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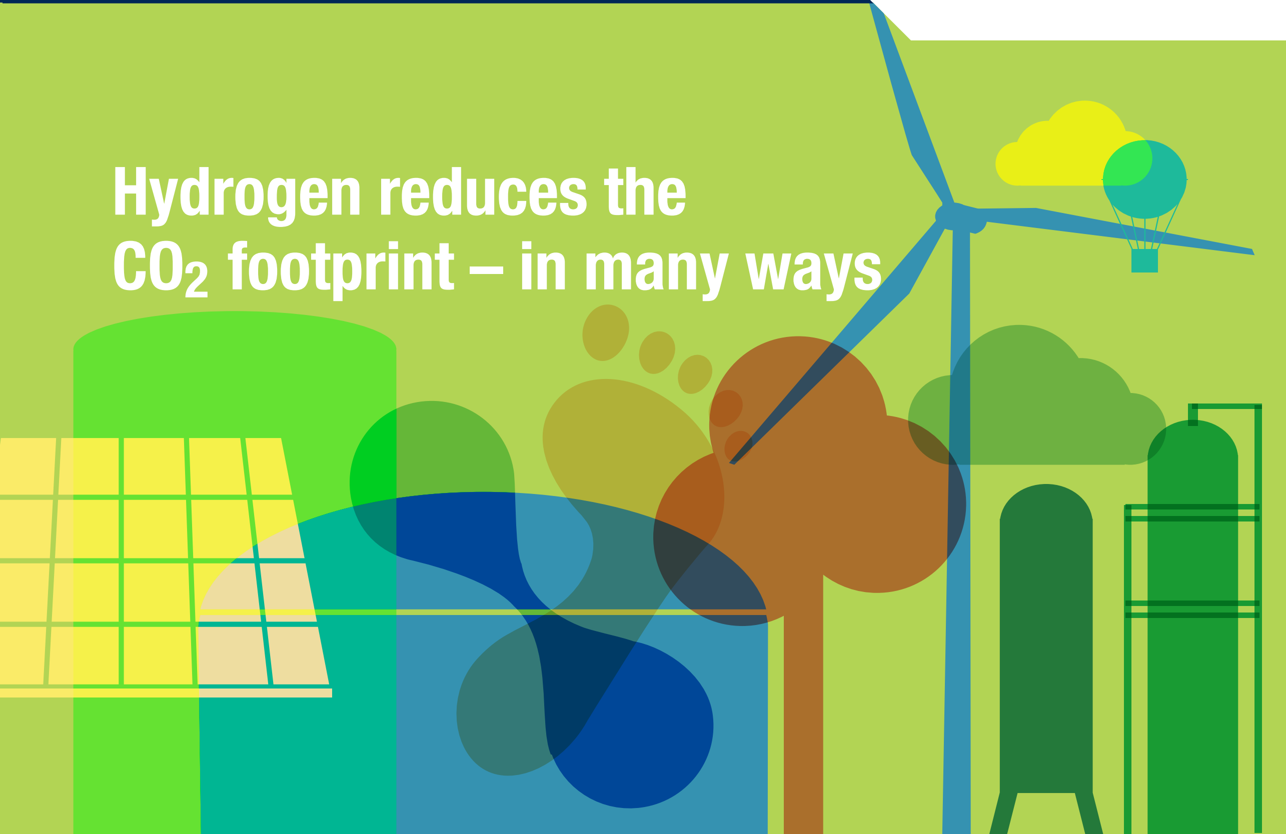
Hydrogen reduces the CO_2 footprint – in many ways



From the “Time for an Energy Ch2ange” series.

The destination is green.

The journey there is colourful.

What it's all about

- Climate-friendly molecules are a driver for the energy transition.
- The production paths and colours of hydrogen are diverse.
- Each hydrogen type leaves a different CO_2 footprint.
- Green hydrogen is (virtually) climate neutral.
- Most importantly, hydrogen is produced in a climate-friendly manner – regardless of how and from what source.

