Each natural-gas driven 2G CHP (l.) can be retrofitted for the use with hydrogen in the future (r.) Source: 2G Energy

Hydrogen CHP – The Enabler

The goal is clearly set: climate neutrality by 2050. In contrast to, for example, the transport sector, where the path via electromobility seems to be firmly defined, the energy sector is faced with the question: How can we become climate-neutral in a cost-efficient manner and ensure the electricity/heat supply at any point in time? Hydrogen-powered CHP can be the decisive backbone and is ready for widespread market launch.

With a view to the continually increasing share of wind and solar energy across Europe, it becomes clear: The major share of the energy mix will come from these two sources in the future and thus make the greatest contribution to achieving the climate targets. However, there is a snag: If wind or sun is available, electricity and heat are usually not needed to the exact extent required. Conversely, the sun does not always shine or the wind does not blow when the need is actually there. An energy storage system is therefore necessary to bridge the time lag between energy generation and energy use. Despite the great successes in the development of short-term storage systems, such as in electromobility, there has so far been no solution to the problem of the seasonal offset of energy generation and energy demand. In addition, the European power grid is already often reaching its limits – especially in densely populated areas. Due to the growing share of heat pumps, electromobility, and increasing computing power due to more digitisation, there is even a further load on the electrical grids. The risk of blackouts increases.

Hydrogen's great potential in the energy sector

In the course of the global climate debate, an old friend has moved more and more into the focus of discussion in recent years: hydrogen. The excess energy generated from wind and solar power can be converted into hydrogen by means of an electrolysis process and can be stored for later use in various applications. The use of this "green hydrogen" in heavy industry or the transport sector is currently being discussed – but there is also great potential in the energy sector.

Hydrogen is already being added to the natural gas grid at many locations in Europe and component manufacturers in all industries are taking an increasing mixing ratio into account when developing new products. Manufacturers of combined heat and power (CHP) plants for the highly efficient use of natural gas through cogeneration are also increasingly developing their products on the basis that a rising proportion of hydrogen in the grid can be expected in the future. The CHP manufacturer 2G Energy AG based in Heek/Germany has now succeeded not only in upgrading its products for operation with a proportion of hydrogen but in developing a range of products for operation with 100% hydrogen. As a result, CHP units become the missing piece of a jigsaw in the energy transition, which harmonises the requirements for climate neutrality on the one hand and security of supply on the other hand.

Early Development of hydrogen CHP

The development of CHP units that run entirely on hydrogen began at 2G more than ten years ago for a funding project in Berlin – a long time before Germany's nuclear and coal phase-out were legally decided. „The spirit of innovation that has always been strong at 2G, coupled with many years of experience in the field of gas engine development, was the ideal pioneer to enable the use of hydrogen in CHP units," explains CTO Frank Grewe (figure 1). „The fact that the time of technical market maturity goes hand in hand with the increasing identification of hydrogen as an important element of the future energy world is of course very positive", continues Grewe.

But what is the fundamental difference between a hydrogen-powered CHP and conventional natural gas or biogas-powered CHP? First of all, not much – all main components such as generator, heat exchanger, pumps, etc. are almost identical and even the engine itself is based on existing natural gas variants that have been installed thousands of times by 2G worldwide. This fact accompanied by almost identical manufacturing processes mean that the costs for a hydrogen CHP unit only slightly exceed those of a natural gas variant or biogas variant.

The mixture generation is the decisive difference

Besides the adaption of the compression ratio by using other pistons, the main difference is primarily in the process of mixture generation before the combustion. Whereas in regular natural gas or biogas operation the external mixture generation takes place in the gas mixer and before compression, in hydrogen operation, this 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 ignition-ready mixture is fed to the combustion chamber – the intake manifold direct injection. Hence, in hydrogen operation, only the air is compressed and cooled (figure 2).

