Summary of the DECHEMA and FutureCamp study for the VCI

Working towards a greenhouse gas neutral chemical industry in Germany

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VCI


CO_2

Introduction

Climate protection has become a key concern for society and a dominant topic in German politics. The German government has committed to the target of becoming greenhouse gas neutral by 2050. The chemical industry has tasked experts with analysing if and how it can also become greenhouse gas neutral. As Germany's third biggest industry, it sees itself as being responsible for delivering solutions to contribute to the long-term climate targets. Thanks to more efficient processes and energy generation with lower CO_2 emissions, the German chemical industry has already come a long way: between 1990 and 2017, greenhouse gas emissions from energy requirements and processes decreased by 48 percent.

The path to greenhouse gas neutrality presents a great challenge for the chemical industry as well as for other energy-intensive sectors: on the one hand, today's processes require abundant energy, and the generation of this energy involves high levels of greenhouse gas emissions. On the other hand, CO_2 emissions generated from the carbon content in the products are also becoming relevant in an increasingly carbon-neutral world. In this respect, the chemical industry differs from other sectors. That is why the study also includes this aspect in the carbon footprint.

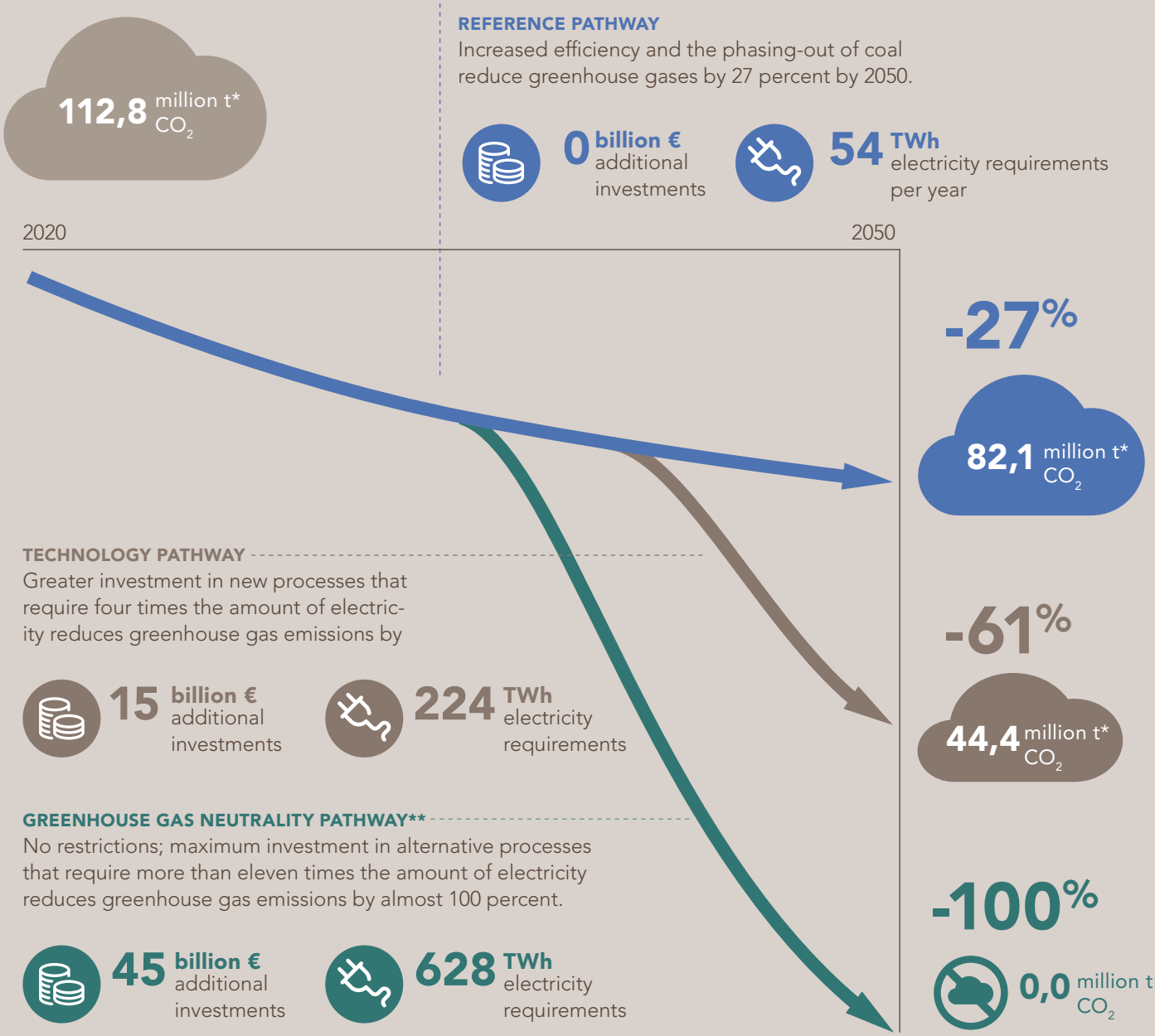
To play a role in meeting the long-term climate protection targets for 2050, the industry faces a transformation that will last for decades. Companies need to develop sustainable – economically, ecologically and socially viable – alternative processes and implement these by investing in new plants. To do this, they require economic conditions and an energy-policy framework that make this kind of forward-looking project possible. The key prerequisites are that energy and raw materials must be available in sufficient quantities and also be affordable.

