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energy innovation austria

Current Developments and Examples of Sustainable Energy Technologies

Bridging technologies on the way to a climate neutral future

New strategies for capturing and utilizing carbon dioxide

Around the world climate policy strategies are aimed at bringing global warming to a standstill. Alongside measures to conserve energy, increase energy efficiency and switching to renewable sources of energy, technologies for capturing and utilizing carbon dioxide from power stations and industrial facilities can help to achieve the climate goals set in the next few decades.

Laboratory facility at TU Wien (Vienna University of Technology), fluidized-bed stage of adsorber
Photo: TU Wien/Egon Zehetner

To the right: laboratory facility at TU Wien (Vienna University of Technology), photo: TU Wien/Julius Pirklbauer
Below: TU Wien (Vienna University of Technology) TSA cold model, photo: TU Wien/Egon Zehetner

Subject of international research
Capturing and utilizing carbon dioxide efficiently

The bulk of global warming is attributable to the rising concentration of greenhouse gases in the atmosphere caused by mankind. Here the carbon dioxide formed when fossil sources of energy are burnt plays a decisive part in augmenting the natural greenhouse effect. Many countries are taking part in an intensive search for ways of permanently cutting back carbon dioxide emissions. The most serious challenge for climate policy is to achieve a major reduction in greenhouse-gas emissions while coping with the worldwide demand for energy, which is constantly increasing. According to the International Energy Agency (IEA) the only way to do this is to combine a variety of strategies, including technologies and measures to conserve energy and increase energy efficiency, along with adopting renewable sources of energy on a very large scale.

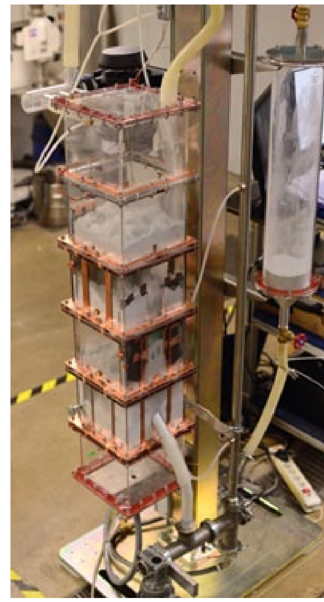
Carbon Capture and Storage (CCS) is a climate-policy option for large emitters such as power stations or industrial plants.[1] Research is also in progress on energy-efficient processes designed to utilize captured carbon dioxide as an industrial input so as to close the carbon dioxide cycle (Carbon Capture and Utilisation/CCU). While utilizing carbon dioxide technically/chemically cannot be an overall global solution to the problem of cutting back carbon dioxide emissions, it can become an important component in an overall climate-policy strategy.

The scenario "Less than 2 °C"

IPCC's calculations say that negative emissions – removing carbon dioxide from the atmosphere – are necessary to limit mean global warming to at most 1.5 °C, as intended by the 2015 Paris Agreement. Also the majority of the scenarios aimed at limiting global warming to 2 °C are based on the assumption that there will be processes capable of achieving negative emissions. In particular, BECCS (bio-energy with CCS) could well play an important part here. In 2017 the IEA calculated (alongside the 2 °C scenario) a scenario "Less than 2 °C" for the first time, spotlighting cutting-edge routes to decarbonization. Here the most energy-intensive industries (steel, paper, aluminium and cement) are regarded as key players. Efficient, low-cost methods of capturing and utilizing carbon dioxide could be put to work as bridging technologies to help achieve these ambitious climate-policy goals in the next few decades.

R&D activities in Austria

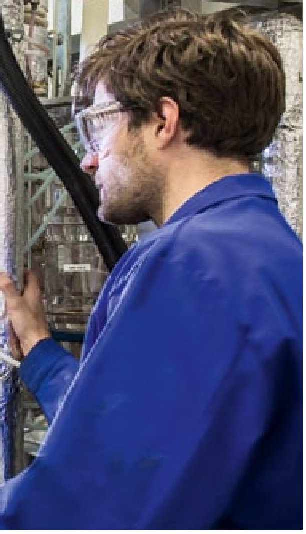
To capture and utilize carbon dioxide efficiently and at low cost, pioneering technologies and strategies will be needed. Austrian experts are involved in various international R&D initiatives, such as the IEA Greenhouse Gas R&D Programme (GHG). National R&D projects concerned with CCU are being carried out by Austrian research institutes and firms with support from the Federal Ministry for Transport, Innovation and Technology (bmvit) and the Climate and Energy Fund. The new solutions are being tested and developed further in demonstration facilities. In this issue we present some cutting-edge projects in this field. ◘