This change is necessary primarily due to the different physical properties of hydrogen and natural

Figure 1. Frank Grewe, CTO of 2G Energy: „The fact that the time of technical market maturity goes hand in hand with the increasing identification of hydrogen as an important element of the future energy world is of course very positive"

Source: 2G Energy

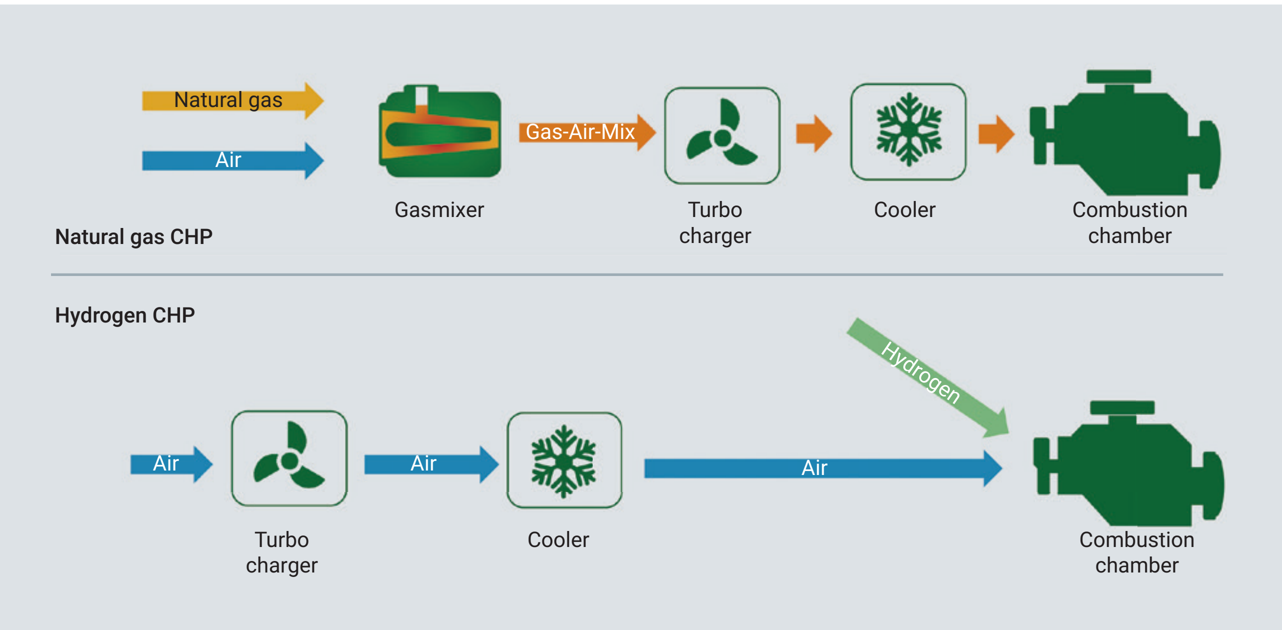

Figure 2. Comparison natural gas CHP vs. hydrogen CHP

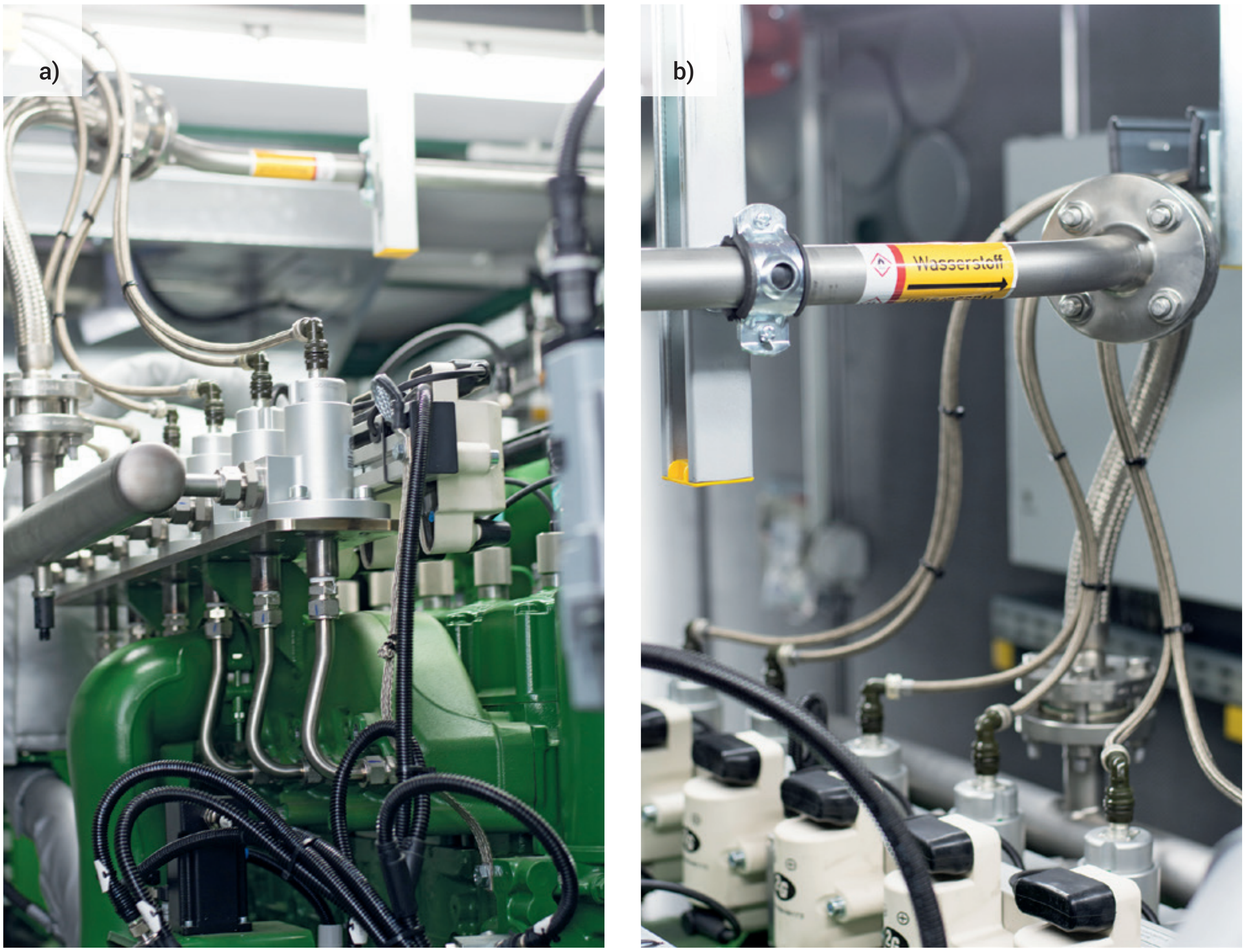

Figure 3. Hydrogen is added directly in front of the combustion chamber via gas injectors Source: 2G Energy

gas or biogas. In addition to being more easily ignitable than conventional gases, hydrogen also has a faster laminar flame speed. So the compressed air is only mixed with the hydrogen shortly before combustion, to avoid uncontrolled ignitions. In contrast to natural gas, however, the hydrogen engine is always operated very lean with an air ratio (lambda) greater than 3 which makes the theoretical ignition energy almost identical in a direct comparison. Grewe finds this hint important to dispel reservations about the safety of hydrogen in internal combustion engines: “When it comes to hydrogen, many people still think back to chemistry lessons at school with oxyhydrogen experiments and associate ‚danger‘. When dealing with gases, a certain respect is of course always necessary – but there is absolutely no latent danger from hydrogen in a CHP.” In addition to the already mentioned change in mixture generation, which prevents an ignitable mixture from penetrating into parts other than the intake tract, all gas warning technology is also adapted to hydrogen operation.

Low nitrogen emissions as a side effect

The complete avoidance of CO_2 emissions combined with the already high overall efficiency of cogeneration systems makes hydrogen attractive for combustion in CHP plants at all. But by taking a closer look on the emission side, there is another advantage caused by the lean combustion: Thanks to the very wide ignition limits of hydrogen and the special design of the hydrogen engine, a gas-air mixture with a very high excess of air is burned. Hence, low exhaust emissions with maximum engine power are possible. Even without complex exhaust gas after-treatment, the nitrogen oxide emissions within the engine are reduced to the lowest values close to the detection limit. The combustion of hydrogen would be much hotter with the same air ratio as in the case of natural gas combustion. As a result of the lean mixture, however, this is much lower, which prevents the formation of nitrogen oxide emissions and thus also leads to low exhaust gas temperatures.

