Press release

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CO_2 is ready to go as a fuel and chemical feedstock

Dynamic technological developments – Investors await market incentives

At the beginning of October 2013, 140 leading minds from the world of CCU (carbon capture & utilization) met for three days in Essen at Europe's largest conference on "CO_2 as chemical feedstock – a challenge for sustainable chemistry". By late November all 35 presentations will be available to download, giving a complete overview of these exciting new technologies.

While carbon dioxide is generally seen as a "climate killer", which should best be avoided or stored underground (carbon capture and sequestration), a growing number of scientists and engineers are considering how this virtually limitless source of carbon can be used or recycled as a fuel or chemical feedstock. CO_2 is an inert molecule that must first be broken down again using energy to make it usable, a process that chemists call "reduction". If renewable energy is used, this opens up a variety of interesting and environmentally friendly possibilities for storing energy, producing methane and liquid fuels, or making chemicals and plastics. What sounds like a fairytale is well on the way to becoming a reality. Many demonstration facilities and the first commercial plants are already up and running, most of them in Germany.

These feature various key technologies to utilise CO_2 as a source of materials and energy. Some of these are "artificial photosynthesis" technologies such as electrolysis and catalytic water splitting, imitating plants which produce biomass in the form of sugar, starch, oils and cellulose from carbon dioxide, water and sunlight. Scientists and engineers would like to develop artificial means of running this process more efficiently and independently of biomass. However, biotechnological techniques also exist to reduce CO_2 and make it available for use with the help of special bacteria, for instance. Lastly, CO_2 can be directly incorporated into polymers and chemicals without any need for splitting.

Electrolysis

Electrolysis uses electricity to break water up into hydrogen and oxygen, and the energy-rich hydrogen then reacts with CO_2 to form methane, methanol or DME, along with other chemical building blocks. If solar or wind power is used for this process, then this kind of system can be described as "artificial photosynthesis". The advantage of this path is the possibility of rapid implementation. Modern PEM electrolysis processes (reverse fuel cells) already operate at 75% efficiency and can therefore convert surplus solar and wind power into methane, for example, with acceptable losses, and store it in the natural gas grid. Solar and wind power can be stored by this method. The overall efficiency of solar to methane can already attain 10% today, thereby exceeding the efficiency of plants (approximately 0.5% through to biogas or biofuel).

About 20 of these power-to-gas demonstration plants are already in service in Germany. The economic problem is that clean water and most importantly pure CO_2 is required for the whole process; the latter is costly to purify and has a market price of €70-100 per tonne.
The company Carbon Recycling uses this method and geothermal energy in Iceland to produce methanol, which is then blended with fuel.
Dr Norbert Schmitz of Meo Carbon Solutions GmbH in Cologne presented the very first ISCC sustainability certification system for CO_2-based methanol, which sticks closely to the Renewable Energy Directive (RED) guidelines and has only been applied to biofuels to date. If CO_2 is seen as waste without environmental burden then the CO_2-based methanol from this first plant represents a 90% worldwide reduction in CO_2 compared to fossil fuels. Not even second- and third-generation biofuels can achieve equivalent reductions. If Brussels would count CO_2-based methanol and other fuels such as CO_2-based DME as part of the RED quota for renewable fuels, perhaps even with quadruple counting, this could provide significant incentives for investors.

Artificial leaves – catalytic water splitting plus CO_2 reduction

Another technology that was discussed in detail at the conference - and which some purists consider to be the only true form of artificial photosynthesis – is catalytic water splitting followed by CO_2 reduction. Unlike electrolysis, this process does not use sunlight to produce electricity. Instead, individual photons can split the water directly via one catalyser and a second catalyser then reduces the resulting hydrogen using CO_2 into methane, methanol or formic acid. This technology could lead to artificial leaves that would produce chemical building blocks from sunlight, water and CO_2 in large-scale as well as small, decentralised plants. Panasonic presented a first system along these lines back in 2012.
Many new developments involving catalysers in particular were presented at the conference. This kind of system currently achieves an efficiency rate of less than 1%, yet they are considered to have the greatest efficiency potential in the long term. Professor Dr Ernst Sudhölter from Delft Institute of Technology (the Netherlands) showed a catalyser system for splitting hydrogen that has already demonstrated overall efficiency of almost 5% in the laboratory, which is about 10 times that of crops.
The problems with this technology are linked to choosing the most appropriate catalyser materials, which should, for instance, contain no rare metals, have a good lifespan and be recyclable. Much work is still required on these aspects.
One further problem is that as a rule only purified CO_2 can be used without damaging the catalyser.
Professor Michael North of the University of Newcastle (Great Britain) surprised the audience with a new aluminium-based catalyser design that can also work with impure CO_2 of the kind produced directly in a fossil power station.