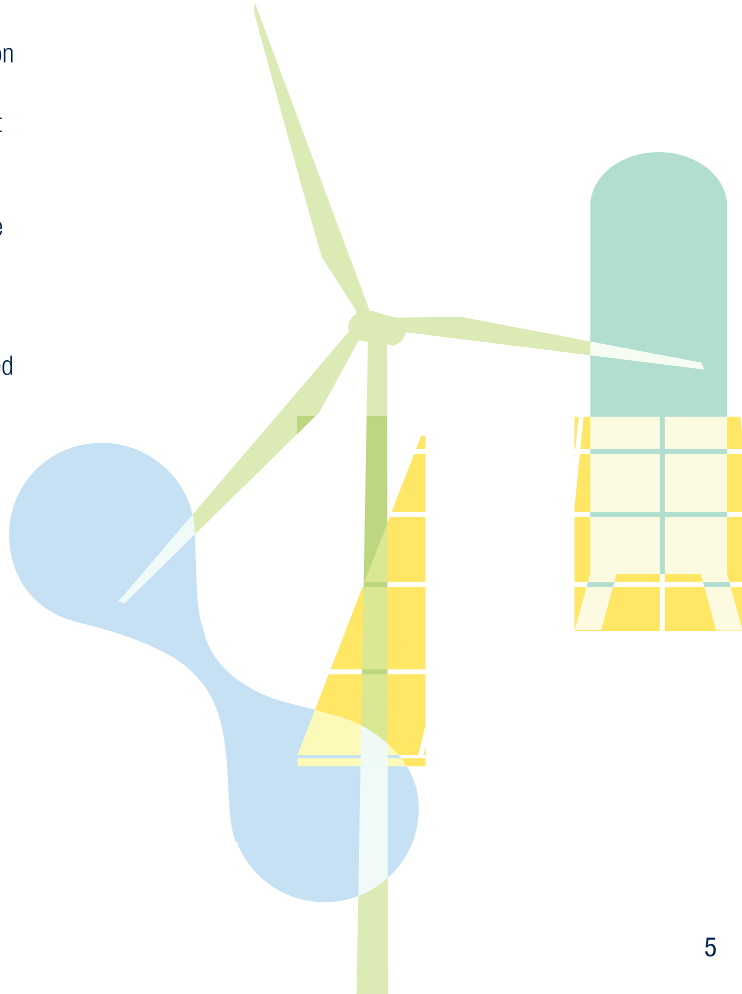
Climate-friendly molecules – drivers of the energy transition

The European Union, and with it Germany, has committed to meeting the Paris climate protection targets by 2045 as planned. This means that society must become climate-neutral within the next two decades. The speed of the energy transition must therefore be increased in all sectors of the economy. This requires all measures and technical options that minimise greenhouse gas (GHG) emissions in the short, medium and long term.

Alongside the expansion of renewable energies and electrification, the use of climate-friendly gases also offers the opportunity to reduce emissions – and these are needed to achieve climate neutrality as quickly as possible. This is because molecules from fossil fuels currently account for the vast majority of energy consumption in Europe and especially in Germany. Not all of them can be replaced through the use of “green electrons” from wind or solar power.

But hydrogen (H_2) in particular is a gaseous energy carrier that can pave the way towards a climate-neutral society in all areas – in industrial processes, in mobility, in the centralised and decentralised supply of heat to households and businesses and as a storage medium. Hydrogen is therefore a fundamental building block of the energy transition.

Several processes are currently available for its production, which leave a small or even negative carbon footprint depending on the base material and type of energy used. Experts from the DVGW Research Centre at the Engler-Bunte Institute of the Karlsruhe Institute of Technology (DVGW-EBI) have calculated how high the GHG emissions are for each method of hydrogen production and come to the following conclusion: With hydrogen, greenhouse gas emissions can be reduced by at least 70 percent compared to today's natural gas if it is produced in a climate-friendly manner.



The production paths and colours of hydrogen

Two processes are commonly used to produce hydrogen: steam reforming and electrolysis. Other methods also exist. Depending on the production method, hydrogen is assigned different colours.

Currently, **grey** hydrogen is mainly obtained from fossil fuels, such as crude oil or natural gas, via steam reforming. The energy source is converted into hydrogen and carbon dioxide (CO_2) under the influence of steam and heat. The CO_2 is released into the atmosphere unhindered during this process.

