon management and removal technologies in order to achieve the 1.5 degree target.

**Investments need a competitive framework**

The measures towards a climate-neutral chemical sector will not come for free. According to estimates by Accenture and NexantECA, investments of 1 trillion euros will be necessary in Europe alone. And time is pressing, because new plants have a typical lifetime of 30 to 50 years - which means they should also be able to operate under the primacy of net-zero emissions.

The industry is convinced that this is technically possible. For example, the DECHEMA study "Roadmap Chemistry 2050" states: "The comprehensive use of new technologies makes it possible to still achieve the goal of almost complete greenhouse gas neutrality in 2050".

*Author: Armin Scheuermann is a chemical engineer and freelance trade journalist.*

**About ACHEMA**

ACHEMA is the world forum for chemical engineering, process engineering and biotechnology. The world’s leading show for the process industry takes place every three years in Frankfurt. The spectrum ranges from laboratory equipment, pumps and analytical devices to packaging machinery, boilers and stirrers to safety technology, materials and software, thus covering all the needs of the chemical, pharmaceutical and food production industries. The accompanying congress, featuring scientific lectures and numerous guest and partner events, complements the wide range of exhibition themes. The next ACHEMA will take place from 10 to 14 June 2024 in Frankfurt am Main. [www.achema.de/en](http://www.achema.de/en)