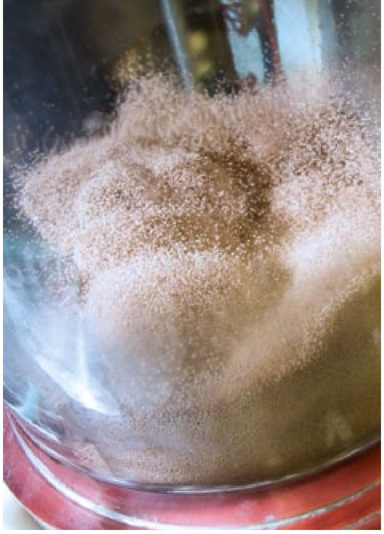


CCS and CCU technologies in the SET Plan

The European "Integrated Strategic Energy Technology Plan" (SET Plan) provides a framework for developing and implementing low-cost low-emission energy technologies. The target is to cut the EU's greenhouse-gas emissions by 80 to 95 % by 2050 with the aid of these energy technologies, which will help to limit global warming to 2 °C. The SET Plan emphasizes the importance of CCS and CCU technologies for global decarbonization: *"Carbon capture and storage (CCS) together with carbon capture and utilization (CCU) are important technologies for the global decarbonization of the power generation and energy intensive industries in a cost-effective manner."*
https://setis.ec.europa.eu/low-carbon-technologies/ccus

[1] In Austria, the geological storage of CO_2 is permitted only for research purposes and only with a planned total storage volume of less than 100,000 tonnes. (CCS Gesetz, BGBl. Nr. 144/2011, www.ris.bka.gv.at/Dokumente/BgblAuth/BGBLA_2011_I_144/BGBLA_2011_I_144.pdf)





Close-up of fluidized-bed stage in adsorber, Photo: TU Wien/Julius Pirklbauer

Photo: Shell

„We need to offer practical solutions that will help shape the energy transition. Carbon capture and storage is one of these solutions. CCS can capture CO_2 from power plants and industrial sites and store it safely underground. In the ViennaGreenCO_2 project we aspire to develop and demonstrate, in collaboration with our partners, innovative approaches for capturing CO_2 that can improve the effectiveness of this technology"

Rob Littel
Technology Opportunity Manager CO_2 abatement, Shell

ViennaGreenCO2

New separation process to capture carbon dioxide from exhaust gases

Carbon dioxide is not only a greenhouse gas, but also an input employed in various industrial sectors, such as the food industry or agribusiness. To be able to filter carbon dioxide out of exhaust gases from power stations or industrial processes, to concentrate it and to make use of it, we need efficient technologies. Currently aqueous amine solvents (e.g. based on monoethanolamine – MEA) are considered for the separation of carbon dioxide from exhaust gases. The drawback of this method is the associated large energy demand that is required for regeneration of these type of solvents. For a CO_2 separation efficiency of 90 %, the regeneration energy demand can be up to around 4.0 GJ per tonne of CO_2, which typically leads to seperation costs of around 100 Euros per tonne of CO_2.

In the energy research flagship project "ViennaGreenCO_2" researchers at TU Wien (Vienna University of Technology) and the University of Natural Resources and Life Sciences (BOKU) are collaborating with Shell and other partners on developing a new low-cost, energy-efficient CO_2 separation/capture technology for separating carbon dioxide. The advantages of this capture technology will be demonstrated in a pilot plant that is expected to be operational in the first half of 2018. The pilot plant will be connected to the biomass power plant that is located at the power plant site of Wien Energie in Simmering. Here the new technology will be tried out under practical operating conditions.