Blue hydrogen is also produced in the first step through steam reforming. However, the CO2 produced in the process is captured and directly stored. In addition to storage, there is also the option of utilising the CO_2, for example for the production of plastics (Carbon Capture Use and Storage, CCUS). In this way, the greenhouse gas is not released into the atmosphere.

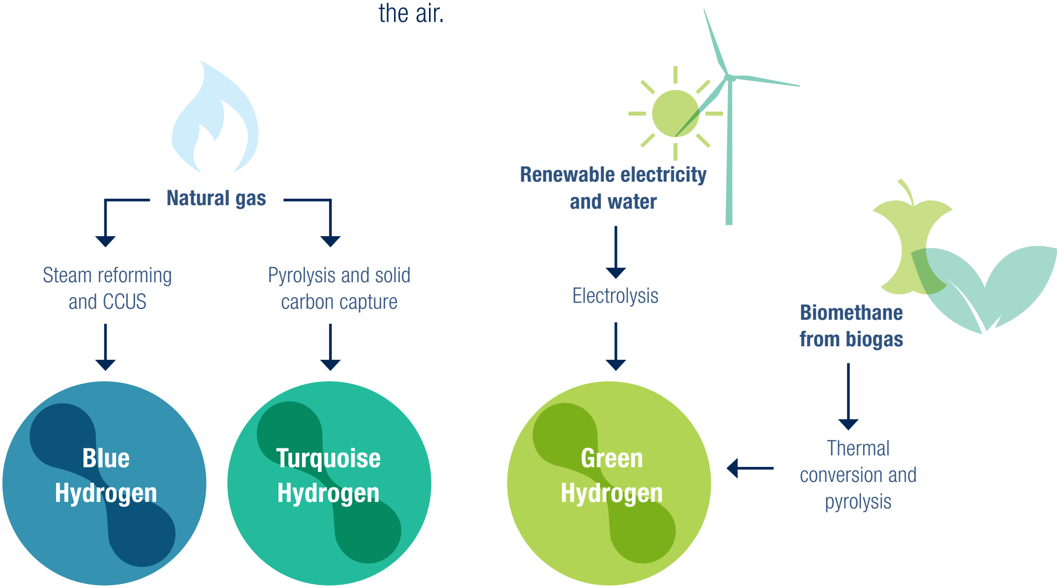
Turquoise hydrogen is produced when the methane (CH_4) contained in natural gas is separated directly into hydrogen and solid carbon at very high temperatures in the absence of oxygen. This process is called pyrolysis. The carbon is produced in solid form and is therefore easier to handle than gaseous CO_2.

Green hydrogen is produced through the electrolysis of water. Electricity from renewable energy sources is used to split water (H_2O) into hydrogen (H_2) and oxygen (O_2). High-purity water is required for this, which can be produced either by treating fresh water or seawater.

Special case: Green hydrogen from biogas

Just like natural gas, biomethane can also be used to produce hydrogen, for example through pyrolysis.

The carbon contained in the biomethane is first extracted from the atmosphere by plants via photosynthesis and separated during the process. This allows a "CO_2 sink" to be created and CO_2 to be removed from the air.



Simplified depiction of hydrogen production processes

Every hydrogen type leaves a different CO_2 footprint

The different processes make it clear that not all hydrogen is the same – especially in terms of its GHG reduction potential. How climate-friendly a production process or type of hydrogen is depends largely on the resources utilised and the energy carriers used for the process.

For example: If natural gas is used as the base material, this increases the footprint. If only renewable energy sources are used, as is the case with green hydrogen, lower quantities of GHG emissions are produced. In addition to the type of base products, their origin and the emissions generated during the manufacturing process of the system components are also relevant.

Whether the production process can be categorised as low-GHG or climate-neutral therefore does not depend solely on the process itself, but rather on a complex interplay of various factors. Each process has its own peculiarities in terms of its carbon footprint; not all factors influence it equally.

Origin of the base material is decisive for the size of the boot

DVGW-EBI researchers have calculated that there is a significant difference between processes that use natural gas as a base material and electrolysis, in which hydrogen is simply produced from electricity and water. In the production processes for blue or turquoise hydrogen, the emissions in the upstream chain of the base product have a significant influence on the overall GHG balance.

The footprint varies depending on the source of the natural gas or the electricity used.