The VCI (German Chemical Industry Association) tasked DECHEMA and FutureCamp with investigating a possible path for this transformation in the study "Auf dem Weg zu einer treibhausgasneutralen chemischen Industrie in Deutschland" (working towards a greenhouse gas neutral chemical industry in Germany). This study investigates the measures and technologies that the chemical industry needs, how far it can progress towards complete greenhouse gas neutrality and the investments it requires. The roadmap sets out the tasks facing the chemical industry over the coming decades. It also outlines the necessary policy and economic frameworks that are needed to support this path.

The roadmap does not cover the services that the chemical industry contributes to climate protection with its products – such as basic materials for wind and solar power, energy stores, lightweight materials for the automotive industry and insulation materials for buildings. Overall, chemical products save considerably more greenhouse gases in their usage than the amount emitted during their production today. Climate protection would be impossible without the chemical industry.

The results in brief

Greenhouse gas emissions from processes, energy requirements and products*



Electricity cost assumption: EUR 0.04 per kWh including levies and taxes

** A small volume of emissions remains which must be reduced using additional technologies and was not part of the study.

Results for the pathways

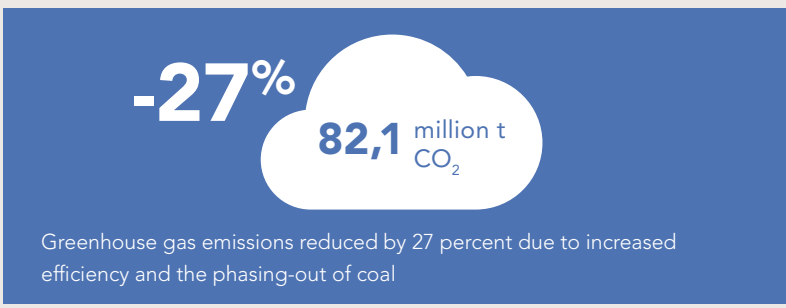
The roadmap presents a detailed picture of developments in the chemical industry on its way to becoming greenhouse gas neutral by 2050. Whichever milestones are achieved by the middle of the century, one thing is clear: the chemical industry will be able to continue cutting its greenhouse gas emissions in the future too. However, its progress will depend on the measures implemented. Each of the three levels of ambition would enable the chemical industry to progress around one third further towards greenhouse gas neutrality.

Reference pathway

If the industry continues to improve its current plants and use electricity with ever lower CO_2, it can reduce its CO_2 emissions by 27 percent, from 112.8 million to 82.1 million tonnes of CO_2, between 2020 and 2050. Relative to the chemical industry's climate footprint to date (not including CO_2 emissions from carbon dioxide generated from the carbon content in products), this represents a decrease in greenhouse gas emissions of around 80 percent since 1990 (see graph on page 9). The chemical industry's footprint is also benefiting from the phasing-out of coal in Germany.

The decommissioning of coal-fired power stations and the continuing development of renewable energies are reducing emissions from general electricity production and thus also from the production of electricity purchased by the chemical industry from outside. Companies are reducing the use of oil and coal in their own power stations. They are also continuing to maximize the efficiency potential of the current plants in the basic chemicals and speciality chemicals segments, resulting in an energy saving of around five percent. Advances in the circular economy are also having a positive impact.