Carbon-neutral technology

The new process also uses amines, but not in liquid form; instead, solid particles are brought together with exhaust gas in a fluidized-bed process. The amines are applied to the surface of these porous particles. The key feature here is that the exhaust gas and the stream of amine-enriched particles move in opposite directions; the gas flows upward from below, losing carbon dioxide on the way, while the particles flow downward from above, adsorbing more and more carbon dioxide as they travel through the multi-stage fluidized-bed column. The particles are then diverted to a second fluidized-bed column, where they are heated up, release carbon dioxide, and can then be reused for more separation cycles.

Successful laboratory tests

The tests at TU Wien were most successful, establishing that the basic principle works; more than 90 % of the carbon dioxide was separarted in the test facility. The researchers anticipate that with the new technology energy consumption can be lowered by up to 40 %. Fluidized-bed systems can be built more compactly and thus potentially at lower costs than conventional separation facilities. So it is expected that seperation costs per tonne of carbon dioxide can be cut by up to 25 %.

Pilot plant in Simmering (Vienna)

The test facility in TU Wien can separate roughly 50 kg of carbon dioxide per day; the pilot plant in Simmering is planned to capture about 1 tonne per day. Long-term trials are intended to establish how cost-effective the approach is. Combining the new carbon dioxide separation reactors with biomass combustion facilties (BECCS) would be a a promising future application of this technology. The project is also intended to demonstrate how a sustainable carbon dioxide cycle might look: part of the carbon dioxide captured is to be used as fertilizer in a test greenhouse operated by LGV-Frischgemüse Wien. ◻

LGV greenhouse, Photo: LGV-Frischgemüse Wien reg. Gen.m.b.H.

Bioreactor at EVN site in Dürnrohr/Lower Austria, Photo: EVN AG

CO_2USE
Plastic from bioreactors

A new way of utilizing carbon dioxide is to recycle it by way of biotechnological processes, in which carbon dioxide from off-gas is introduced into a plant production cycle and converted to biomass by photosynthesis. Fixing carbon dioxide in biotechnological processes was investigated in the "CO_2USE" project, with the aim of developing a novel, sustainable, environmentally friendly process for producing bioplastics. The project was carried out by EVN AG in collaboration with ANDRITZ AG and a number of research partners (University of Natural Resources and Life Sciences, Vienna, Graz University of Technology, JOANNEUM RESEARCH Forschungsgesellschaft, Czech Academy of Science).

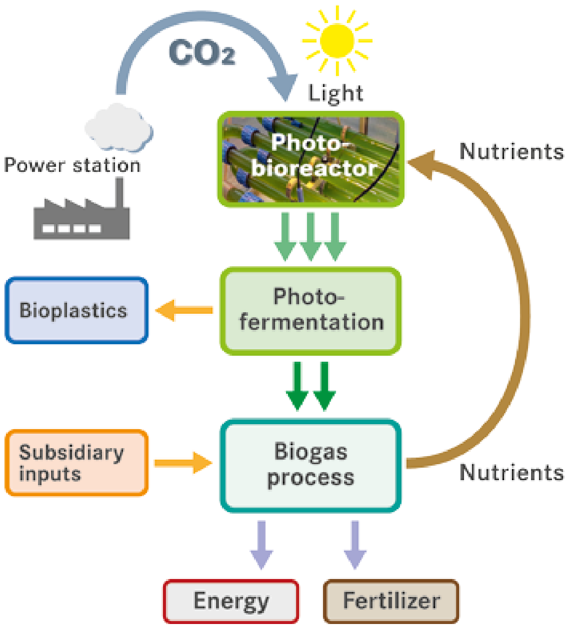
Pioneering approach

First of all, the use of treated carbon dioxide obtained from off-gas to grow photoautotrophs (cyanobacteria, purple bacteria and microalgae) was investigated. Cyanobacteria are micro-organisms that occur everywhere in natural bodies of water and are particularly good at fixing carbon dioxide. The carbon dioxide captured is introduced into a special bioreactor with micro-organisms. With the aid of sunlight and water they convert the carbon dioxide, i.e. they store energy in the form of polyhydroxybutyric acid (PHB), provided that enough nutrients are on hand. This property is comparable to the way in which human beings produce fat. PHB is a bioplastic very similar to the widespread fossil plastic polypropylene (PP). PHB can thus be used as a raw material (usually mixed in so-called blends with other bioplastics) for many different applications (i.e. as a housing or packaging material or as a plastic in automobile construction).