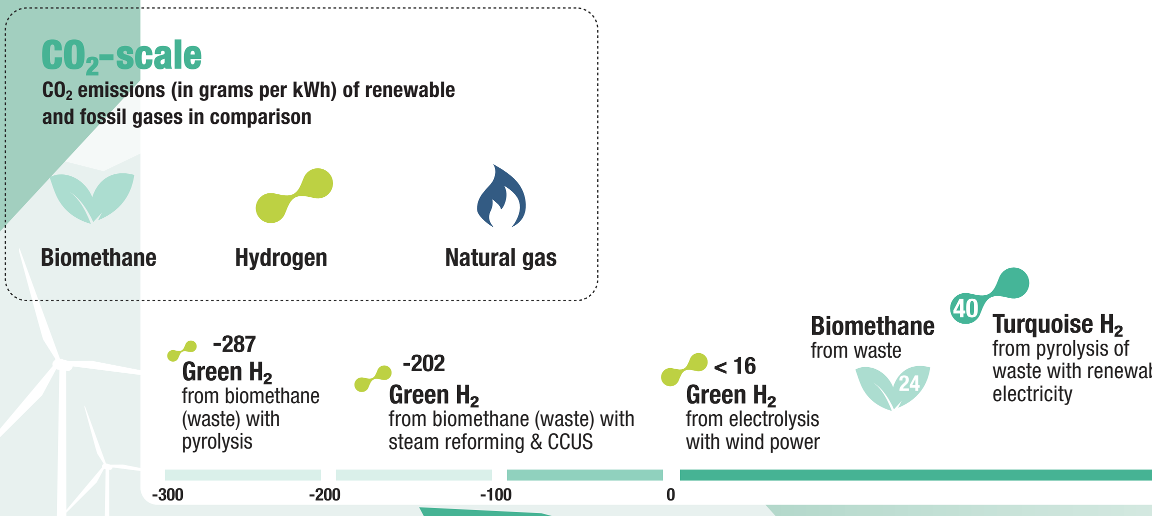
Playing a decisive role here is the region of origin from which the natural gas comes and the method by which it is extracted and transported. This is because greenhouse gases are emitted during the extraction and transport of the natural gas, which must be taken into account as upstream emissions in the balance of the hydrogen produced from it. For example, Norwegian natural gas has much lower CO_2 “baggage” than liquefied natural gas (LNG) from North America.

The type of electricity used also has a significant influence. As the pyrolysis process is more electricity-intensive compared to other processes, the upstream chain emissions of electricity have a particularly strong impact on turquoise H_2. This means that the more electricity from renewable energies, the smaller its footprint. In other words: The lower the emissions of the electricity used, the more relevant the influence of the natural gas upstream chain.

Green hydrogen is (virtually) climate neutral

Green hydrogen is virtually climate-neutral. A closer look at its upstream chain reveals that it also has a CO_2 footprint, albeit a small one. By definition, the electricity used comes from renewable energy sources. However, the production of solar and wind power systems produces GHG emissions, mainly in the production of the components and the materials used for them, such as steel, concrete, copper, aluminium, etc.

These emissions have a particular impact on green hydrogen because electrolysers do not operate continuously, but only when the wind is blowing or the sun is shining. This results in a shorter operating time over the entire service life than with the other processes. In contrast, with blue and turquoise hydrogen, the emissions resulting from the construction of the production facilities can be neglected due to the long operating time and high material throughputs.

