Geological history in fast motion: renewable natural gas produced from solar power and water, 1,000 metres underground

Subhead: Underground Sun Conversion research project – the only one of its kind in the world – headed by RAG

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Unique worldwide: the Underground Sun Conversion project

The highly encouraging results of the Underground Sun Storage research project (2013-2017) are the basis for the unique Underground Sun Conversion project, which is now under way.

Geological history in fast motion: natural production of "renewable natural gas"

Over 1,000 metres below ground, where natural gas formed millions of years ago, "organic natural gas" can now be produced from hydrogen and carbon dioxide for the first time – using a microbiological, environmentally friendly process initiated specifically for this purpose by RAG and its project partners.

Storing renewables

Renewable energy can be stored in underground gas reservoirs – renewable natural gas is an energy source for industry, heat generation and transport that can enhance security of supply.

Outstanding potential

The aim of the research project is to carry out research into the principles for producing large quantities of renewable natural gas in the future, and storing it in environmentally friendly, naturally formed reservoirs. This will provide urgently needed flexibility for renewable energy sources.

The successful Underground Sun Storage project, which focused on the storage of wind and solar energy in naturally formed gas reservoirs, is to be taken to the next stage. Building on the research conducted so far, for the first time the Underground Sun Conversion project will enable production of natural gas directly within a gas reservoir using a microbiological process initiated specifically for this purpose by RAG, and to store it in the same reservoir. This innovative method is unique worldwide, and recreates the natural process by which gas originates, but shortens it by millions of years – geological history in fast motion.
First, hydrogen is produced from solar or wind energy and water in an above-ground facility, and then injected into an existing gas (pore) reservoir, together with carbon dioxide – creating a sustainable carbon cycle. At a depth of over 1,000 metres, in a relatively short time naturally occurring microorganisms convert these substances into renewable natural gas which can be stored in the same reservoir, withdrawn as needed at any time, and transported to consumers via the existing pipeline network.

This environmentally friendly process has three major advantages:

- Carbon neutral thanks to carbon cycle
  Renewable natural gas is carbon-neutral, if carbon dioxide that originates, for example, from burning biomass – is utilised for the production process. This creates a carbon cycle.
- Renewable energy becomes storable
  Solar and wind power output fluctuates due to changing weather conditions, meaning that production cannot be adjusted to demand. The problem of storing renewable energy is solved by converting it into renewable natural gas.
- Existing infrastructure is used
  Infrastructure already in place can be used for the natural production process, as well as for underground storage in natural gas reservoirs, and environmentally friendly transportation to consumers.

The aim of the RAG-initiated project, implemented in collaboration with partners, is to carry out research into the principles for producing large quantities of renewable natural gas using a carbon-neutral process, and storing it in environmentally friendly, naturally formed reservoirs, which will in turn provide urgently needed flexibility for renewable energy.

The project has been designated a flagship project by **the Austrian Climate and Energy Fund** and granted EUR 4.9 million as part of the fund's energy research programme. **The Austrian consortium is managed by RAG**. The total cost of the project amount to EUR 8 million.
The project partners are the **University of Leoben**; the BOKU - **University of Natural Resources and Life Sciences, Vienna** (Department of Agrobiotechnology, IFA-Tulln); acib - **Austrian Centre of Industrial Biotechnology**; the **Energy Institute at Johannes Kepler University Linz**; and **Axiom Angewandte Prozesstechnik**.
The project is scheduled to be completed by the end of 2020.

Detailed information

In-depth research on methods to sustainably reduce carbon dioxide emissions is being carried out worldwide. As the shift to erratic renewable generation gathers pace, the need for storable forms of energy is greater than ever. There is a particularly strong need for energy sources with high energy density, such as methane, for industrial processes, heat generation and transportation.

Research performed as part of the newly launched Underground Sun Conversion project is aimed at identifying a process that offers a way to produce high-density energy forms as well as finding a solution to the question of storage. Another objective is to make full use of the gas infrastructure already in place in many parts of the world. The starting point is power-to-gas technology, which converts excess power generated from renewable sources (wind or solar) into hydrogen and/or methane by means of electrolysis.

The aim of the research project is to use existing gas (pore) reservoirs as natural reactors. The methanisation process and storage take place in underground pore reservoirs, representing a huge source of potential, and providing the urgently needed flexibility that renewable energy currently lacks.

The process replicates and repeats the biogenic process by which gas originates. Methanisation takes place naturally in underground geological formations, but the process is shortened by millions of years.

Initial laboratory tests conducted as part of the forerunner project Underground Sun Storage – which is also supported by the Austrian Climate and Energy Fund – show that hydrogen injected into the reservoir with carbon dioxide is converted into methane by microbiological processes. This enables the creation of a sustainable carbon cycle. Laboratory tests, simulations and a scientific field test at an existing RAG reservoir will be carried out in collaboration with a group of project partners. A further objective is to test whether the outcomes can also be achieved at many other reservoirs all over the world. Consequently, the results that the project aims to achieve are highly significant to further enhancing Austria's leading position in seasonal storage of renewable energy in natural gas reservoirs, and for the widespread export of both the technology and know-how underlying the process.

