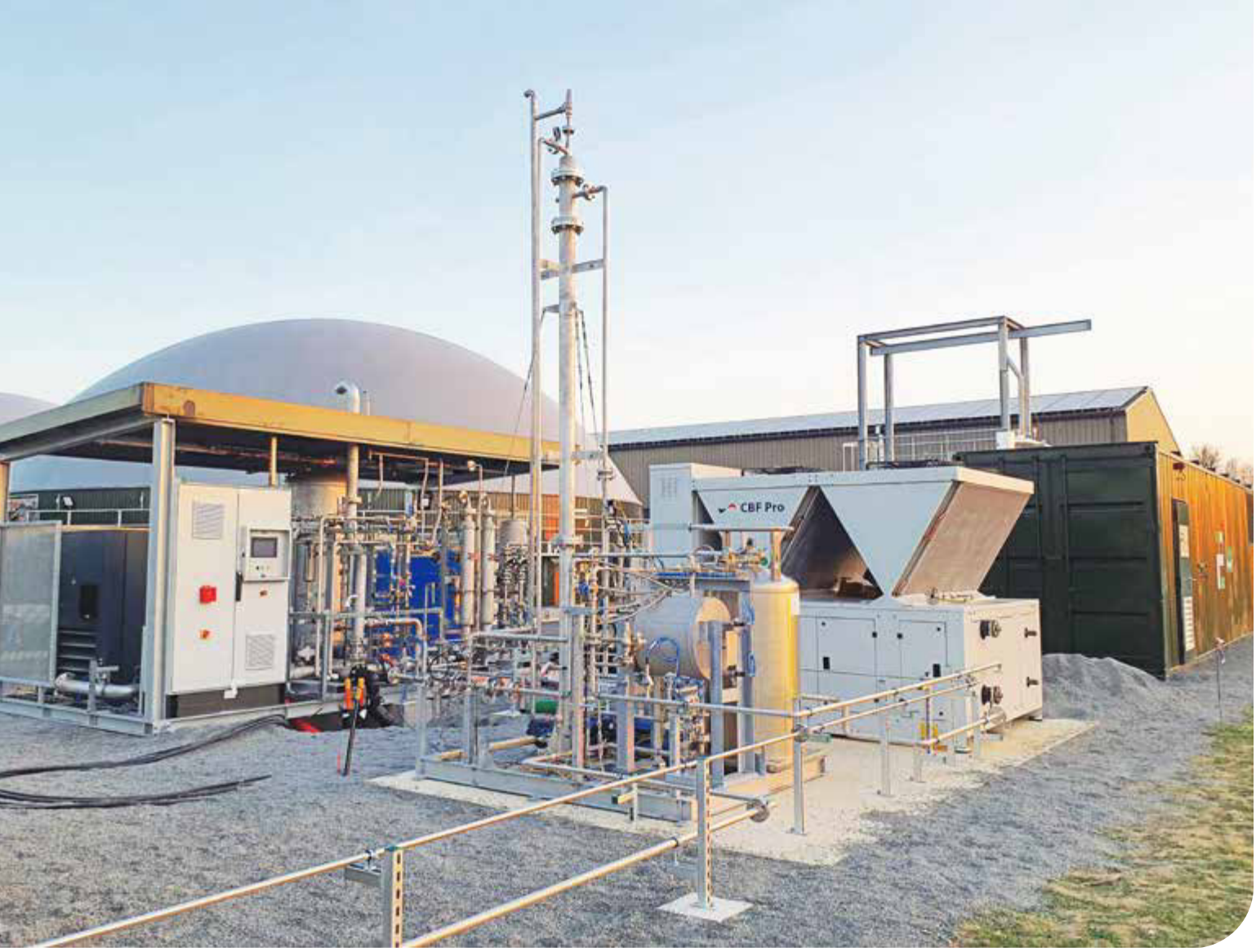

PROVEDAL CO_2 liquefaction system on a biogas plant.

Biogenic CO_2 from Biogas

The focus on carbon dioxide (CO_2) typically revolves around excessive emissions that contribute to climate change. However, last autumn, headlines were dominated by a shortage of CO_2, which particularly impacted the food industry. CO_2 is crucial in various processes such as food packaging and carbonation. This sector primarily relies on CO_2 generated as a byproduct in the energy-intensive production of fertilizers. German biomethane injection plants could potentially contribute significantly to alleviating this shortage

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In recent months, the nitrogen industry had partially shut down or scaled back production due to high gas prices. By the end of September 2022, representatives from the beverage industry reported a shortage and increased cost of carbon dioxide (CO_2). The Bavarian Minister of Economic Affairs, Hubert Aiwanger, convened various experts for a discussion on how to ensure the continuous supply of CO_2 to the food industry, which is estimated to require around 1 million tons annually in Germany.

