



Expert Report

Heating and process heat using climate-neutral hydrogen

Daniel Gosse MBA, Dipl.-Ing. (FH), Head of Marketing for Bosch Industrial Boilers

Europe is aiming to achieve climate neutrality by 2050. When analysing their carbon footprints, many manufacturing companies realise that a considerable portion of their direct CO₂ emissions can be attributed to heating and process heat. Energy suppliers are also facing the same challenge when operating local or district heating grids on a megawatt scale. So how can decarbonisation be achieved in heating and process heat applications? Various technologies for green energy sources are available in the market, including those based on green hydrogen. As well as offering a high boiler efficiency rate of up to 98%, combustion of this green fuel is also entirely CO₂-neutral. The following technical report focuses on solutions using hydrogen boilers and on technical measures for safe, clean hydrogen combustion.

Decentralised stand-alone solutions with hydrogen

Experts and gas network operators have been discussing proportionally mixing green hydrogen into the natural gas network for some time. Current opinion states that 10–15% hydrogen can be mixed into existing networks safely and with little effort or expenditure. It is important to note that hydrogen only contains around one third of the net calorific value of natural gas per unit volume

(15% hydrogen in the grid = approx. 5% energy share).

As such, it is unlikely that the proportion of renewable energy used in the natural gas grid can be ramped up to 50% or even 65%.

In the short- and medium-term, therefore, decentralised solutions with 100% green hydrogen represent a more attractive alternative for achieving CO₂-neutrality quickly.

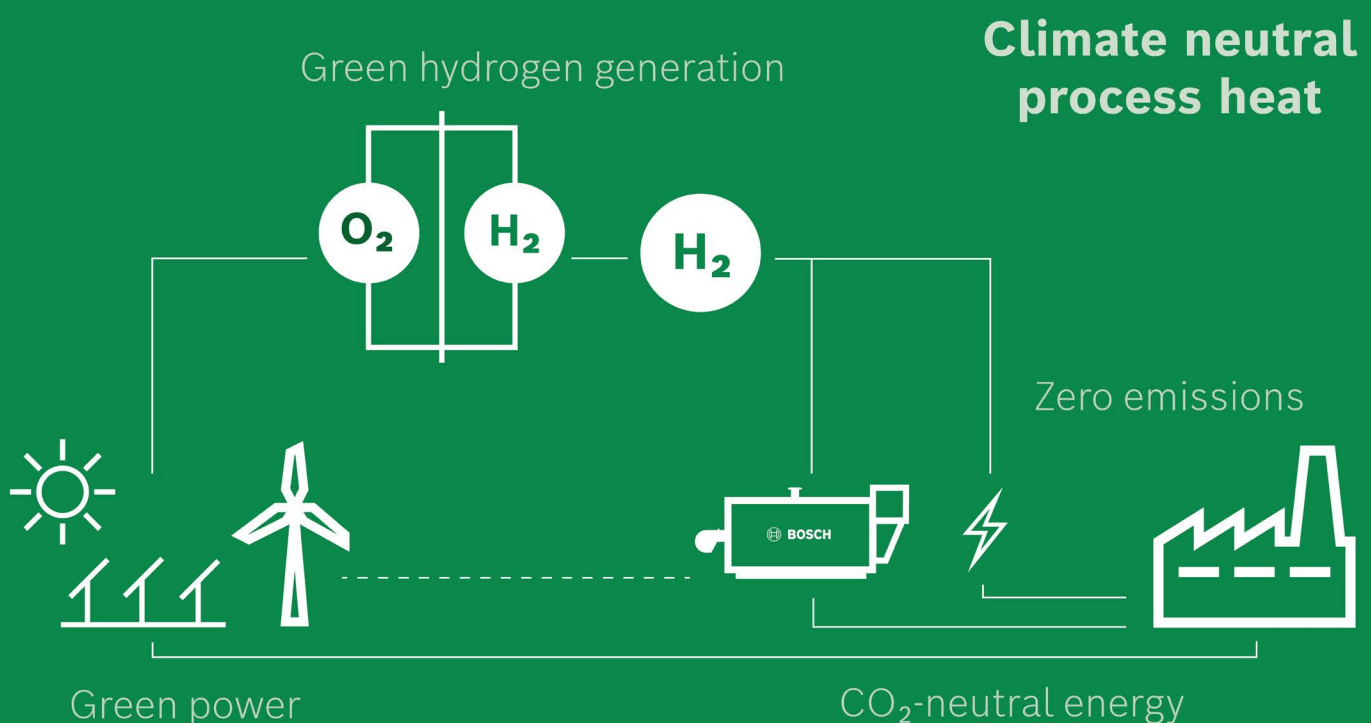
A number of pilot projects are currently under way on industrial areas and in regions with a high energy density in different locations around the world. In Wunsiedel in Germany, for example, an electrolyser with an electrical power intake of 6 MW in the initial development phase was erected. In future, it will be possible to use surplus hydrogen, for example in a 5 MW Bosch boiler, to supply heat and also to dry wood products in a sawmill. Conceivable applications also include other combinations of district heating and electromobility, as well as decentralised green energy supply, for example for municipalities.

