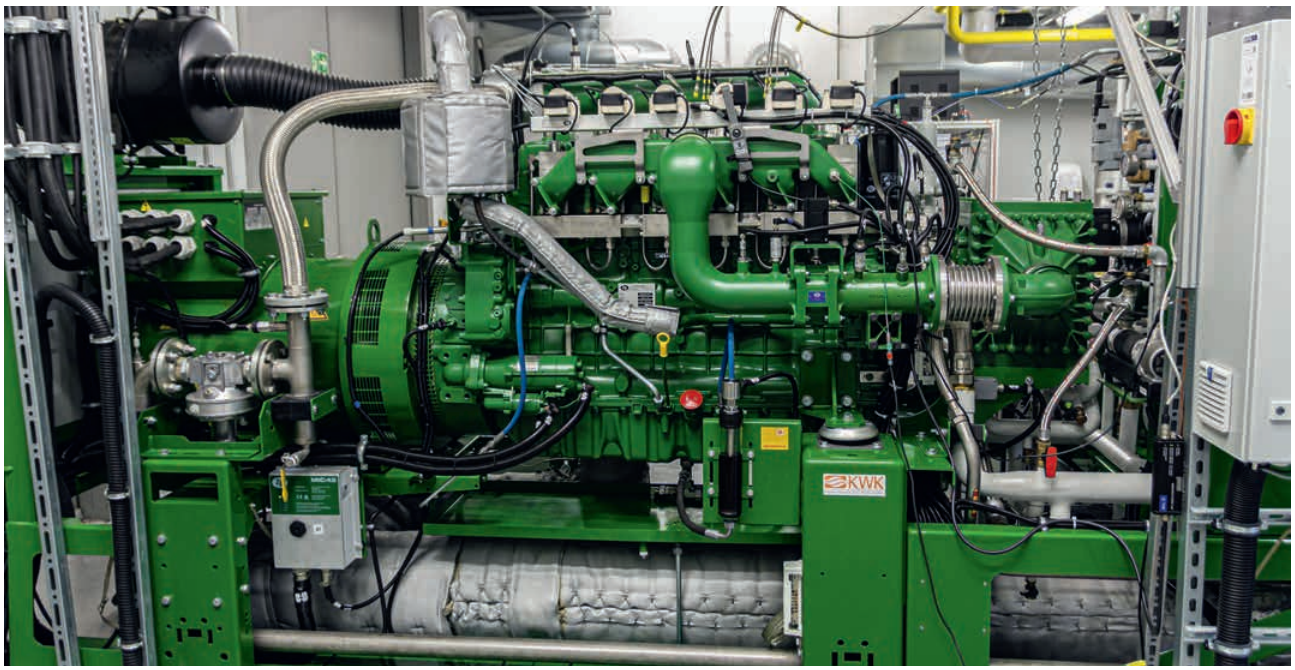

The converted decentral CHP with added hydrogen supply

Source: Andreas Keck, OTH Amberg-Weiden

Hydrogen Retrofit of Existing Natural Gas CHP Becomes Reality

In the recent years lots of decentral combined heat and power (CHP) applications around the globe were installed which are operated with 100% hydrogen. Besides the rising demand for new projects, there is also a massive potential for retrofitting existing natural gas CHP projects for hydrogen use. The university in Amberg-Weiden, Germany, and CHP manufacturer 2G have succesfully completed the first transformation.

For many years the role of hydrogen in the energy transition was more or less limited to heavy-duty transport or energy intensive industry. Nowadays, hydrogen is perceived as one of the core element with regards to the necessary backbone for the volatile energy supply of wind and sun.

At the moment, the question is primarily about how accurate the timeline will be for the urgently needed expansion of hydrogen-capable gas-fired power plants. Especially when it comes to creating these regenerative backup capacities, there are massive opportunities in decentralisation, as thousands of CHP plants at municipal utilities, in industry or in district supply already ensure security of supply locally. An important building block in the creation of hydrogen-capable power plant capacities is therefore the conversion of the existing system to operate with 100% hydrogen. Reason enough for 2G Energy AG, Heek/Germany, together with Ostbayerische Technische Hochschule Amberg-Weiden (OTH Amberg-Weiden), to turn this conversion into reality.

