Green hydrogen

Speeding the transition to a low-carbon energy future

Ilona Dickschas from **Siemens Gas and Power** explains why green hydrogen is key to a carbon-free future

Despite the lack of consensus achieved at the COP25 in Madrid late last year, there is no longer any dispute that urgent action is required to combat climate change. Mounting public concern is increasing the pressure on politicians and industry to act, and quickly, to decarbonise.

This momentum has become a key driver for energy policies worldwide and is climbing the corporate agenda for utilities. In an attempt to meet the existing commitment from the 2015 Paris Agreement that requires net zero emissions between 2030 to 2050, the share of electricity from renewable sources has increased to 25% around the globe. But the most significant challenge that needs to be faced is to reduce the 60% of carbon emissions that fall outside the power sector.

One potential solution to this dilemma, and one that Siemens believes is the optimum answer is Power-to-X. It allows for the conversion of renewable energy into green hydrogen or synthetic e-Fuels, making it possible to couple and power other sectors like industry, heating and mobility with a sustainable energy supply.

Hydrogen is an important component of many industries and has been called the perfect fuel by many of its advocates because of its clean burning properties. It can be used in mobility, both in fuel cells and an internal combustion engine, it can be combined chemically with most elements and utilised as an industrial chemical in a wide range of applications. It is also valuable as an energy storage medium that can provide an essential back-up source for the power grid.

> 70
> Hydrogen is produced in vast quantities, over 70 million tons per year

A flexible fuel

There is no doubt that hydrogen is incredibly versatile. True, it requires a certain effort to compress and store it under high pressure, in high density, and over a very long period as a gas or in liquidised form. However, it has a significant advantage when used directly.

Industrial applications like in the steel industry, in feedstock for refineries, in chemical industries and in the production of ammonia are good examples. Benefits of hydrogen in other applications include fuel-cell drives, or when used as an input product to produce hydrocarbons. Of course, hydrogen can also be fed into the gas grid or used for re-electrification as fuel gas in gas turbines.

It is currently produced in vast quantities, at the last count over 70 million tons per year. Half of that is used for the synthesis of ammonia, which is the basis for ammonia phosphate or urea and other chemicals. Hydrogen is also used in refineries for hydrocarbon cracking and other processes. In the food industry, hydrogen is used for fat hardening.

Traditionally, hydrogen is produced through the steam reforming process, in which steam reacts with natural gas to produce synthetic gas or syngas, a mixture of hydrogen and carbon monoxide. In this process CO is converted to CO_2 (carbon dioxide), which further down the process is removed from the stream and emitted to the atmosphere, which blights hydrogen's environmental credentials. In this form the hydrogen is dubbed grey hydrogen. However, there is a downside with hydrogen, namely in CO_2 emissions. It takes 8-10kg of CO_2 to produce one kilogram of hydrogen.

There is a more environmentally friendly version available. In this process hydrogen is produced via the same process as grey hydrogen but with the carbon emissions captured and stored or reused. This is called blue hydrogen.

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The power of electrolysis

However, it is possible to go even greener and produce green hydrogen, which is generated by renewable energy sources without producing carbon emissions in the first place. The generation of green hydrogen via electrolysis of water with electrical energy from renewable sources is completely free of CO_2 emissions from the beginning.

Electrolysis is not a new technology. While electrolysis itself was invented 100 years ago, the first industrial synthesis of hydrogen and oxygen through electrolysis dates back to 1888. This well-established phenomenon has become a key component in the energy transition because the chemical bond energy in hydrogen can be extracted and exploited in numerous ways.

There are three electrolyser technologies that can be used to produce hydrogen. The first, alkaline water electrolysis, has a long heritage in the industry. In this scenario there are two electrodes operating in a liquid alkaline electrolyte solution of potassium hydroxide or sodium hydroxide. These electrodes are separated by a diaphragm, separating the product gases and transporting the hydroxide ions (OH−) from one electrode to the other.

In solid oxide electrolysis a solid oxide fuel cell operates in regenerative mode to achieve the electrolysis of water by using a solid oxide, or ceramic, electrolyte to produce hydrogen gas and oxygen. The final option is proton exchange membrane (PEM) electrolysis. With PEM technology the electrolyser can be switched on and off without preheating, leading to high flexibility and overall system efficiencies even at part loads. It is therefore perfectly suited for the load profiles of renewable power sources like wind and solar, which are volatile by nature.

