Electricity and carbon dioxide – raw materials for a sustainable chemistry?

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Ten Fraunhofer Institutes led by the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT have joined forces to work on the Fraunhofer lighthouse project ”Electricity as a Resource”. Their aim is to develop and optimize processes that enable low-carbon power to be used to synthesize important base chemicals. This lecture presents ideas and results whether electricity and carbon dioxide could become new resources for a sustainable chemistry.

In order to achieve the global two-degree target, the net emissions of CO_2 need to reach a value of nearly zero in the second half of the century. Thus the fossil based economy of today has to be transferred into a sustainable carbon economy, where energy and industrial production is solely based on renewables and sustainable carbon sources. A complete “decarbonisation”, e.g. a substitution of carbon components in industrial production, is not possible, as the reduction of iron ores in the steel industry, the production of limestone in the cement industry as well as plastics and other products in the chemical industry depends on carbon based compounds. Looking for sustainable carbon based materials; biomass and CO_2 are the only available carbon sources.

“Carbon Capture and Utilisation (CCU) technologies” – also called “Power-to-X or Power2Products-Technologies” – use CO_2 as a feedstock for the chemical synthesis of fuels and chemical products. The energy needed for the activation of CO_2 comes from renewable but fluctuating sources like wind and solar and with that, low carbon energy could be transferred from the energy sector to the industrial and transportation sector. As storing of CO_2 in products is only temporary, CCU can not solve the problem of CO_2 emissions by its own. But anyway, CCU is an important linking element in a sustainable carbon economy, because it allows a cascading utilisation of carbon compounds, so that biomass – a limited resource because of landuse – could be used more effective and efficient. This requires the cooperation and coupling of different industrial and energy sectors.

The changing in the German electrical power system from fossil and nuclear to a renewable based system with its specific characteristics creates interesting innovation conditions for CCU technologies.

Within this lecture important aspects of a power and CO_2 related refinery will be discussed as well as systemic conditions. Additionally, final results from the development of a electrochemical high pressure process for the production of organic components are presented. Most of the literature in this area is performed by purging gaseous CO_2 via aqueous solutions under ambient conditions. Because of the high stability of CO_2 high overpotentials are required. Thus, in aqueous solutions hydrogen evolution is predominant and competitive to CO_2 reduction, causing low faradaic efficiency of carbon based products. This problem can be tackled by the use of supercritical CO_2, which acts as a solvent itself and requires very little amounts of water. This approach can allow higher yields and efficiency of the process.