ASPEN GLOBAL CHANGE INSTITUTE ENERGY PROJECT

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Guest Perspective

This article was invited to provide a perspective from within the chemical industry on opportunities that one company (BASF) is pursuing to reduce its emissions during the manufacturing of various chemicals. As such it is a perspective piece as opposed to a traditional research review on the topic. This perspective provides an insight into what the energy transition can look like in practice, which we recognize is not always captured in published literature.

Developing Low-Emission Technologies for the Chemical Industry: A perspective from within the industry

By Brigitta Huckestein, BASF

Population growth and rising prosperity levels are accompanied by an increasing need for food, housing, mobility, comfort, and energy. The shift toward a climate-friendly, sustainable society requires new solutions for all of these areas. Here, chemical products and new materials play an essential role. They are key for enabling low-emission mobility, energy-efficient housing, and carbon dioxide (CO_2)-free power production. But to fully contribute to reaching global climate targets, the chemical industry's emissions have to be reduced considerably, even while increasing production.

For BASF, the second-largest producer and marketer of chemicals and related products in North America, climate protection and reaching the Paris goal of limiting global warming to well below 2°C are core priorities. To reduce the greenhouse gas (GHG) emissions of our own energy-intensive production, we have bundled our activities in a "Carbon Management" approach. The underlying premise: Many crucial materials that we encounter every day consist of carbon. We can't do without carbon, but we can manage it. For us, managing carbon includes three elements:

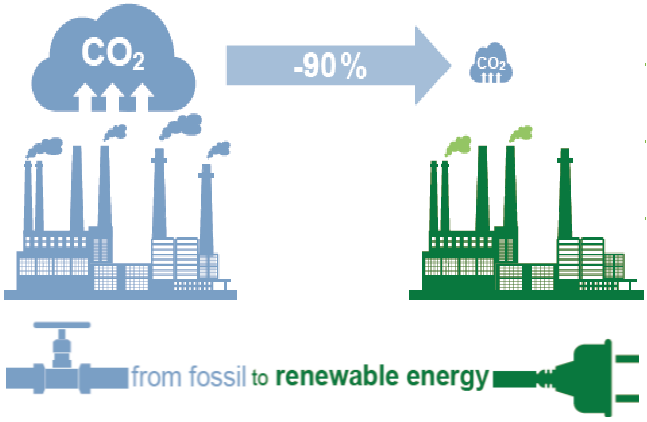
- The gradual transition from fossil to renewable energy purchases;
- The ongoing effort to use energy as efficiently as possible; and
- The fundamental transformation of production processes by innovative solutions.

The third element is the subject of this article.

Within the Carbon Management Research and Development (R&D) Program, we decided to focus our research activities on base chemicals because of their immense potential to substantially reduce CO_2 emissions: Just 10 basic chemicals are responsible for about 70 percent of the chemical industry's GHG emissions. As an indispensable starting point for the value chain and all our innovations, these

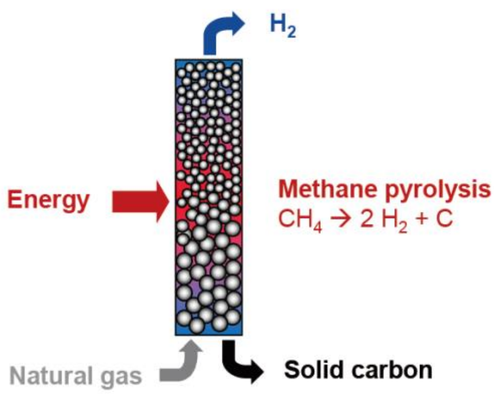
chemicals are critical when it comes to transforming the chemical industry. Fortunately, through electrification and new processes, base chemicals could be produced almost free of GHG emissions.

E-Furnace: Electrification of BASF's steam cracker



Because energy is needed to perform chemical reactions, fossil fuels are the chemical industry's largest source of CO_2. BASF's steam crackers, for example, must reach 850°C to break down naphtha into olefins and aromatics for further processing. Sourcing this energy from renewable electricity instead of the natural gas typically used now, could reduce CO_2 emissions as much as 90 percent. BASF therefore aims to develop the world's first electrical heating concept for steam crackers within the next five years. At the same time, material testing will be necessary to determine which metallic materials can withstand high electrical currents and are therefore suitable for use in this type of high-temperature reaction.