Power-to-X

A key strategy to increase the speed of decarbonisation across a disparate cluster of sectors is the concept of coupling the use of excess green electricity from renewable energy sources to convert various compounds into industrial feedstocks, as well as to displace fossil fuels in other heavy industries and sectors. This is where Siemens' Power-to-X technology comes to the fore with the 'X' standing for hydrogen or e-fuels.

In this strategy the surplus of renewable energy is used to ▸

convert water into hydrogen via the proton exchange membrane (PEM) electrolyser. In order to produce green hydrogen, Siemens has developed the Silyzer portfolio family: an innovative electrolysis system based on PEM technology. PEM takes its name from the proton exchange membrane, which is permeable to protons (H+) but tight for gases and electrons. In other words, this kind of membrane acts as an electrical isolator between the anode and cathode side as well as a physical separator, preventing hydrogen and oxygen from remixing.

Compared to alkaline electrolysis, PEM technology is ideal for working with fluctuating wind and solar power sources, as it allows a highly dynamic mode of operation and can be rapidly turned on and off without pre-heating. This method allows optimum efficiency at high power densities and good product gas quality even at partial loads. The operation is low-maintenance and reliable without the use of chemicals or foreign substances. The Siemens hydrogen generation plant is a facility that integrates key technologies to produce green hydrogen. This innovative solution could serve, connect, transform and reduce carbon emissions in multiple industries.

An integral part of decarbonising mobility

There are several pathways for Power-to-X technology but probably one of the most important for the decarbonisation of the mobility sector is using e-Fuels synthesised from green hydrogen with CO_2, e-Methane (CH_4, via the Sabatier process), e-Methanol (CH_3OH) or via the Fischer-Tropsch process electricity-based jet fuels, diesel or waxes (CxHy).

Producing it from renewable energy sources would directly avoid the net CO_2 emissions stemming from the conventional supply chain. Via the Methanol-to-Gasoline (MtG) process, fully sustainable e-Gasoline could be produced. Other subsequent products are fuel additives (MTBE), formaldehyde, formic acid or olefins (MTO). Alternatively, fuel cells can be used to store energy from green hydrogen.

A hydrogen-powered car can then use electricity from a fuel cell. When the fuel cell is filled with hydrogen from the vehicle's fuel tank it mixes hydrogen with oxygen to create H_2O in an electrochemical process. This reaction generates electricity which is then used to power the electric motors. Fuel cells can not only be used for road transportation in cars or fuel cell trucks, which are already being manufactured, but also for rail transportation and local shipping to replace diesel engines.

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Facing future challenges

To make green hydrogen a viable possibility, a further, significant expansion of renewable energy infrastructure is required to produce enough quantities of green hydrogen. That is one of the biggest challenges we face. Recent studies have estimated that by the time coal is phased out in 2038 more than 240GW of installed capacity from renewable energies will be available in Germany.

For a policy incorporating green hydrogen to be feasible, a holistic approach is crucial. To achieve the decarbonisation targets for the overall energy system a strategy that gradually integrates all sub-segments of the energy system is required. This includes green energy sources such as green hydrogen as well as the expansion of small and large storage facilities, grids and clever energy management systems.

Another challenge that the so-called hydrogen economy faces is a lack of an effective and coherent legal framework. Stronger regulatory integration of a future hydrogen economy into the energy system, initially combined with financial incentives for green hydrogen and its further use in the heating, electricity, mobility and industry sectors is essential. With all that in place we can expect to see a significant breakthrough of hydrogen as an important energy source – and a smoother route plotted through the energy transition to a low-carbon future.

From my point of view, we have only made the initial, small steps and there is much more yet to do, but the projects that we have underway are both promising and exciting. These and future projects that feature collaboration between energy suppliers, research institutions and technology manufacturers, will help us move towards a carbon-free, environmentally friendly energy supply. We are collaborating to master the challenges that lie ahead because we are convinced that hydrogen will be an important part of our future. gw

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