Overall, the results for the reference pathway show that the German chemical industry's climate footprint will improve considerably by 2030, owing to efficiency measures and the phasing-out of coal. After 2030, however, emission levels will only decrease slowly. This makes it clear that the chemical industry has already completed a great deal of the groundwork over the past decades: it has almost exhausted its potential to cut emissions by optimizing conventional processes.



Greenhouse gas emissions reduced by 27 percent due to increased efficiency and the phasing-out of coal

Technology pathway

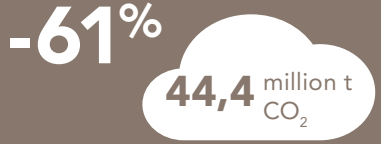
The reduction of greenhouse gases after 2030 will be significantly greater if the German chemical industry invests heavily in new process technologies for basic chemicals. If it does so, it can significantly cut energy-based and process emissions that were previously attributed to the chemical industry. It would be left with greenhouse gas emissions resulting from the use of fossil resources as raw materials and for combustion processes. Even these can be partially replaced by alternative sources. The industry can achieve further progress by using improved mechanical and chemical recycling processes to reuse plastics as feedstock for the production of basic chemicals.

If these measures are taken in addition to those set out in the refere pathway, the chemical industry can cut its emissions by 61 percent between 2020 and 2050. This pathway does not enable the industry to achieve extensive greenhouse gas neutrality by 2050. However, considering the greenhouse gases under the statistical scope up to now (process and energy related greenhouse gases) there would be a reduction of 95 percent compared to 1990. Practically the only emissions left would be those from carbon dioxide generated from the carbon content in the products, which are now taken into account.

The first of the new-generation plants could be installed around 2035. These plants would reduce CO_2 emissions from chemical production as of the early 2040s, in particular. However, to transform the processes, huge volumes of renewable electricity are required: the German chemical industry alone would require 224 TWh of electricity per year from 2040 (2018: 54 TWh). This corresponds to roughly the total amount of renewable electricity produced in Germany in 2018 or the current electricity consumption of all of Germany's industry.

To have the technologies in place by 2040, they would need to be market-ready by then. During the lead time, companies would have to invest heavily in researching and developing the processes. They would need state funding and support in these endeavours. To build new plants for the six basic chemical products investigated in the study, the chemical industry would have to significantly increase its investment budget. A total of at least EUR 15 billion of additional funds would be required by 2050 for the market launch alone (not including development costs), with the greater part of those as of 2040. Furthermore, in addition to the processes for basic chemicals looked at in the study, other processes in other parts of the production chain also need to be transformed. This increases the actual investment volume required.

In view of the costs for companies, the transformation of the basic chemicals segment to low-emission processes is only feasible if backed by a suitable policy framework: in addition to the relief scheme regulations in the reference pathway, there would have to be regulations to protect European production sites in order to implement the measures in the second pathway.



Greenhouse gas emissions reduced by 61 percent due to greater investment in new processes that use four times the amount of electricity.

Greenhouse gas neutrality pathway

To achieve extensive greenhouse gas neutrality in the German chemical industry by 2050, the efforts described in the limited technology pathway would have to be ramped up. In this pathway, technologies are implemented if their use results in a saving on CO_2, irrespective of their economic viability. All conventional basic chemical procedures would thus be replaced by alternative processes without CO_2 emissions by 2035 to 2050. The greatest decreases in CO_2 emissions would not be seen until the 2040s once the technologies have a widespread impact and Germany's electricity mix has been extensively decarbonized.

The downside: the new, electricity-based procedures would mean an increase in the electricity required by the German chemical industry to 628 TWh per year as of the mid-2030s, which is more than all of the electricity produced in Germany in 2018. The costs would also increase rapidly compared to the second pathway. Just to produce the six products examined in the study, companies would have to invest some EUR 45 billion more between 2020 and 2050, and the larger part again as of 2040.

-100%  **0,0** million t CO_2

Greenhouse gas emissions reduced by almost 100 percent due to investments of EUR 45 billion in alternative processes that use eleven times the amount of electricity.