CO_2 free hydrogen: Methane pyrolysis



The chemical industry uses large quantities of hydrogen as a reactant, for instance in ammonia synthesis. The production of hydrogen, however, releases significant volumes of CO_2. Together with partners, BASF is developing a new process technology to produce hydrogen from natural gas with fewer emissions. This technology splits the gas directly into its components, hydrogen and carbon (Dagle et al. 2017). The resulting solid carbon could potentially be used in steel or aluminum production, but also could be stored. The methane pyrolysis process requires more electricity than existing processes do, but less electricity than water electrolysis, which is most important when renewable electricity is scarce. Thus, hydrogen can be produced continuously on an industrial scale with very low CO_2 emissions (Machamer et al. 2016). In the future, hydrogen will become even more important, as it will be an essential element for many sustainable energy carrier and energy storage applications. This may lead to a new type of hydrogen infrastructure, incorporating methane pyrolysis.

CO2-free methanol

Methanol is an important basic material for many products in chemicals value chains. Typically, methanol is made from syngas—a fuel gas mixture, which until now has been primarily obtained from natural gas via a combination of steam and autothermal reforming. Using special catalysts, this can then be turned into crude methanol, which can be further purified and used for downstream production in the value chain. In BASF's new process, syngas is generated by partial oxidation of natural gas, which does not cause any CO_2 emissions and has proven advantageous in a study jointly conducted with Linde Engineering. The subsequent process steps—methanol synthesis and distillation—can be carried out nearly unchanged. Ingenuity was required to address the merging and processing of the waste gas streams that arise during methanol synthesis and distillation and which

cannot be avoided even with optimal process management. These waste gas streams consisting of methane, carbon monoxide, CO_2, and hydrogen are incinerated in an Oxyfuel process with pure oxygen. This results in a small volume of flue gas with a maximum CO_2 content. The flue gas is then scrubbed using BASF's proven OASE® process for full recovery of the CO_2. To ensure that the carbon contained in the CO_2 is not lost and that it can be used again for methanol synthesis, the captured CO_2 is fed back into the beginning of the process. This does, however, require additional hydrogen, which BASF also aims to produce without any CO_2 emissions, for example via methane pyrolysis.

We expect it will take around 10 years before this new process could be carried out in an industrial-scale plant. If it can be successfully implemented at an industrial scale, the entire production process—from syngas production to pure methanol—will no longer emit CO_2 .

Development of new catalysts

As a central, high-volume intermediate, olefins represent an especially important area in which BASF is looking to develop new low-emission processes. The considerable CO_2 emissions resulting from current production steam cracker methods could also be significantly reduced through "dry reforming" of methane. This process creates a syngas, which is then transformed into olefins via an intermediate step of dimethyl ether. BASF researchers have found a way to do this for the first time, utilizing high-performance catalyst systems. These new-generation catalysts are being marketed in cooperation with Linde. Depending on the availability of raw materials and renewable electricity, this innovative process could be a complement or alternative to the e-furnace described above.

Technological transformation is possible—with enough cost-efficient green electricity

The development of new, low-emission production processes is moving forward. But research and technology represent only one necessary element. Availability of clean electricity from renewable sources at competitive prices is another. With the new processes envisaged in our R&D program we expect a significant increase in electrical demand, estimated to be at least three times as high as that required today.

New processes need huge investments with higher risks. How can additional costs associated with low-carbon technologies be accommodated in a competitive market? Answering this question is a prerequisite for making investments in low-emission production processes sustainable in the long term. One approach is a globally comparable price on carbon emissions. Climate protection must take place at a global level in order to be effective, cost-efficient, and economically compatible. With such approaches, innovations from chemistry can advance a climate-friendly economy and society.

Additional Resources

Carbon Management at BASF – R&D Strategies to reduce CO2. Press Conference. 2019.
https://www.basf.com/global/en/media/events/2019/basf-research-press-conference.html

BASF develops process for climate-friendly methanol. News Release. 2019.
https://www.basf.com/global/en/media/news-releases/2019/05/p-19-218.html

Dagle, R., V. Dagle, M. Bearden, J. Holladay,T. Krause, S. Ahmed, Argone National Laboratory/Pacific Northwest National Laboratory, November 2017, An Overview of Natural Gas Conversion Technologies for Co-Production of Hydrogen and Value-Added Solid Carbon Products (prepared in response to the U.S. Department of Energy Fuel Cell Technologies Office's fiscal year 2017 Congressional direction).

Machamer, O., A. Bode; W. Hormuth, 2016. Financial and Ecological Evaluation of Hydrogen Production Process on Large Scale, Chem. Eng. Technol. 39, No. 6, 1185–1193.