"Austria is again breaking new ground for renewable energy. This research project is a world first: we are producing natural gas from solar and wind power for the first time – and within a few weeks instead of millions of years. We are doing the work of an entire geological period at rapid speed. And we are taking another step towards energy independence for Austria," said Jörg **Leichtfried**, Federal Minister of Transport, Innovation and Technology.

Theresia **Vogel**, Managing Director of the Austrian Climate and Energy Fund, said: "Our Energy Research Programme supports selected application-driven projects that go far beyond conventional research funding. This is the only way that we can realise positive effects for the climate and achieve the necessary technological breakthroughs and cost reductions. Underground Sun Conversion will deliver insights that point the way forward to the energy system of the future."

RAG CEO Markus **Mitteregger** explained:
“Our research project is unique worldwide. It is like geological history in fast motion – and has massive potential. It is carbon-neutral, solves the huge problem of storing renewable energy, and allows us to use infrastructure that is already in place. It is also extremely environmentally friendly, because it reproduces natural microbiological processes on a reduced scale, and we can store the renewable natural gas produced at the same site – in a natural gas reservoir over a thousand metres underground. The results from lab tests conducted so far in the Underground Sun Storage project are very promising. We are even more excited about the additional insights that the Underground Sun Conversion project will generate.”

Further information on the project can be found at
www.underground-sun-conversion.at

Background information

Solar and wind power output is erratic because of changing weather conditions, meaning that generation cannot be adjusted in response to demand as is the case with conventional power stations. In some parts of Europe, such as the north of Austria’s Burgenland province, on windy days the amount of power generated by wind farms is already well in excess of demand. With the growth in wind and solar generating capacity, and because of the intermittent nature of wind and sunshine, energy storage is becoming an increasingly pressing issue. Even Austria’s pumped storage plants in the Alps are no longer sufficient to meet this need.

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Background information on the project partners

RAG

RAG is Europe's fourth-largest gas storage operator. The company has developed and also operates its own storage facilities at Puchkirchen and Aigelsbrunn, as well as the Haidach gas storage facility in a joint venture between RAG, Gazprom and Wingas, and the 7Fields storage facility in partnership with Uniper. Both of the latter facilities straddle the border between the provinces of Salzburg and Upper Austria. With storage capacity now totalling around 6 billion cubic metres, RAG makes a major contribution to security of supply in Austria and Central Europe as a whole. The company sees itself as a partner for renewables and also develops geothermal energy projects.

RAG's role in the Underground Sun Conversion project

RAG is the lead company and biggest investor in the group that is undertaking this pioneering project. In addition to its long track record in developing, constructing and operating storage facilities, RAG will contribute the know-how and insights gained from the Underground Sun Storage project.

RAG's priority is to carry out research on the technology for methanisation in reservoirs as part of scientific field tests. The technical infrastructure required for this will be designed, installed and operated by RAG. Experts from RAG are also involved in all of the other work packages that make up the project. They are assisting with the provision of test materials, and verification of the relevance of the laboratory tests and simulations to real-life reservoir conditions.

MUL – Montanuniversitaet Leoben

The Montanuniversitaet Leoben (MU Leoben), established in 1840, is unique in its high degree of specialization: the major research areas and degree programs are embedded in in the value chain from raw materials to recycling: the portfolio ranges from extraction and mining to the processing of resources and basic materials, metallurgy, high-performance materials, process and product engineering, environmental technology and recycling, complemented by power engineering and production logistics. Most of the degree programs reflecting this value chain are only offered at MU Leoben in Austria. Close cooperation with industry, both at national and international level, is characteristic for MU Leoben. Creating "added value for the future" is the central theme at the university.

Montanuniversitaet Leoben contributes as scientific partner to this project with its expertise in material science, particularly corrosion, as well as with process technological aspects of the plant scale-up. Main goals of the material research are the identification of failure mechanisms for metals and cements in the reservoir, and consequently the determination of suitable materials of construction. Furthermore, a process concept is elaborated which considers the specific location framework conditions. The required surface infrastructure is defined, and the technical aspects for the up-scaling of the elaborated process concept are determined.

University of Natural Resources and Applied Life Sciences, Vienna
Department for Agrobiotechnology, IFA Tulln Institute of Environmental Biotechnology

The Institute of Environmental Biotechnology has many years' experience in applying and researching environmental microbial processes, with a particular focus on producing biogenic methane, and developing environmental biotechnology processes for treating waste streams and degrading organic pollutants in soil and groundwater. Alongside investigation of basic microbiological processes, potential industrial applications and their technical implementation are a research priority.