TECHNOLOGY PORTFOLIO
for the technology pathway and the greenhouse gas neutrality pathway

ELECTRICITY-BASED PROCESSES	▸ Methanol from electrolytic hydrogen and CO_2 ▸ Ammonia and urea from electrolytic H_2 and CO_2 ▸ Electrically heated cracking ▸ Electrically heated steam reforming ▸ Synthetic naphtha/methane from electrolytic H_2 and CO_2
ALTERNATIVE RAW MATERIALS/PROCESSES	▸ Chemical recycling of plastics (pyrolysis, gasification, depolymerization) ▸ Thermo-catalytic biomass conversion into BTX ▸ Synthetic naphtha/methane from biomass ▸ Co-firing with biomass ▸ Methane pyrolysis
DOWNSTREAM PROCESSES	▸ Ethylene/propylene via methanol-to-olefins (MtO) ▸ BTX via methanol-to-aromatics (MtA) ▸ Olefins from synthetic naphtha and cracking ▸ Olefins from synthetic methane + oxidative coupling of methane

Overall results

The roadmap for the German chemical industry shows that it is technologically feasible for chemical production in Germany to become extensively greenhouse gas-neutral by 2050. New methods of closed-loop circulation, CO_2-free hydrogen production and the use of CO_2 as a raw material make this possible.
The extent to which the chemical industry can actually tap this technical potential depends on multiple factors.

The basic prerequisite for companies to research, develop and finally launch alternative process technologies on the market is their economic viability. The more ambitiously the target of greenhouse gas neutrality is pursued, the more the associated costs rise. Just the transformation of the processes in the basic chemicals segment that were examined in the roadmap would require extra investments of up to EUR 45 billion. During the initial phase, new plants would not be able to compete with older, depreciated plants which offer cheaper production. The higher costs for alternative processes cannot conceivably be passed on to customers in view of the global market prices for basic chemicals.

Companies can thus only pursue a transition to zero emissions if they can remain competitive during each phase and have an optimum framework. But even then, the chemical industry faces considerable obstacles in its pursuit of greenhouse gas neutrality: a key prerequisite for almost all new technologies is the availability of renewable electricity in enormous volumes from today's viewpoint and at a price of EUR 0.04 per kilowatt hour. Without these basic conditions, it would not be worthwhile for companies to introduce new technologies to cut CO_2. If electricity prices are higher than this, the implementation of new

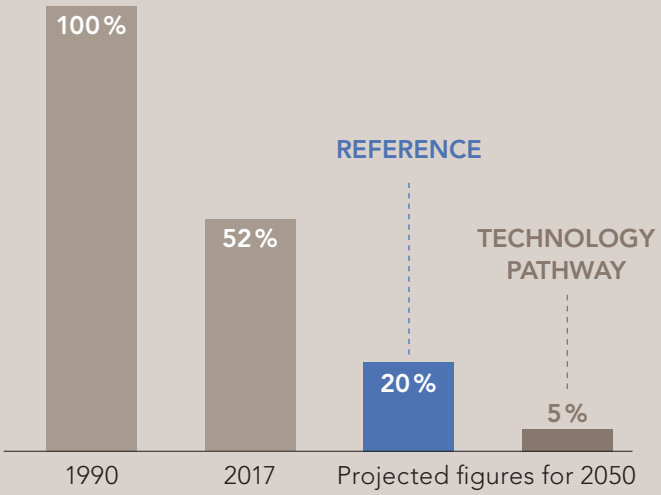
USING CO_2 AS A RAW MATERIAL
View of a German chemical plant that uses carbon dioxide in production

processes will be delayed far beyond 2050. The consequences: the current relief scheme and carbon leakage regulations will not be enough on their own to create competitive electricity prices for industry. Policy-makers will have to increasingly introduce further measures to keep electricity costs low for industry.

They have the power to support the chemical industry's transition with funding. Based on the given assumptions, the new processes would all only become economically viable and thus also marketable as of 2030, with some not until after 2040, according to analyses in the roadmap. If there are policies in place to support this process during both the development phase and the market launch, certain processes could be implemented earlier.

THE INDUSTRY'S CLIMATE FOOTPRINT

Emissions from processes and energy requirements (not including carbon dioxide generated from the carbon



Methodology

The roadmap offers a detailed investigation of production processes and raw materials in the chemical industry that are particularly energy and emissions-intensive. It specifically examined alternative processes for the production of the key basic chemicals. It analysed greenhouse gas emissions generated during production itself as well as emissions resulting from the use of electricity and heat (steam). As an important new step, the roadmap also included the carbon dioxide content of chemical products as a source of CO_2 for the first time. It therefore offers a more complete picture of the situation than was possible with previous climate statistics for the German chemical industry. Because of this, the share of emissions attributed to the chemical industry is considerably higher. The study's figures for future reductions can therefore not be compared directly to previous footprints. However, it is possible to convert these (see graph on page 9).

