



Federal Ministry
of Education
and Research

From Waste to Raw Material

Can CO₂ replace crude oil in the future?



Sustainability and climate protection in the chemical industry? – CO₂ makes it possible

Carbon touches almost every aspect of our lives. The element, which is abbreviated with the symbol 'C' is not only an essential part of any living matter, it is also contained in almost all chemically produced everyday products – from plastics to pharmaceuticals or diesel. To date, we are only able to extract carbon from fossil resources such as crude oil. However, this dependency on crude oil is a threat to both our economy and the environment. For example, producing one single car tyre requires 28 litres of crude oil, which in turn releases enormous amounts of CO₂.

But what if we could turn this process around? Can we possibly extract carbon from carbon dioxide rather than crude oil? And can we thereby turn the climate-damaging gas CO₂ into a valuable raw material?



” Today, plastics and fuels are largely made from crude oil. However, the search for sustainable alternatives to fossil oil is making important progress. That is why the Federal Ministry of Education and Research supports research projects to make use of climate-damaging CO₂ as a raw material of the future. “

Johanna Wanka

Prof. Dr. Johanna Wanka
Federal Minister of Education and Research

The chemical industry has been utilising CO₂ as a raw material for a long time, e.g. as industrial gases, but also as shielding gas for packaged foodstuffs, as fertiliser or for producing pharmaceuticals. All in all, however, there are still too few processes that use CO₂ as a replacement for crude oil. Further research is required. If we can manage to make these methods more efficient and economically feasible, we can further reduce the use of fossil carbon.

How and where is CO₂ already being used?

- **Sparkling and refreshing** – The beverage industry uses CO₂ to make fizzy drinks.
- **Fighting fire** – In gas-based extinguishing systems, CO₂ serves both as propellant and extinguishing agent.
- **Fresh and clean** – In the textile industry, CO₂ is used as a detergent.
- **A clear head** – Climate change and CO₂ have been causing headaches for years. But CO₂ can alleviate head pains too – as an ingredient of aspirin.
- **Well packed** – CO₂ is a shielding agent in the foodstuff industry as it increases the durability of foodstuffs such as meat.

However, utilising CO₂ does not necessarily decrease its emission – its production usually requires a great deal of energy, which in turn releases CO₂ into the atmosphere.

To date, research has suggested promising approaches towards solving these problems. With the current activities of the Federal Ministry of Research and Education in CO₂-utilisation, Germany is currently on a good path. The goal of a sustainable and environmentally friendly industrial society is already within reach.

CO₂ – What dreams are made of

In 2013, almost 300 million tons of plastics were produced, an ever increasing figure. Plastics are present in many everyday products and are mainly made of crude oil. However, crude oil will not only become a scarce resource in the future; we also need to limit the utilisation of fossil raw materials to protect our climate. In order to keep our standard of living, we urgently need alternative raw materials for the production of plastics. Furthermore, these raw materials should result in lower greenhouse gas emissions.



Working with partners from industry and academia, researchers at Covestro (formerly Bayer MaterialScience) have developed a novel process in a unique project. In this process a large proportion of crude oil can be replaced by CO₂ in foam materials. In this product, the CO₂ is permanently bound and cannot leak from the material. A team at RWTH Aachen University calculated that approximately 20% fewer greenhouse gases are emitted, compared to the traditional process. But is this result commercially attractive for the companies? The answer clearly is yes. The foam material developed in the project 'Dream Production' will be sold on the market for the

very first time in 2016 – in the form of mattresses. Thus, one dream has come true; yet the researchers keep on dreaming. Following the successful development of the foam material they are now developing production processes for other plastics that will contain a large amount of CO₂.

For example, these innovative plastic materials can be used for ski boots or car interiors. Consequently, the German economy will become increasingly independent of fossil carbon as a raw material: more crude oil will remain underground and less CO₂ will be emitted into the atmosphere in the future.



CO₂ in numbers

- Average concentration in the atmosphere: 400 ppm (parts per million)
- Increase since pre-industrial times: 120 ppm (50% since 1980)
- Yearly worldwide anthropogenic CO₂-emissions: app. 30 Gt (30,000,000,000 t)
- 2.2% (912 Mt) originate from Germany.
- Current utilisation of CO₂: 110 Mt (110,000,000 t, approx. 0.4% of the global emission, mainly for fertilisers)
- Potential CO₂-utilisation in the future: 3 Gt (3,000,000,000 t, app. 10% of the global emission)
- Fossil raw material consumption of the German chemical industry: 19 Mt (only utilisation as raw material). This equals approx. 15% of the yearly German raw material consumption.

On the way to energy transformation and how chemical energy storage can help

In Germany, we aim to establish renewable energies whilst maintaining a high standard of living as well as the excellent position of German companies. Energy storage is essential to tackle this challenge, as a secure supply of energy is imperative, also at night and even if there is no wind. A potential basis could be the chemical energy storage technologies power-to-gas and power-to-liquids, which produce synthetic fuels i.e. diesel from CO₂.

Synthetic diesel from CO₂ – is this possible? Having built a plant that produces this environmentally friendly fuel, the cleantech company sunfire from Dresden has no doubt whatsoever. In 2015, the German Federal Minister of Research fuelled her car with precisely this diesel. Novel combinations of established processes enable the



Diesel: facts & figures

- 30 billion litres of diesel are consumed every year in Germany. This corresponds to a volume of 20,000,000 cubic meters – enough to fill 6,000 swimming pools.
- Every day, 170 million litres of petrol and diesel are consumed in Germany. With this amount, a single car could go 2.5 billion kilometers. When driving economically, this amount would enable a single car to cover 2.5 billion kilometres, the equivalent of 8 round trips from the Earth to the sun.
- Production of synthetic diesel from water and CO₂: The sunfire pilot plant produces up to 159 litres of diesel per day. At the moment, the scale is low – only a few of the start-up's employees could switch to the new fuel – but the plant is the proof of feasibility and an important step towards sustainability.

production of fuels for cars, ships, aeroplanes, as well as chemicals – simply from CO₂, water and renewable energy. However, the plant is capable of so much more: the reversible functionality guarantees that electricity is produced, even if the power supply is low. This is a huge leap towards safeguarding the supply without crude oil.



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