CH2P project as one of the cornerstones

However, the joint research and development work did not begin with the decision to convert existing natural gas plants for operation with hydrogen. Since 2019, these have been running on a 2G H_2-CHP installed in Haßfurt, Germany, as part of a joint project between Stadtwerk Haßfurt and the Institute of Energy Technology (IfE) at OTH Amberg-Weiden.

Building on the experience gained there, a consortium led by 2G Energy has been developing next-generation CHP plants in a new research project since 2022 in order to provide electricity and heat from hydrogen in a highly efficient and cost-effective manner. The project with the project name "CH2P" is funded by

the 7th Energy Research Programme of the Federal Ministry for Economic Affairs and Climate Action (BMWK) with around €2.36 million and, in addition to the CHP Competence Centre of OTH Amberg-Weiden and 2G Energy, is home to seven other partners from industry and science. The main aim of the project is to further increase the power density of the units, so that efficiency increases and the costs for decentralised CHP plants are reduced. The project also focuses on reducing emissions and using new materials.

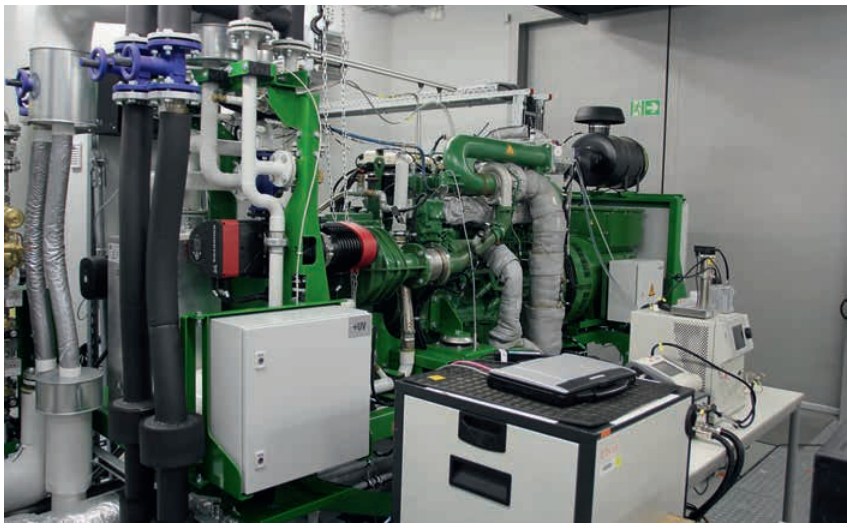

Figure 1. H_2 CHP plant equipped with measurement technology for combustion and emissions analysis
Source: Andreas Keck, OTH Amberg-Weiden

Experience from many new installations helps with the conversion

The basis for the conversion measure that has now been carried out was an existing natural gas CHP with an electrical output of 250 kW, which was installed at OTH in Amberg in March 2019 and has already been used for various measurements in the context of research and teaching since commissioning. For Frank Grewe, CTO at 2G Energy, the planning to convert natural gas to hydrogen was the logical consequence of the development work of recent decades: "The highly efficient use of green gases has always been the focus of our company philosophy and has made a significant contribution to the positive development of the company – think of the ramp-up of the biogas market in the early 2000s. It was only through the experience gained there that we were able to deal with other types of gases such as hydrogen at an early stage."

The conversion of existing natural gas-powered CHP plants is now the next step, Grewe continues: "The political direction is clear: away from natural gas – towards biogas and, above all, hydrogen. We see this direction first and foremost as a great opportunity to make an important contribution to the transformation of the energy system with the help of our thousands of installed systems."

Adaptation of combustion chamber geometry, pistons and mixture formation

Specifically, the conversion measure took place in December 2022 and was of rather little challenge from a technical point of view, Grewe explains: "We have been designing our plants in modular design for several years now, so that we can ensure immediate hydrogen operation by replacing individual components."