Fuel flexibility – even during operation

As already mentioned at the beginning, there is already an admixture of hydrogen in the natural gas grid in many places, which usually does not cause any problems on the side of the energy conversion units. 2G has even approved its standard products up to a mixing ratio of 40% hydrogen. Up to this value, no major changes to the hardware become necessary. Grewe refers to the many years of development experience, which plays a major role in the admixture of hydrogen: "The adaptation of an internal combustion engine to changed gas qualities or the use of completely different types of gas always requires a large number of different individual measures that must be coordinated with one another. Even apart from major changes, such as the different fuel supply, there are many little things that matter. This ranges from adapting the ignition timing to optimized turbocharger settings to individual control and software solutions that we develop almost entirely in-house." This technical flexibility makes it possible to change the hydrogen content during operation. If the hydrogen content is expected to exceed 40%, the engine is delivered as a complete hydrogen variant, which can then also be operated with natural gas with a slight loss of efficiency. "Many of our customers around the world are developing innovative concepts for their own energy supply in the future. We are happy to support them as a project partner and adapt the parameters of the CHP unit individually, e.g. to the seasonal availability of hydrogen on-site", explains Grewe.

Easy conversion of existing natural gas or biogas-operated CHP plants

From the very beginning onwards one of the main goals of the development of hydrogen technology at 2G was the possibility of retrofitting existing natural gas or biogas-operated systems for operation with hydrogen. Grewe refers to specific inquiries: "We already have a number of pioneers within our range of customers who, given the right framework conditions, would rather start operating a hydrogen CHP

Figure 4. The CHP unit in Rostock/Germany is operated with 100% hydrogen
Source: 2G Energy

unit today than tomorrow. Almost every CHP plant installed today can be converted for operation with hydrogen at a later stage in the course of a regular maintenance work. We therefore advise every operator: Install a natural gas CHP today – convert it to hydrogen tomorrow." CHP plants are subject to structured maintenance and service plans in which the essential components should always be replaced at the same time. If the maintenance plans are intelligently linked with the conversion plans to hydrogen operators can save a lot of money. Pistons, for example, which would have to be replaced anyway during the 32,000 hours maintenance interval, can be installed directly as a hydrogen variant. "Depending on the time of the retrofitting, technical situation on site, etc. we calculate with very moderate costs of around 15% based on the original investment in the CHP", Grewe specifies the financial outlay. Besides changing the fuel supply and the combustion chamber components, this also includes adapting the system control and updating the software. In addition to the advantage for the individual operator, this approach also has great economic benefits, as an increase in the hydrogen economy can build on the existing infrastructure. „With our concept, we have primarily created an economic solution that makes the energy transition affordable", Grewe puts the development in the context of energy policy.

The industry is ready – the development continues

The advantage of using hydrogen in internal combustion engines is obvious: It is a technology that has proven itself all over the world for ages and therefore no uncertain outcome has to be feared. 2G is very familiar with the physical laws, material behavior, etc. and is already developing reliable and robust products for operation with 100% hydrogen. So far, the company has been able to deliver five CHP units in different output classes between 100 and 400 kW for operation with 100% hydrogen (figure 4) – the trend and the interest are steadily increasing. Nonetheless, Grewe still sees room for improvement in the development of the hydrogen portfolio: "The projects that have already been implemented show that the technical feasibility is not a problem. For us as a manufacturer, the only challenge is to further improve the engine's output. We have currently approved our hydrogen engines with up to 14 bar mean pressure compared to 18 bar mean pressure for the natural gas series, which reduces the output to a certain extent. On the development test bench, however, we already run hydrogen at 18 bar, so that the performance will be identical in the medium term."

European and global perspective as the key

In the future, a 100% renewable energy system will be an efficient mix of different energy sources and energy carriers – made possible by intelligent digitisation solutions. But it is also clear that solutions can only be found in a European context or even a global context. Similar to the current energy consumption of individual countries, where supply and demand rarely match, the availability of regeneratively produced hydrogen will also differ from regional demand. Decentralized storage of hydrogen at the point of energy consumption becomes necessary. The CHP technology, which has been matured over decades, and the associated infrastructure appear to be the most efficient solution for achieving visible short-term success in climate policy and at the same time setting the long-term framework for a decentralized, climate-neutral energy supply. Today natural gas – tomorrow hydrogen.

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