In this context, the biogas sector can turn adversity into an opportunity. During the purification of raw biogas into biomethane, a significant amount of CO_2 is typically removed. Rather than emitting it into the atmosphere, it can be liquefied and utilized in various ways. Manuel Maciejczyk, Managing Director of the German Biogas Association (FvB), highlighted the potential: "With adequate logistics and the availability of appropriate liquefaction technology, we could theoretically install CO_2 liquefaction at every biomethane plant immediately."

An initial rough estimate shows that the amount of biogenic carbon dioxide generated from biomethane production is roughly equivalent to the demand in Germany. Maciejczyk states that they could immediately begin utilizing this resource, as he knows

PHOTO: PRODEVAL

from discussions with expert committees such as the DVGW (German Technical and Scientific Association for Gas and Water) that all the necessary regulations are in place.
What is interesting is how to optimally exploit this potential and what specific actions need to be taken to better utilize the biogenic source from biomethane production. Therefore, an assessment of current conditions and development prospects is being conducted. Key features along the value chain can be identified on the basis of some successful models and various interviews with experts.

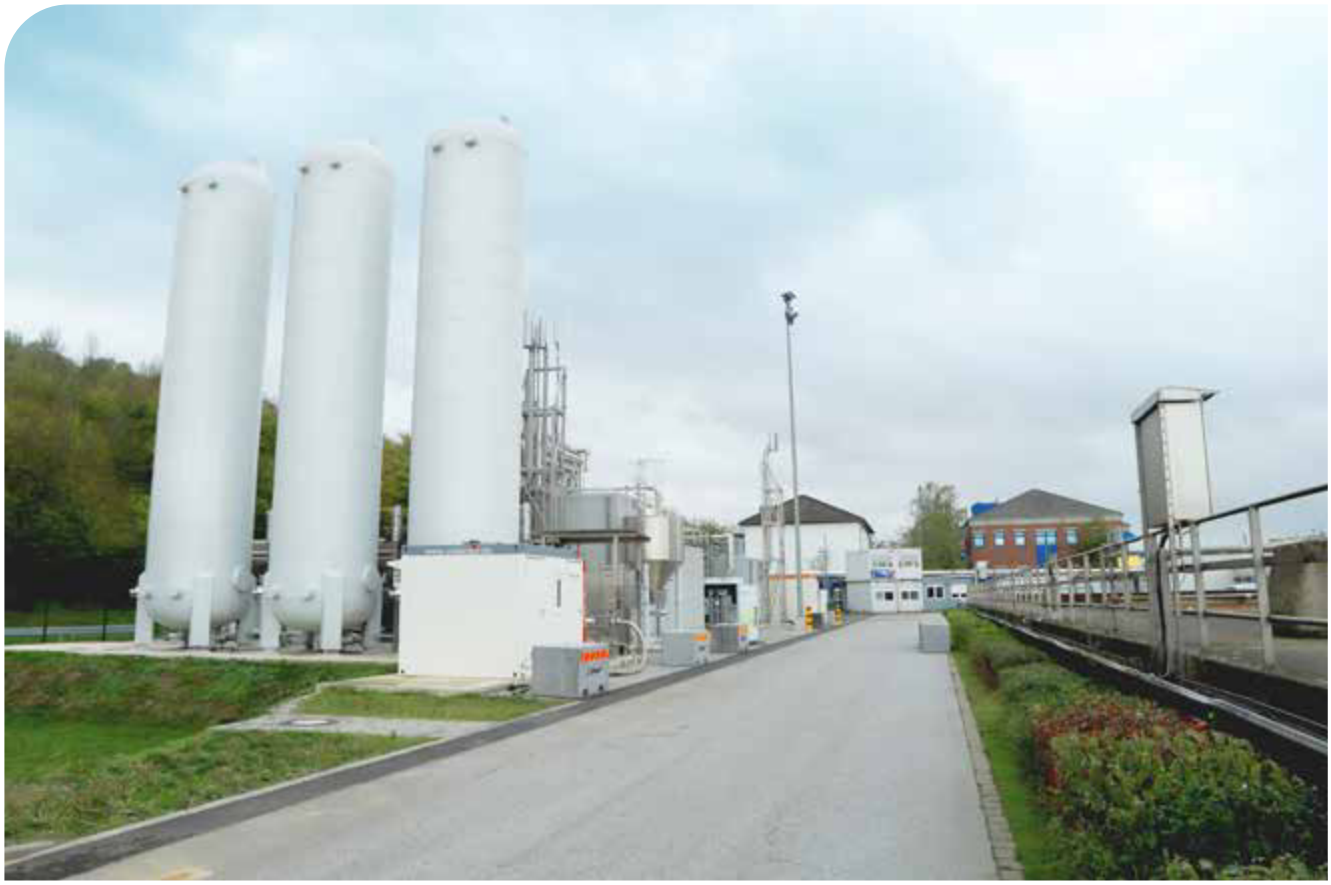
Successful Flagship Projects

On Parkstraße in Krefeld, EGK Entsorgungsgesellschaft Krefeld GmbH & Co. KG operates a waste incineration and sewage treatment plant in a unique plant association. Here, the operators not only ensure waste disposal for the city on the Lower Rhine, but also generate electricity, heat and, more recently, biomethane and...liquid carbon dioxide. The new plant was officially put into operation at the beginning of November 2022 during a visit by Mona Neubaur. The Minister for Economic Affairs, Industry, Climate Protection and Energy of the state of North Rhine-Westphalia praised the potential of biogas and the exemplary nature of the project.
For years, the biogas from the wastewater treatment plant was used in the waste incineration plant's flue gas scrubber. EGK has meanwhile switched to a different technology for flue gas cleaning, so the digester gas is now processed into biomethane. The raw gas, which contains 65 percent methane (CH_4) and 35 percent CO_2, is pre-cleaned and then processed in a membrane plant to produce biomethane, which is fed into the gas grid.

The carbon dioxide produced at the same time is liquefied in a further cryogenic process step at -25 degrees Celsius (°C) and stored in gas tanks. From an annual raw gas volume of 7.5 to 12 million cubic meters (m^3), 4.9 to 7.8 million m^3 of biomethane with over 96 percent CH4 content and 5,250 to 7,700 tons of carbon dioxide with 99.9 percent CO_2 content can be obtained in food quality. The investment for the processing amounts to around 7 million euros.