Biotechnology

Lastly, there are also promising biotechnological procedures in which bacteria, archaea and algae in particular either produce hydrogen from water or else are able to reduce the CO_2 directly to obtain a wide variety of chemical building blocks for fuels and plastics. To do this, the bacteria require energy, which they either gain from sunlight, heat or directly from electrical power. Prof. Dr Ludo Diehls from the Flemish Institute for Technological Research (Belgium) presented bacteria that use individual electrons to reduce CO_2, split it and make it available for use.

The great advantage of biotechnological techniques is that they do not need purified CO_2 but can use CO_2 straight from power stations or from industry. This makes the whole process far more viable, even if its overall efficiency is likely to remain below that of electrolysis or catalysers.
One pioneer of direct CO_2 use is LanzaTech from New Zealand, a company that was represented at the conference by Grainne Smith. LanzaTech has developed fermentation systems to produce ethanol, butanol and other products from unpurified gas emissions from the Chinese and US steel industries. Dr Arne Seifert from Krajete GmbH (Austria) presented a fascinating method for methanising carbon dioxide at unusually low temperatures and pressures using archaea which results in extremely reactive systems to make the best use of CO_2 in biogas plants.
BASF is working on the biotechnological production of acrylates, which play an important role, especially as functional polymers and super-absorbers - in nappies, for example – as Dr Núria Huguet explained. Such applications lead us into the field of chemistry and polymers.

Chemicals and plastics

As with biomass use, energy in the form of liquid and gaseous fuels has been the main outlet for CO_2 use up till now, in part because such uses can lay claim to existing support mechanisms for renewable energy and fuels. The framework conditions for material use are far less advantageous, despite the fact that it offers special processes that render it particularly interesting to use CO_2. Carbon dioxide does not necessarily have to be reduced for use in chemical building blocks, but can instead be directly incorporated into chemical structures, partly even into exothermic processes. Prof. Matthias Beller of the Leibnitz Institute for Catalysis in Rostock presented to the conference various methods of direct CO_2 incorporation that have been developed in recent years. One of these processes is already operational. Dr Christoph Gürtler from Bayer MaterialScience (BMS) in Leverkusen (Germany) presented the current progress of his "dream production". From 2015, a commercial facility is to be built in North Rhine-Westphalia (Germany) that is scheduled to produce several thousand tonnes of foam material from CO_2-based polyol. For the very first time, there was a presentation of a life-cycle assessment of the "dream production", which had been jointly carried out by RWTH Aachen (Germany) and BMS. Nicklas von der Assen of RWTH Aachen was able to show at the conference that CO_2-based polyol production performs better in the life-cycle assessment than fossil-based production. The assessment included the CO_2-emitting power station as well as all its power production.
Dr Xiaoqing Zang and his CSIRO agency (Australia) are working with composites made from CO_2-based polypropylene carbonate (PPC), which is already produced in the USA, China and South Korea. Zang showed various composites containing wood and natural fibre with PPC compared with PLA and petrochemical polymers. PPC is well suited for wood-plastic composites. It binds well with cellulose and improves its impact resistance. Mixtures of biodegradable PPCs (30-40%) and biopolymers are also of interest for grocery bags, for example. Zang expects mass production to bring the price down to $1 per kg.
Prof. Dr Klaas Hellingwerf from the University of Amsterdam presented genetically tailormade bacteria, algae and enzymes that can produce lactic acid directly from CO_2 for PLA production.

Where should the CO_2 be taken from?

CO_2 is available in sufficient quantities worldwide, but which is the most attractive current source? At present this would appear mainly to be carbon dioxide emissions from fossil-burning power station and industries such as the steel industry, as well as bioethanol plants. These produce large volumes of CO_2 that would have to be cleaned so as not to destroy the catalyser or the electrolysis unit. Direct air capture would be the ideal way, as one would not have to resort to large-scale fossil-powered plants but could obtain CO_2 as a raw material anywhere on the globe, including places where inexpensive renewable energy is available. This is however still a long way off, although Christoph Gebald from the Swiss company Climeworks AG did tell the conference about a new method of separating CO_2 directly from air with the help of cellulose fibres; this method can also be applied on both small and large scales. The first demonstration plant is due to come into service next year with a production of 1,000 t/yr and aims to sell purified CO_2 at €800 per tonne. In 2016 a first commercial plant is to produce liquid CO_2 at €200-300 per tonne, and commercial production of fuels and chemicals is scheduled to begin in 2018.
To increase competition for the best use of atmospheric CO_2, Virgin Airlines (Great Britain) has launched the "Virgin Earth Challenge" with a $25 million prize. David Addison explained this subject's critical importance to Virgin and presented the competition in detail. Climeworks AG is one of the finalists.