Since 2011 the EVN AG has operated a research facility to capture carbon dioxide at the Dürnrohr power station in Lower Austria, in collaboration with ANDRITZ AG. The photobioreactor at this location was planned and constructed in collaboration with the University of Natural Resources and Life Sciences.

Sustainable cycle of materials

Apart from establishing a reliable, stable method of producing PHB from micro-organisms, a second important goal was achieving a closed cycle of materials. After the target substance has been obtained, the residue of cyanobacteria is converted in an anaerobic process to biogas, which can then be used in the overall process and for other requirements. The nutrients released are recycled in the cultivation process of the photoautotrophic micro-organisms. The effluent is treated. The complex interaction between these processes was a central concern of the project team.



Concept CO_2USE
Illustration: Projektfabrik Waldhör KG, Basis: EVN AG

Bioreactor at EVN site in Dürnrohr, Photo: EVN AG

Photo: ANDRITZ AG

„The CO_2USE research project confirms that bioplastics can be produced from off-gas carbon dioxide in an environmentally friendly way by means of biotechnological processes.“

Guenter Gronald
KAP Air Pollution Control
Director Engineering, ANDRITZ AG

Ecological balance sheet for entire process

An ecological assessment of various approaches to producing PHB showed that in favourable circumstances, e.g. if energy consumption for cultivation and harvesting is minimized, cell concentration is high and subsidiary energy requirements are covered by renewable sources of energy and waste heat, greenhouse-gas emissions can be up to 75 % lower than in conventional polypropylene production. Given such conditions, aggregated fossil primary energy consumption could be reduced by up to 85 %.

Follow-up project CO_2USE+EPP

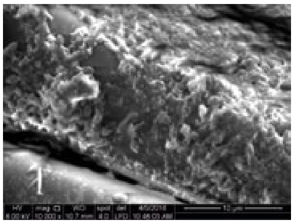
Producing bioplastic (PHB) from the carbon dioxide in off-gas by means of photoautotrophic cyanobacteria is a very promising strategy. PHB is non-toxic, decomposes biologically with no harmful residues, and is capable of replacing high-grade fossil plastics. The novel production process in question involves neither valuable farmland nor drinking water nor fertilizers. To make the process economically interesting, though, the amount of PCB produced must be increased from 5 to 10 % currently to 30 to 40 % of the cell mass.

In the follow-up project CO_2USE+EPP (Enhanced Plastics Production) the project team is investigating various ways of improving the strains of bacteria employed and boosting productivity. Low-cost sources of carbon dioxide, such as flue gas from thermal power stations or biomass combustion plants and fermentation gas from bioethanol facilities, are analysed to cultivate cyanobacteria in a pilot plant. ◘

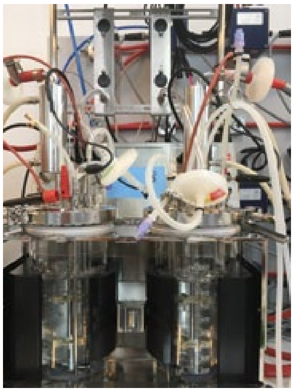
Hydrofinery

Obtaining liquid and gaseous sources of energy from hydrogen and carbon dioxide

“Hydrofinery” is a project in which researchers at the University of Natural Resources and Life Sciences’ Institute of Environmental Biotechnology in Vienna are investigating how to utilize hydrogen and carbon dioxide to obtain gaseous and liquid sources of energy. The pioneering approach in question may well offer an alternative form of storage for hydrogen or carbon dioxide via the intermediate product acetate. In the course of the project various microorganisms, such as clostridia, homoacetogens and methanogens, will undergo a screening procedure, and suitable metabolic paths will be explored.