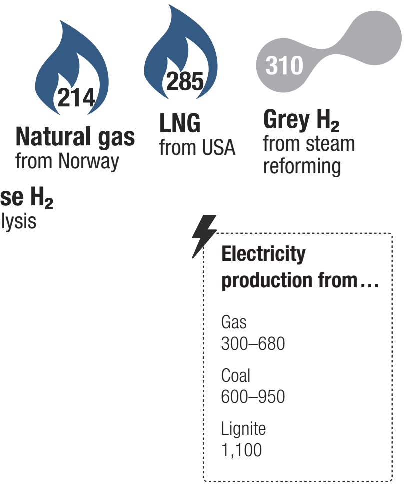


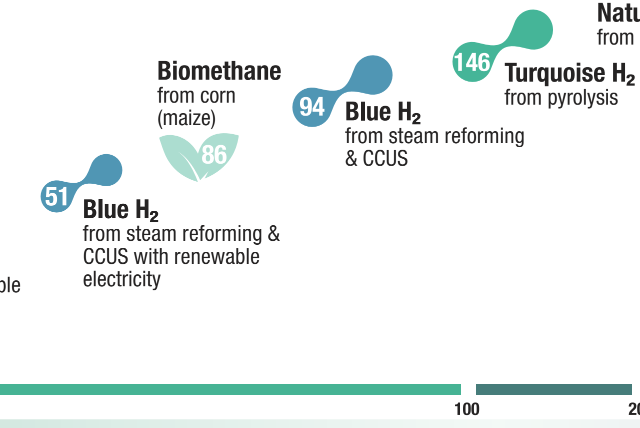
Hydrogen from biogas takes CO_2 out of the air

The production of hydrogen can also utilise biogas from biomass instead of fossil natural gas. If biogas is used, the effect is similar: both steam reforming with CCUS and pyrolysis bind CO2 from the atmosphere and thus create a “CO_2 sink”. In this case, the CO_2 balance is negative.

How deep this sink is depends on the base material. The use of biogas from plant matter offers a major advantage: the CO_2 contained in the biogas was previously extracted from the air through photosynthesis by the plants and is separated and stored during steam reforming with CCUS or pyrolysis.

In turn, H_2 production with biogas from manure makes it possible to reduce GHG emissions from livestock farming. In this way, the agricultural sector can be supported in reducing emissions and additional energy can be generated. The CO_2 contained in the biogas is also not released into the atmosphere.





Most importantly, hydrogen is produced in a climate-friendly manner – regardless of how and from what source

Needless to say, green hydrogen produced using electrolysis and renewable electricity has the smallest CO_2 footprint of all current processes. The aim is to utilise as much of it as possible. However, the production potential in Germany will not be sufficient to cover future demand. Imports from other European countries or from other continents will be necessary for this – but also hydrogen produced using other methods.

In addition to the rapid expansion of electrolysis and import capacities, the production of blue and turquoise H_2 will also be necessary. This is because these can also be produced in a climate-friendly manner, contribute to decarbonisation and reduce GHG emissions – provided that renewable electricity is used for the process. DVGW-EBI analyses show that the GHG emissions of hydrogen can be significantly reduced compared to the currently available technology by using natural gas pyrolysis, for example.

Ultimately, it should not be the colour that determines whether and how which type of hydrogen is used, but the respective availability in combination with the potential to reduce GHG emissions. Thanks to different processes and base materials, energy sources can be diversified and the system can be made resilient.

The emission reduction potential of hydrogen from biomethane or biogas is considerable. Even if these processes are not yet available on a large scale, this path should be pursued further. This is because the growth of plants, their utilisation and the separation of carbon make it possible to create a "CO_2 sink".

"The use of blue, turquoise and green hydrogen already has the potential to reduce GHG emissions by 50–95% compared to current technology."

FRIEDEMANN MÖRS

Group Leader Process Engineering at the DVGW Research Centre at the Engler-Bunte Institute of the Karlsruhe Institute of Technology

"Time for an Energy Ch2ange" DVGW publications

Hydrogen is the energy carrier of the future and an important building block for climate protection and the energy transition in Germany. The DVGW has been active in this field for over ten years. Its research institutes are involved in numerous projects on the question of how and where hydrogen can be produced, transported, distributed and utilised.

Three years ago, the DVGW commenced adapting its technical regulations to the switch to hydrogen. In our "Time for an Energy Ch2ange" series, we present the current state of research and the technical expertise gathered from the work on the regulations in a concise format.

Already published:

- Klimafreundliche Gase. Mehr als genug Potential (Climate-friendly gases. More than enough potential; in German only)
- Das Gasnetz – Rückgrat der Wasserstoffwelt (The gas grid – backbone of the hydrogen world; in German only)
- Wasserstoff vor Ort. Für Wärme und mehr (Hydrogen on site. For heating and more)
- Largely H_2-ready now: grids, storage facilities, components
- Hydrogen: Demand and Procurement Pathways

More information at:

www.h2-dvgw.de

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Further information on the project and the results in detail can be found at: www.dvgw.de/co2-footprint
(in German only)

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