The solution to all our climate and raw material needs, or just a small contribution?

How significant could CO_2-based technologies be for protecting the climate and securing raw material supplies? This was one of the most keenly debated questions of the entire conference, which included substantial time for such discussions.
Simon Bennett of the International Energy Agency (IEA) underlined very clearly that even if renewable energy was to develop very fast, carbon capture and sequestration (CCS) would remain central to achieving our climate protection goals. On the other hand, he estimated that the potential of carbon capture and utilization (CCU) would be fairly marginal at first, mainly because the sources of CO_2 flows from power stations and industry were very limited. This is, however, true for CCS as well as CCU. The observation that non-purified CO_2 can be increasingly used (see above) was new to many people, and this immediately adds to its potential.
Over the course of the day, people began to realise that CCS and CCU had fundamentally the same potential and that their potential largely depended on whether the CO_2 could be tapped directly from the atmosphere. This would generate almost limitless potential, the only constraint being the quantity of available renewable energy.
Michael Carus, managing director of nova-Institute GmbH, gave a vivid illustration of the possibilities of CCU. If the European chemical industry were to meet its entire carbon needs from CO_2 rather than fossil sources such as oil, gas and coal, it would use or recycle 5.5% of Europe's total CO_2 emissions, despite being responsible for just under 2% of Europe's CO_2 emissions. Professor Gabriele Centi from the University of Messina and Professor Sang-Eon Park from Singha University in Seoul made a strong case for the great volume potential of CO_2 as feedstock for the chemical industry by giving examples of a broad spectrum of very different products.

Political framework conditions: an incentive to use CO_2?

The rate at which CO_2 will establish itself as a feedstock depends largely on the political framework conditions, the support measures available to develop it further and the incentives for commercial implementation.
Dr Lothar Mennicken presented the German Federal Ministry of Education and Research's comprehensive research programme, which funds 33 projects with 166 partners from a total budget of €150 million. €100 million of this came from the Ministry and the remaining €50 million from industrial partners. The project's results must first be assessed and evaluated early in 2014 before further research programmes are established.
European support has been directed almost exclusively at CCS, and there are a few projects that are part of the bio-based programmes. This is due to change in 2016 with SPIRE (Sustainable Process Industry through Resource and Energy Efficiency), which should explicitly include CCU.
Michael Carus, managing director of nova-Institute, highlighted the possibilities of accessing existing programmes for the bio-based economy and renewable energy until specific CCU support schemes have been published. This is, however, only possible if, firstly, "green CO_2" from biomass incineration is used and the CCU products therefore become virtually "bio-based", and secondly all the energy used is from renewable sources. This second point is also essential for achieving a decent life-cycle assessment.
Along with research programmes, the important factor is the political framework conditions that are created for CCU technologies. If DG Energy includes CCU fuels in the Renewable Energy Directive with multiple counting, this could send a powerful signal to investors and give significant impetus to the use of CO_2. Further options are being sought to supplement biofuels and electric vehicles. CCU fuels offer one such option that can draw on the endless reserves of CO_2.
As the conference clearly demonstrated, new technologies are raring to go, and there are many options that are being developed and are just waiting for implementation. This sleeping giant could come of age faster than politicians and the public imagine, as long as the right direction is set.

You can order all 35 presentations given at the three-day conference for €150 at the following address: http://www.nova-shop.info

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nova-Institute is a private and independent institute, founded in 1994; nova offers research and consultancy with a focus on bio-based and CO_2-based economy in the fields of feedstock, techno-economic evaluation, markets, LCA, dissemination, B2B communication and policy. Today, nova-Institute has more than 20 employees and an annual turnover of about 1.8 Mio. €.

Find attached photos from the conference on "CO_2 as chemical feedstock – a challenge for sustainable chemistry"(please include the photographer's name). Use of the material is free of charge for press purposes.

You can download photos of the conference at this link:
http://co2-chemistry.eu/media/2nd_Conference_on_CO2_nova-Institut.zip (2 MB)

The zip-file includes the following pictures:

- 13-10-07 Dr_Lothar_Mennicken.jpg, Dr Lothar Mennicken from Federal Ministry of Education and Research, Germany, during his presentation (source: nova-Institut/Winkler)
- 13-10-07 Michael_Carus.jpg, Michael Carus from the nova-Institute during his presentation (source: nova-Institut/Winkler)
- 13-10-08 audience.jpg, delegates at the conference during a presentation (source: nova-Institut/Winkler)
- 13-10-08 audience2.jpg, delegates at the conference during a presentation (source: nova-Institut/Winkler)
- 13-10-09 panel_discussion.jpg, speakers engaged in discussion with the audience (source: nova-Institut)