SEM image of Acetobacterium woodii, Photo: IFA Tulln/BOKU, Steger



Reactor to produce acetate, Photo: IFA Tulln/BOKU, Windhagauer

A two-stage process is involved. First, homoacetogens convert hydrogen and carbon dioxide into storable acetate. Two types of fermentation can follow. On the one hand making biomethane, a gaseous source of energy, from acetate (converted by archaea) is being investigated. On the other hand it is intended to obtain liquid sources of energy, mainly biobutanol, bioethanol and bioacetone, from the ABE process (acetone–butanol–ethanol fermentation by means of clostridia). Alternatively, converting hydrogen and carbon dioxide into biomethane directly by means of hydrogenotrophs is being investigated in detail. ◘

Underground.SUN.Conversion
Producing natural gas renewably

RAG facility in Pilsbach/Upper Austria, Photo: RAG

A new research project by RAG (Rohöl-Aufsuchungs Aktiengesellschaft) builds on the successful energy research flagship project "Underground.SUN.Storage", which was concerned with storing wind and solar energy in natural-gas storage space (cf. energy innovation austria 2/2015). In the follow-up project "Underground.SUN.Conversion" an Austrian consortium headed by RAG is investigating the basis on which large quantities of natural gas can in future be produced renewably in a carbon dioxide neutral way, stored environmentally friendly in natural storage facilities and utilized flexibly at any time. The consortium includes Montanuniversität (University of Mining and Metallurgy) Leoben, the Interuniversity Department of Agrobiotechnology (IFA Tulln) within the University of Natural Resources and Life Sciences, Vienna (BOKU), the Energy Institute at the Johannes Kepler University (JKU) Linz, the electricity supplier Verbund and Axiom Angewandte Prozesstechnik GmbH.

Photo: RAG

Photo: RAG

„Our unique research project is in a sense geological history sped up, and has considerable potential. It is carbon dioxide neutral, solves our biggest problem of how to store renewable sources of energy and utilizes existing infrastructure. What's more, it is extremely good for the environment, since it copies natural microbiological processes in fast motion, and we can store the resulting renewable natural gas right where it is produced.

The results obtained in laboratory experiments as part of the previous project 'Underground.SUN.Storage' are most promising – so we now look forward eagerly to further insights from the research project 'Underground.SUN. Conversion'."

Markus Mitteregger
CEO RAG Rohöl-Aufsuchungs Aktiengesellschaft

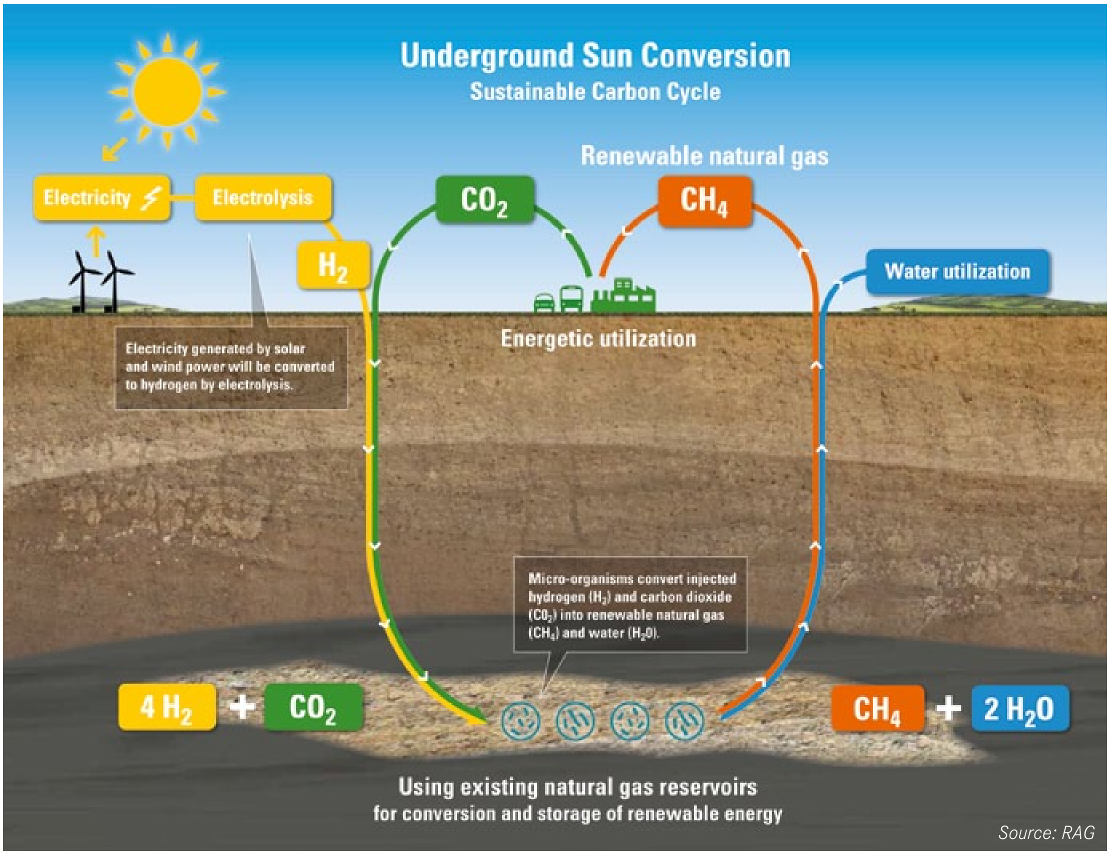
RAG facility in Pilsbach/Upper Austria, Photo: RAG/Steve Haider