CO_2 liquefaction perfectly complements material cycles from disposal and supply and links various sectors. Biomethane is predominantly used in transportation, while the carbon dioxide is marketed through a gas dealer for technical purposes. Overall, 22 million tons of CO_2 can be saved per year. In addition, the cryogenic treatment also filters out the remaining methane from the lean gas flow of the membrane system and feeds it back again, so that methane emissions are close to zero. Another waste treatment facility in Augsburg also produces biomethane and liquid CO_2 (LCO_2). In the 3_2022 issue, the Biogas Journal reported on the local CO_2 marketing. Numerous other projects are under construction or in development. This is not only interesting because biogenic CO_2 is used as a raw material, thus avoiding CO_2 emissions. It is also worth noting in the context that medium to long-term negative emissions are required for climate protection in greenhouse gas accounting. This involves permanently removing and storing CO_2 from the atmosphere (Carbon Capture and Storage – CCS) or using it (Carbon Capture and Usage – CCU). Hence, there are opportunities for emerging new processes and business models.

Innovative Service Provider

Münchener Landwärme GmbH operates as a biomethane supplier, service provider and ▶



Pilot projects such as this new plant of EGK Krefeld ensure greater climate protection: Less CO_2 emissions with biomethane and, on top of that, less grey CO_2 with biogenic LCO_2.

consultant throughout Europe and is an independent trader of biomethane. The company is committed to forward-looking solutions to protect the climate and strengthen value creation in agriculture. Caroline Braun, the team leader at "Business Development & Carbon Removal" states: "The green source is becoming increasingly important, which is why we see great opportunities. By 2030, the biogas industry in the EU aims to provide 35 billion m³ of biomethane. We estimate that this could generate LCO_2 in the order of 100 million tons." In the meantime, Landwärme has developed suitable business models to drive the industry forward.

Landwärme launched a CCS project in cooperation with the start-up Reverion, for which it won the innovations prize in the "Sustainable Production" category awarded by the German gas industry. Starting next year, the biomethane plant in Reimlingen, Bavaria, will actively extract CO_2 from the atmosphere. Landwärme is gaining first-hand experience here to keep pace with future developments.