The investments needed to reduce greenhouse gases were also calculated along with the emissions. The use of new technologies depends considerably on when they become economically viable compared to conventional methods. The analysis is based on multiple assumptions: the footprint thus includes the transformations in the energy business caused by a changed mix of electricity and fuels owing to the phasing-out of coal and the expansion of renewable energies. The study also assumes that the price of CO_2 will increase by 2050. For industrial production, the roadmap assumes a constant production volume of basic chemicals and a slight increase in speciality chemicals up to 2050. In addition, the study assumes that companies in the chemical industry will continue to have carbon leakage protection, unless competitive regions implement comparable climate protection measures like the EU and Germany.

The roadmap describes the route to greenhouse gas neutrality from 2020 to 2050 with three pathways that represent varying levels of ambition. These differ in terms of specific basic assumptions and thus influence the extent to which the chemical industry is able to develop and implement technologies to reduce CO_2:

- **Reference pathway**
  Companies continue using only today's technologies in production. Their investments remain at the current level of EUR 7 billion per year and are used to maintain and boost the efficiency of the plants. Companies also utilize more recycling. Assuming that there will be no more coal-fired power plants in Germany by 2038, Germany's electricity generation will produce ever fewer emissions, which will also have an impact on the chemical industry.

- **Technology pathway**
  This depicts how far the chemical industry can progress in terms of climate protection if it also invests in new production technologies for basic chemicals such as ammonia and methanol. However, the industry is subject to economic and technical restrictions:
  it is assumed that a maximum of 224 terawatt hours (TWh) of renewable electricity will be available for chemical production. The budget for extra investments is also limited owing to economic reasons. New technologies for reducing CO_2 would be introduced if economically viable. It is assumed that the state will support the development of the technologies. Self-generated renewable energies also have a role to play, as does a greater recirculation of products containing carbon dioxide thanks to chemical recycling.

- **Greenhouse gas neutrality pathway**
  There are no more restrictions; greenhouse gas neutrality is the target for the mid-century. This pathway determines which technologies and investments would be required and how much electricity would be needed to achieve zero emissions by 2050. All conventional processes in the basic chemicals segment would be completely replaced by alternative processes. The assumptions for this are more optimistic, with new technologies being brought onto the market faster, for example.

Policy-based conditions to speed up the availability of new processes

Availability of affordable renewable electricity

- New, low-emission processes in the basic chemicals segment are only possible if the necessary electricity is available. To achieve greenhouse gas neutrality, the annual electricity requirements of the chemical industry would increase to more than eleven times (628 TWh) the current amount (54 TWh).
- Electricity costs must remain permanently low. The roadmap assumes an electricity price of EUR 0.04 per kWh for industry – a very low price from today's viewpoint. If the price of electricity is EUR 0.06, the chemical industry cannot become greenhouse gas neutral by 2050 because the relevant plants would not be economically viable. However, a drop below EUR 0.04 could enable new technologies to become economically viable faster.
- The sooner CO_2 emissions from German electricity production are cut, the faster new processes can lead to a reduction of CO_2, including in the chemical industry.

Support for new technologies

- New processes should be promoted in every phase, from research and development through to demonstration plants and large-scale plants.
- Their launch on the market can be sped up with state subsidies for investments.

Policy framework

- Cheap raw material costs have a positive impact on the economic viability of new processes. Policies can create competitive prices for the provision of low-emission hydrogen, for example, that is not subject to taxes.
- New technologies must be recognized as progress in regulations and must not be hampered by additional obstacles.
- Germany and the EU must work towards an international climate protection agreement in order to create comparable competitive conditions for industry. In the absence of global regulations, existing carbon leakage measures must be retained and improved.
- Obstacles to the use and generation of renewable energies in industry must be removed.

CHEMIE IST ZUKUNFT

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The chemical industry is the future. To make sure this statement still applies in tomorrow's world, the VCI commissioned three studies. The results should help to future-proof the industry in Germany:

- Expectations of customer industries for the chemical industry (study conducted by: Santiago)
- Working towards a greenhouse gas neutral chemical industry in Germany (study conducted by: DECHEMA and FutureCamp)
- Paths to the future – paving the way for sustainable development in the chemical and pharmaceutical industries in Germany (study conducted by: Prognos)

The results of the first two studies were incorporated into the VCI-Prognos study. Taking society's growing wish for sustainability into account, the final study examines which opportunities this development offers the industry in the long term.

The studies are available to download from the Internet:
www.vci.de

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