Pioneering process

A new process should make it possible to produce natural gas in a gas storage facility directly, by means of a microbiological process induced systematically. Here the existing pore storage space is treated as a natural reactor. This process (an industry first worldwide) copies the way in which natural gas originates in nature.

First, hydrogen is produced from solar or wind energy above ground; together with carbon dioxide (e.g. from biomass combustion) it is then pumped down to an existing gas storage facility more than 1,000 metres below ground. In the preceding project laboratory tests showed that the hydrogen/carbon dioxide mixture supplied to the storage space is converted to methane by micro-organisms in a fairly short time. Methanization thus takes place naturally in underground rock formations, but accelerated by millions of years. At the same time a sustainable carbon cycle is established. The renewable natural gas produced in the depths can be stored right there, tapped into as the need arises and transported to consumers via the existing grids.

In the course of the project, which will run till 2020, laboratory experiments, simulations and a scientific field test in an existing RAG storage facility will be carried out. A further aim is to analyse how far the findings obtained are applicable to many other storage spaces around the world. ◘



Source: RAG

Univ.-Prof. Dr. Hermann Hofbauer
TU Wien (Vienna University of Technology), Institute of Chemical, Environmental and Biological Engineering

Photo: TU Wien

At TU Wien you are developing new, efficient processes to seperate carbon dioxide. Do these count as bridging technologies on the way to a future low in carbon dioxide?
The carbon seperation processes developed at TU Wien have three different aims:

- capturing carbon dioxide from off-gas (mainly from plants operated with fossil fuels) so as to minimize global warming,
- treating a product gas to improve its quality (e.g. treating biogas to achieve natural-gas quality) and
- obtaining carbon dioxide as an input to production processes (e.g. methanol synthesis).

In some cases two aims (or even all three) can be achieved. In the first point the label "bridging technology" certainly makes sense. Until we complete the transition to sustainable sources of energy, CCS can be used in conjunction with existing infrastructure (originally based on fossil sources of energy); this would reduce carbon dioxide emissions significantly, while avoiding more serious consequences of a continuing man-made climate change.

How can the carbon dioxide captured best be used?
The carbon dioxide captured should be used as productively as possible. It can serve as an input to several chemical processes, but also as a fertilizer for plants, as it will be tested in the ViennaGreenCO_2 project. Methanization in the course of power-to-gas projects is also an instance of carbon dioxide being put to work. In all honesty, though, we must admit that man-made carbon dioxide emissions are at least an order of magnitude greater than current industrial demand for carbon dioxide.

Is there a future for combining these technologies with bioenergy?
Combining these processes with biomass is full of potential if carbon dioxide can then be removed from the atmosphere in a short time. In the case of sustainable use the carbon dioxide emissions from biomass can be regarded as neutral. If carbon dioxide is captured in addition, this results in negative carbon dioxide emissions, i.e. the bottom line is that carbon dioxide is removed from the atmosphere.

Which issues will your team focus on in future?
The main emphasis in our future research will definitely be on developing new carbon dioxide seperation technologies and improving the existing ones, with the aim of boosting the quality of a product gas stream (e.g. treating biogas to achieve grid quality) and utilizing the carbon dioxide captured. Ideally we hope to make progress on all three fronts mentioned above.

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