But why should anyone choose the complex path of generating their own hydrogen (Fig. 1), accepting a loss of efficiency of around 30% in the process? After all, green electricity can be used directly in electric boilers, achieving a high degree of efficiency. When focusing solely on electrification of thermal plants, however, the fact that the fossil fuel-powered grid currently delivers around ten times the output of an electrical grid is a challenge that must be overcome. The local infrastructure and the distance from the closest major green power plant can then potentially serve to limit the use of green

energy for covering heat demands. Fluctuating availability due to weather conditions, as well as the time of the day and the season, represents another important point. Whether sunny or windy, the energy is available directly for high temperature applications with a degree of efficiency of over 99% for both plants and production operations. During the winter months and on low energy days, however, an additional CO₂-neutral energy source is required in many cases to compensate for the lack of output. This is where hydrogen can really play to its strengths: not only can it be stored comparably simply, effectively and affordably, it can also be used very efficiently.

Hybrid process heating concepts, such as boilers with multi-fuel firing unit and electric heating bundle (Fig. 2), are therefore likely to become an ever more attractive option. This combination of direct use of green electricity and hydrogen as a second energy source represents a highly efficient solution. Another option is to use a purely electrically heated boiler (Fig. 3) and a hydrogen-fired boiler to secure reliable and CO₂-neutral supply that is not dependent on fossil fuels.

Fig. 1: Simplified illustration of green hydrogen production with process heat integration.





Hybrid and H₂-ready

Fig. 2: Hybrid boiler at the Bosch factory shortly before being shipped to Spain. The electric heating bundle uses more than 5 MW of green electricity from the customer's own photovoltaic system. The burner then reliably covers additional requirements. Since the plant is to use on-site electrolysis, the boiler system has already been designed to operate with up to 100% hydrogen.

100 % electric

Fig. 3: Purely electrically heated boilers represent another important component that supports the change in energy policy.



What makes hydrogen combustion different

When comparing hydrogen use to natural gas, there are certain factors and differences to consider. The flame, which reaches approximately 2000 °C, is hotter, which facilitates the thermal NO_x formation. What's more, this fuel burns and ignites much more quickly – which is why a mixture of hydrogen and oxygen is also known as detonating gas. As the smallest atom in the universe, hydrogen is able to diffuse through a variety of materials and even metals. It is essential that the unintentional formation of detonating gas is prevented.

As mentioned at the start of the article, hydrogen's net

calorific value per unit volume is only around one third that of natural gas. This means that three times the gas volume is required for the same amount of energy.

Another significant difference is the colourless flame when pure hydrogen is burned – however, the addition of just a small amount of natural gas causes it to change to a blue colour. The heat emission is also different. While a natural gas flame produces a large amount of radiation in the infrared spectrum, a hydrogen flame emits a low, albeit measurable, amount of ultraviolet radiation. In certain combustion systems, this is used as a measured variable for combustion control.

Technological requirements for hydrogen-powered heating boilers and steam boilers

The use of hydrogen in boiler systems, and the corresponding technology, is commonplace in sectors in which hydrogen is created as a waste product of chemical processes. As a result, there are a range of known technological requirements for safe, efficient handling. Over the past years, Bosch Industrial Boilers has manufactured and commissioned a number of systems for customers in the chemical and pharmaceutical sector (Fig. 4) and plastics manufacturing industry, and for green heat supply.

The following solutions, among others, are suitable for making use of this environmentally friendly gas: The prerequisites include comprehensive technical measures and components that enable triple the fuel volume to be provided and make it possible to control the higher combustion temperatures and faster combustion behaviour. This concerns lines, nozzles, high-temperature-resistant components that come into contact with flames, burner fans and the combustion chamber, in particular. The hydrogen burner is usually designed as a complex multi-fuel firing unit with a correspondingly demanding control system, in order to enable full flexibility and supply reliability.

Proven measures on the flue gas side are available to handle the increased thermal NO_x formation encountered when burning hydrogen. For example, exhaust gas recirculation (EGR) can be used to reliably comply with the applicable emission regulations in terms of NO_x. In this process, the flue gas generated by the boiler, which is low in oxygen, is mixed with the combustion air. The partial

pressure of the oxygen content is reduced, which delays the reaction between the hydrogen and oxygen, thereby lowering the average flame temperature. This results in an effective reduction in thermal NO_x formation. For those looking to retrofit an existing plant, exhaust gas recirculation and a corresponding system design can make it possible to equal the original nominal output, while at the same time complying with the strict NO_x limits.