The partner Reverion is developing its new, patented and validated technology there on the basis of high temperature fuel cells. The product is the first comprehensive solution with a reversible system design, capable of electrochemically converting biogas or hydrogen into electricity with an efficiency of 80 percent. It can also switch to the electrolysis mode to produce green hydrogen or methane. The performance of existing biogas cogeneration units could be doubled, achieving an electrical efficiency of 80 percent, by replacing outdated combustion engines with highly efficient solid oxide fuel cells.

Competing with Grey Carbon Dioxide

The service provider agriportance primarily supports agricultural biogas plant operators in areas such as greenhouse gas (GHG) accounting and certification, as well as in marketing. The company currently works with more than 250 operators, with a focus on the shift towards mobility using biomethane. Founded two years ago in Münster, the company positions itself with its own digital platform as a link between producers and mineral oil companies. Notably, agriportance itself is not a gas dealer, so there is no corresponding margin.

According to Henning Dicks, the co-founder of agriportance, marketing the CO_2 was considered from the outset. However, it has only been about a year since there was a significant increase in demand for green CO_2 among CO_2 consumers. This demand arises both from the desire for a greener product and from the goal of becoming independent from grey CO_2 derived from the production with fossil natural gas. There is a strong focus on regional value chains, aiming to eliminate long transportation routes.

A biogas plant with a capacity of 350 standard cubic meters (Nm³) of biomethane per hour or 1.5 megawatts of installed electrical capacity can easily provide 5,000 tons of CO_2 per year. The order of magnitude of the customers is similar at 5,000 to 20,000 tons of CO_2 per year. He sees a particular opportunity here for plants whose EEG remuneration is expiring. ▶

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Trade fair activities, here the Landwärme stand at e-world, also reach stakeholders outside the biogas sector (Caroline Braun in conversation with John Cosmo Dwelle).

Regionally Differing Prices

CO_2 prices averaging €40 to €45 per ton (€/t) can be achieved with a long-term contract for over seven years. But higher prices are also possible regionally, for example around Hamburg or in the Rhine/Main region at over €50, or lower at €20 to €30 in the east. In the fuel sector, an additional bonus can be achieved with CO_2 marketing with the help of GHG quotas. This means that plant operators can improve their GHG balance by 30 to 40 grams, so that the producer also receives better biomethane prices. It is interesting to note that this makes it competitive with grey CO_2.

However, Henning Dicks also points out that the CO_2 bonus can only be applied in the fuel sector, and that it is not a long-term option due to sustainability criteria in the so-called RED II if mainly renewable materials are used. Instead, modern substrates like slurry and manure have to be used.

If the quantity falls below a certain minimum, which is 5,000 tons per year, profitability is also at risk. Furthermore, customers should not be more than 200 kilometers away and transport should not cost more than 100 euros per ton. Henning Dicks: "What is foreseeable, however, is that by 2030 a six-figure quantity in tons of LCO_2 will be able to be provided by biogas plants per year. Most of the sources will be in Lower Saxony, the eastern federal states and Münsterland."

Mature Technologies

PENTAIR, an American company based in Florida with its European headquarters in Venlo, offers biogas purification solutions in various sizes. According to the information on its website, PENTAIR boasts 75 years of experience in CO_2 equipment and comprehensive expertise in CO_2 recovery systems. The company also distributes additional systems for carbon dioxide liquefaction under the name of "Pentair CO_2Bolt-on" and complete systems for biomethane and carbon dioxide extraction under the name of "Pentair BioComplete".

In the biogas purification process using membrane technology, the separated CO_2 is compressed in two stages to 18 bar using CO_2 compressors in the cultivation unit, with any resulting condensate being drained. Traces of impurities and residual moisture are then removed. The purified CO_2 gas is then directed into the cooling system where it is liquefied. The exhaust formed during this process contains all non-condensable gases (CH_4, O_2, N_2), which are cleaned and returned to the inlet of the purification unit. The final purified liquid CO_2 product is then directed into an on-site storage tank at 17.5 bar.

Challenges on the Marketing Side

ETW Energietechnik from Moers, a German provider of CHP (Combined Heat and Power) and biogas purification systems, has also expanded its portfolio to include a carbon dioxide liquefaction module. Here, too, the combination of purification (PSA technology) with CO_2 liquefaction enables the production of high-quality biomethane as a direct substitute for fossil natural gas, as well as liquid food-grade bio-CO_2.

The systems can also be operated emission-free and without methane losses, making a significant contribution to reducing greenhouse gas emissions in the fuel and energy sectors. ETW is currently working on four biomethane projects involving carbon dioxide utilization, with additional projects already in the planning stage.