The institute's **Geobiotechnology and Chemodynamics** working group under Professor Andreas P. Loibner has a wealth of experience in researching, configuring and utilising geomicrobiological processes – these are central to the Underground Sun Conversion project. Activities comprise research into the transport and fate of hydrocarbons in a subsurface environment. This includes characterising sorption and decomposition processes, as well as identifying the microorganisms involved and in-situ application of innovative bioremediation processes.

A fundamental objective of the Underground Sun Conversion project is to control microbiological processes in the underground gas reservoir, in particular systematic conversion of hydrogen and carbon dioxide into methane (hydrogenotrophic methanogenesis), while avoiding adverse processes including homoacetogenesis and pore space clogging. Bioreactor experiments will be carried out using samples from the underground gas reservoir, under conditions simulating those found in the storage facility. An evaluation of the industrial applicability of in-situ methanogenesis in the underground reservoir will then be performed.

acib (Austrian Centre of Industrial Biotechnology)

The Austrian Centre of Industrial Biotechnology (acib) is an international non-profit competence and research centre with more than 140 partners around the world. acib's research focus is in the field of industrial biotechnology. acib adopts tools and methods of nature for new production processes and products with improved ecological efficiency and higher economic efficiency. acib's major fields of research are bioinformatics/modeling, biocatalysis, systems and synthetic biology, process engineering, and cell biology.

Within the current research project acib will focus on mathematical modeling of the growth behavior of microbial communities in underground gas storage reservoirs. The aim is to computationally model and understand the interactions of these communities with the gas flow. By doing so we will computationally analyze the impact of the global, macroscopic dynamics of the gas flow on the local, microscopic growth environments of the microorganisms.

The Energy Institute at the Johannes Kepler University Linz

The Energy Institute at the Johannes Kepler University circumvents single disciplinary research limits by the cooperative work of the three departments Energy Economy, Energy Technology and Energy Law. The combination of these three departments allows for an interdisciplinary approach and comprehensive analyses of energy-related research topics. Besides its multi- and transdisciplinary orientation, the Energy Institute primarily focusses on projects and topics, which center around the further development of the energy system in various dimensions. One of these research topics is Power-to-Gas, on which the Energy Institute has had a focus since 2007. The Institute has conducted a variety of techno-economic, macro-economic, ecological and legal analyses, as well as system and acceptancy analyses. Besides nationally funded project and commissioned work, the Energy Institute also participates in international research cooperations.

The Energy Institute's involvement in the Underground Sun.Conversion project

Within the framework of this project the Energy Institute is responsible for the techno-economic, ecological and legal analyses as well as identifying the technology's potential. The techno-economic assessment of the systems allows for analyzing and predicting process costs and comparing them to relevant benchmarks. Therefore, the analysis incorporates learning curves and the economies of scale. Further, national and international locations suitable for a potential implementation of the technology are identified. Ecological effects are determined by means of a Life Cycle Assessment (LCA) and the legal dimensions of the system are screened and analyzed.

Axiom

Axiom angewandte Prozesstechnik GmbH

Axiom Angewandte Prozesstechnik was founded in 1992 as a company specializing in industrial applications of membrane technology. Besides employing reverse osmosis technology in water purification projects, Axiom carries out intensive research into gas permeation technology, and has secured numerous patents.

In a joint research project with Vienna University of Technology's Institute of Chemical Engineering, Axiom developed new applications for membrane gas separation. These included the recovery of helium and hydrogen, the separation of carbon dioxide from natural gas, as well as biogas treatment. Axiom has steadily extended this area of its expertise, and has applied it with great commercial success, becoming a major supplier for the membrane gas separation process and a leading innovator in the field. Axiom sees membrane technology as one of tomorrow's key technologies.

Axiom angewandte Prozesstechnik GmbH in Underground Sun Conversion:

The Axiom's task in the research project is to develop a membrane separation process for the gas conditioning at the underground biomethanation site. The aim is to modify the product gas parameters after the conversion and especially to adjust the carbon dioxide and hydrogen content in order to make the produced gas compatible with the natural gas infrastructure. The main research focus lies in the process control to guarantee the constant gas quality under variable process conditions and in the development of new membranes with optimized separation performance for both hydrogen and carbon dioxide.

Background information on the funding body

Austrian Climate and Energy Fund

The Climate and Energy Fund was set up by the Austrian Ministry for Transport, Innovation and Technology. The fund's energy research programme promotes research and technology development initiatives that bring together science and business. The focus is primarily on energy efficiency and conservation, renewables, innovative mobility and transport technologies, smart grids and storage. Since 2007 the fund has invested a total of over EUR 370 million in more than 800 energy and mobility research projects via the energy research programme, facilitating internationally recognised research projects. An international jury safeguards standards of excellence in the selection of projects.
The Austrian Climate and Energy Fund has granted the Underground Sun Conversion EUR 4.9 million in funding as part of the energy research programme.