To prevent reignition of the hydrogen firing unit in the fuel supply line, the combustion system features a flame arrestor upstream. This can be designed either statically, e.g. as deflagration or detonation arrestor, or dynamically. The dynamic variant causes a significantly higher gas escape speed from gas ring or gas lances than the flame speed. Regulations or binding rules describing hydrogen burners in industrial boiler plants are not yet available. Even though standardisation relating to hydrogen has gained momentum, it is currently the case that every system must be subjected to an individual inspection. This inspection must take into account issues such as specific explosion protection specifications (ATEX level), materials selection, the suitability of the equipment used, and operational aspects.

In the flue gas technology sector, established design rules and technologies can be used like in natural gas firing units. The hydrogen present in the form of methane in the natural gas is finally also combusted to produce water vapour. This results in the significantly lower CO₂ emissions of natural gas compared to that of coal, which primarily consists of carbon. The high specific thermal



Hydrogen combustion

Fig 4: Example of an implemented fuel concept with hydrogen, natural gas and light fuel oil for a Bosch boiler system at a pharmaceutical company.

Renewable energy

Fig. 5: Renewable sources are the basis for a green energy mix of electricity and hydrogen.



capacity or enthalpy of the water vapour in the flue gas enables condensing technology to be used when combusting hydrogen, as well. During the phase change from water vapour in the flue gas to liquid water, significantly more energy is released than during the pure temperature reduction in waste heat usage. The flue gas temperature can be reduced from 130 °C to 60 °C using condensing heat exchanges, resulting in fuel savings of up to 7%. However, this requires a heat sink, for instance to pre-heat the process water or to heat production halls and offices. In practice, the overall efficiency of systems of this kind is up to 103% relative to the net calorific value, or 98% from a primary energy perspective. When using condensing technology in combination with hydrogen combustion and flue gas recirculation, there are additional aspects to consider, particularly in the case of warm/hot water boilers with low return flow temperatures.

Establishing a sustainable energy supply

So what recommendations can be given to companies in terms of securing a future-proof supply of heating and process heat? Alternatives such as incorporating heat pumps typically only make sense for manufacturing companies when they are used for low-temperature applications, for example as air to air heat pumps for heating purposes. In contrast, many production processes require steam and hot water, often at temperatures far exceeding 100 °C. At these high temperature levels, the efficiency (more precisely, the Coefficient of Performance) of heat pumps is lower – as a result, they cannot be operated

cost-effectively. In addition, there is often no adequate waste heat source available to supply high-temperature heat pumps, as they require an output many times greater than the requisite boiler capacity.

Climate-friendly hydrogen, on the other hand, has the potential to supply heating processes with high temperatures in the megawatt range. As such, it is considered a key instrument in the future energy landscape. While alternative energy sources with annual CO₂ compensation (biogas, bio-oil) are only available in limited scope, a green energy mix (Fig. 5) with hydrogen and electricity has the opportunity to completely substitute CO₂ emissions. The limiting factors are currently still the availability of the fuel and also cost-efficiency. However, the technology itself is already fully developed and ready for the use of both hydrogen and electricity. For many new plants, it is therefore a good idea to already incorporate interfaces for later conversion now and ensure that the boilers are “hydrogen-ready” or produced as hybrids with an electric heating bundle. It is often also possible to modernise existing boiler systems at a reasonable cost, so that they can then use alternative fuels.

In any case, checking existing systems to assess their future suitability is a practical step. This process frequently uncovers many potentials to save CO₂, which can be used, for example, through heat recovery equipment – resulting in not just a decrease in fuel costs, but a sustainable reduction in the company's CO₂ footprint.

Bosch Industriekessel GmbH

Nuernberger Strasse 73
91710 Gunzenhausen
Germany
Tel. +49 9831 56253
Fax +49 9831 5692253
sales@bosch-industrial.com
Service hotline +49 180 5667468*
Spare parts hotline +49 180 5010540*

Bosch Industriekessel Austria GmbH

Haldenweg 7
5500 Bischofshofen
Austria
Tel. +43 6462 2527300
Fax +43 6462 252766300
sales-at@bosch-industrial.com
Service hotline +43 810 810300**
Spare parts hotline +49 180 5010540**

info@bosch-industrial.com
www.bosch-industrial.com
www.bosch-industrial.com/YouTube

*€0.14 per minute inside Germany on a landline; maximum charge on mobile devices €0.42 per minute

**Max. €0.10 per minute inside Austria on a landline

Costs for calls from mobile networks and international calls may vary.

© Bosch Industriekessel GmbH | Images provided for illustration only |
Subject to change | 04/2023 | HC-IN/MKT_en_FB_Wasserstoff_02