According to the Business Development Manager at ETW Dr. Oliver Jende, the existing technology is not the limiting factor for more efficient use of the potential of biogenic CO_2. "Our PSA technology has always been an extremely effective CO_2 separation system. The real challenge lies more on the marketing side. While biomethane can be practically supplied via the gas grid for any purpose and accordingly remunerated, LCO_2 (liquid CO_2) typically needs to be stored temporarily and physically transported to nearby consumers via tank trucks. This requires intensive CO_2 market

PHOTO: MARIE-LUISE SCHALLER

logistics and pricing is strongly determined by regional factors. The selection of optimal marketing concepts and contract modalities compatible with the dynamic biogas production on the feedstock side pose the real challenges for biogas entrepreneurs in this market. Therefore, we would always recommend collaborating with reputable consulting firms."

High Demand, Yet Complex Framework

PRODEVAL GmbH that was founded in 2022 is the fifth international subsidiary of PRODEVAL, which is the largest provider of products and services in the biogas treatment and utilization sector in France. PRODEVAL currently has more than 400 treatment facilities set up in 15 countries. They use membrane technology, which can be applied not only for very small facilities with 150 Nm³/h of raw biogas, but also for very large facilities of several thousand cubic meters.

The equipment module V'COOL® for the production of biogenic LCO_2 completes the range. Benoît Dhoosche, who has been developing biogas projects for PRODEVAL in the German market for a year, notes in the interview that the liquefaction of CO_2 is also almost systematically demanded for biomethane plants in Germany, and that the dynamics are much greater than expected.

He is working on more than ten projects scheduled for commissioning in 2023 and expects even more in the following year. "The particular challenge in Germany is the complex regulation, and this is not just a hurdle for me as a newcomer," says Dhoosche. He also feels that the biomethane lobby is poorly represented at important political events.

A Combination of Facilities from a Single Source Reduces the Need for Coordination

Krieg & Fischer Engineers, a planning office in the biogas sector in Göttingen, is increasingly incorporating CO_2 liquefaction in new constructions or expansions with purification plants. Currently, the planners are working on several projects at different stages of maturity, according to project engineer Tobias Eckhof. Retrofitting an existing biomethane plant with a carbon dioxide facility can often be facilitated legally by means of a notification.

He sees a particular challenge in the fact that the concentration of undesirable substances has to be taken into account, which increases with the number of cycles. For example, this is an issue for hydrogen in membrane systems. This problem does not arise in PSA systems. High VOC (volatile organic compound) levels in off-gas are often problematic for residue plants for use in the food sector.

Eckhof advises procuring the complex of biomethane and CO_2 generation facilities from a single source. Having different suppliers for purification and liquefaction increases the need for coordination and the likelihood of errors due to an increase in interfaces.

Biomethane and Biogenic LCO_2 – an Ideal Combination for Efficient Climate Protection

To limit global warming to 1.5°C, the CO_2 balance must be reduced to "net zero" requiring the removal from the atmosphere and permanent storage of CO_2. Processes that extract CO_2 from the air require high amounts of energy, whereas the CO_2 already captured during the production of biomethane is readily available. Operators of biogas upgrading plants can utilize this CO_2 with a high level of purity, thereby reducing the production of grey CO_2. Alongside the climate protection benefits, this also creates intriguing business models.

However, there is a corresponding demand, particularly in the food industry. Here, biogenic CO_2 from biomethane production can enhance the security of supply through short routes and minimize reliance on large, crisis-prone industries. Moreover, it fulfills the demand for increased application of the principles of circular economy.

The pilot projects that have already been implemented show that economically viable operation is possible under certain conditions. In view of these successful case studies, the mature technology and sufficient regulations as well as the good potential along the value chain, the industry is very interested in rapid expansion of capacities.

Ignored by Politics

Manuel Maciejczyk has noted that the potentials, however, are being overlooked by policymakers. In addition, there is less support for biomethane in the fuel sector in Germany, despite increasing demand from the transport industry. He advocates bringing the players together at a round table to work together for a better understanding on the part of politicians and to develop a comprehensive strategy for biogas and biomethane. Last but not least, this also complies with the principles for promotion under the EU Commission's "Net-Zero Industry Act". This Act aims to expand the production of clean technologies in the EU and ensure that the Union is well-equipped for the transition to clean energy. This initiative was announced by Commission President von der Leyen as part of the "Green Deal Industry Plan" explicitly mentioning biogas and biomethane. ◀

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