An essential component of this is the adaptation of the combustion chamber geometry. In addition to the change in the compression ratio due to the use of other pistons, the process of mixture formation must therefore be adapted during the conversion.

Whereas in regular natural gas or biogas operation, the external mixture formation takes place in the gas mixer and before compression in the turbocharger, in hydrogen operation this only takes place directly in front of the combustion chamber. For this purpose, the hydrogen is fed into the intake tract via a gas injector before the ready-to-ignite mixture is fed into the combustion chamber – the "intake manifold injection".

This change is primarily necessary due to the different physical properties of hydrogen and natural gas or biogas. In addition to increased ignition ability compared to conventional gases, hydrogen also has a faster laminar flame velocity, so that the compressed air is only mixed with the hydrogen shortly before combustion in order to avoid uncontrolled ignition.

Intelligent linking of maintenance and retrofit plans

Both the pistons and the gas injectors have now been standardised to such an extent that they can be replaced or retrofitted at a later date – as is now the case in Amberg. At the same time, the turbocharger was replaced and adapted to the increased requirements of operation with hydrogen. But it's not just the technology itself – 2G is also striving for standardisation at the time of the changeover, as Grewe clarifies: "If the maintenance plans are

intelligently linked to the conversion plans to hydrogen, pistons and turbochargers, which would have to be replaced anyway during the intermediate overhaul, can be installed directly as hydrogen variants. As a result, the cost of the conversion can be reduced to about 10-15% of the original investment."

In addition to the various mechanical adjustments, a control and software update was installed to adapt ignition timings, control strategy or ramps to the new fuel. In order to keep the leverage for the existing plants as large as possible, the hydrogen conversion is possible for all installed CHP units from 2011 onwards without any problems.

Extensive testing of the gas transformation path

For OTH Amberg-Weiden, however, the conversion was only the first step for further research work to scientifically accompany the ramp-up of the hydrogen economy, as Prof. Dr. Raphael Lechner, Professor of Digital Energy Systems and Sector Coupling at OTH Amberg-Weiden, explains: "We have been researching for many years in the field of decentralised combined heat and power generation as a key technology of the local energy transition. In the coming years, the gas industry will be characterised above all by the fact that it will have to create a gradual change towards 100% renewable energies. This change will take place in different places in different ways – depending on the proximity to the European H_2 backbone, local hydrogen production capacities or the availability of biogas in a municipality. With our research, we want to show in particular that decentralised combined heat and power generation plays a key role in these different pathways."

In addition to the new 4 bar H_2 supply with MPI gas injection technology, the plant can continue to be operated with natural gas. Lechner also emphasises the importance of building up own research capacities at his university: "Although we carried out the development in close cooperation with the manufacturer 2G, it is very important to us to further build up our own research team around the decentralised energy supply of the future. In contrast to a unit regularly sold by 2G, we therefore have indepth access to the plant control system and all parameters in our module in order to be able to ensure extensive research operations."

In addition, the unit was equipped with an optical combustion analysis system (Figure 1), which can be used to investigate in detail the topics of mixture formation and combustion anomalies in the context of CH2P.

Next steps in Amberg

The CHP, which generated 250 kW of electrical power in its original state, generates around 170 kW when operated with hydrogen, explains 2G chief developer Grewe: "We have currently released our hydrogen engines with up to 14 bar medium pressure compared to 18 bar medium pressure for the natural gas series, which reduces the output somewhat. At our development test bench in Heek, we also run hydrogen at 18 bar, so that the absolute performance is identical. The colleagues in Amberg also have exactly this clearance to research operations with higher outputs on the part of the scientific community."

Another milestone is to be reached in Amberg shortly: The hydrogen, which is currently still delivered in cylinder bundles (Figure 2), will be provided by a hydrogen storage facility. Lechner is pleased that construction work on the hydrogen supply station for the CHP pilot plant in Amberg will be completed in near future.

Figure 2. The hydrogen is currently still delivered in cylinder bundles

Source: Max Becker, OTH Amberg Weiden

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