Hydrogen conversion to green gas

By Stephen B. Harrison on Jun 19, 2020 | Translate NEWS

With the help of the right microbes, hydrogen and carbon dioxide (CO_2) can combine to form methane and water. If we feed this process with CO_2 captured from industrial processes and hydrogen produced on an electrolyser using renewable electricity, we have the means to produce 'green gas'.

But, why might we want to use hydrogen, which is a combustible and readily transportable gas, to produce methane, which has similar properties?

Part of the answer is quite simply that our gas distribution infrastructure has been built to distribute methane. Methane has a higher heating value than hydrogen per cubic metre – so fair metering and invoicing also comes into the equation.

Furthermore, in many European countries, we must find a reliable way to balance out the seasonal imbalance of renewable electricity generation, which peaks in the summer and the demand for energy, which peaks in the winter. Conversion of hydrogen to methane for long-term underground storage is one way to address that annual supply and demand imbalance.

These are the concepts behind the 'Underground Sun Conversion' project running in Austria.

Using peaks to fill troughs

In Austria, around 65% of the nation's electricity is derived from renewable sources. Much of that comes from hydro-electric power plants on the Danube River. The stream on the river is strong during the summer months when rain is falling but it is quieter in winter when the precipitation falls as snow, which accumulates on the land.

That frozen water is then released to the river during the spring thaw. Solar power is also a major contributor to the Austrian grid in summer but is also not reliable in cloudy winter months. And with lots of snow and fewer sunlight hours in winter, it is naturally the peak demand season for domestic heating with natural gas.

Achieving the first 65% of renewable electricity production has been relatively easy but getting from 65% closer to 100% will become progressively more difficult. Taking the peak in power production in the summer and storing that for use in the winter is therefore the critical challenge that the nation faces. And, they are not alone. Many other central European countries such as Germany, Switzerland and the Czech Republic have similar weather patterns and face similar challenges.

During the summer months, solar power also suffers from over-production during daytime and under-production at night. However, batteries or pumped storage hydro-electricity schemes can effectively be used to smooth out these short-term demand imbalances.

“To provide long-term energy storage which can use the summer peak to fill the winter trough, we must store energy in molecules”. That is the conclusion that Stephan Bauer, Head of Green Gas Technology at RAG Austria has come to. The ‘Underground Sun Conversion’ project which he is running near Pillsbach in Upper Austria aims to prove the feasibility of his assertion.

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There is plenty of logic behind the project name, because millions of years ago microbes used energy from the sun to convert biomass to methane. This is the process that is now being replicated 1000m underground in porous rock.

Bauer explains that, “we inject hydrogen and CO_2deep underground into the rock formation which as previously a productive natural gas field. The natural gas has long since been recovered from this depleted, but the rock structures can still be used to store methane. As we inject the gases underground, millions of microbes are at work in the porous layer of rock down there to convert the hydrogen and $CO_2$to water and methane. We could keep that process going until the gas reservoir is full and that would be years. But our goal is to make the methane in summer and release it to the gas grid in winter.”

In order to fit the long-term net-zero vision for 100% renewable energy, the process must use green hydrogen. And, ‘Underground Sun Conversion’ can also be used to capture and consume abundant quantities of CO_2which are produced throughout the year from industrial processes such as steel and cement production or electricity generation from fossil fuels. “Our process can be thought of as a continuous carbon cycle,” says Bauer. “And, by sourcing green hydrogen we can ensure that it is sustainable and carbon-neutral to support the EU Green Deal 2050 decarbonisation and climate change targets.”

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Hydrogen at the heart of the process

One of the building block technologies in the Underground Sun Conversion project is electrolysis to produce hydrogen.

RAG selected McPhy as a project partner to supply the electrolyser. Bauer explains, “Our selection process was very robust. First, we defined the key purchasing criteria such as: the need to have relevant reference installations; safety management processes; technical quality of the proposal; energy conversion efficiency for our specified operating profile and the initial capital outlay. Our goal was to find a solution with lowest total cost over a 10-year period.”

“Then we initiated a tender process and evaluated the bids. Up to now, we have been very pleased with our decision to use McPhy as a partner in the Underground Sun Conversion project.”

Christopher Braatz of McPhy Energy in Germany explains how his company is involved in the project. “One of our hydrogen electrolysers is right at the heart of this process. It’s a mid-sized unit, by modern standards, consuming 0.5 MW of power to produce 200 cubic metres per hour of hydrogen.”

The commercial production of hydrogen electrolysers is still at an early stage of industrialisation. Cost reductions are still achievable as the size of the electrolysers will scale up from the current 10MW order to magnitude to 100MW and 1GW scale. Braatz explains how this issue is being tackled at McPhy. “We believe that the initial cost of electrolyser units must be reduced to ensure that hydrogen is a cost-competitive energy solution. Part of the key to getting there will be to scale-up. Our units today are based on a modular concept using electrolyser stacks in the 1-2MW range. That’s fine for now and it will also be OK when we are building systems up to 100MW.”

“But when we start building 1GW electrolysers, our vision is to use a modular design based on a new larger stack size, for example at 5 to 10MW. It’s a bit like building a wall: if you want to build a bigger wall, it makes sense to use bigger bricks”.

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Robust safety and quality management systems are key

The industrial gases sector has been handling hydrogen for more than a century. Similarly, gas grid operators have been working with natural gas for decades.

These statements do not mean to imply that the use of hydrogen or methane is risk-free. Nevertheless, they do point to a breadth and depth of expertise which can guide safety management systems related to the production of hydrogen and its use for gas grid injection.

Guntram Schnotz, Technical Manager Natural Gas Sector at the Inspection Body of TÜV SÜD Industrie Service GmbH in Germany, explains how he became involved in hydrogen. "In my team we cover energy gases. Our inspection and certification services were established to focus on natural gas distribution and have expanded to include hydrogen electrolysers."

The combination of expertise in natural gas and hydrogen means that his team are ideally qualified to work on projects where hydrogen is ad-mixed into the natural gas grid.

Deep expertise is essential because the regulatory framework is complex and there are many subtle nuances. "According to the standards in Germany, there is an interesting point that differentiates a gas supply system for industrial use from an energy gas utility system", says Schnotz. "The rationale is that energy must continue to flow. Imagine the gas is used to heat homes during a -20°C winter's night. Nobody wants to experience a supply interruption. This means that energy systems must be designed so that the necessary testing and inspection can be done on the run."

According to the German regulatory framework, gas supply systems which are designed to supply industrial processes may be inspected during shutdown periods.

Regarding hydrogen purity, ISO 14687 is relevant. It stipulates that hydrogen produced for PEM fuel cells must consider many impurities such as ammonia, formic acid and formaldehyde. On the other hand, when hydrogen is produced for ad-mixing with natural gas, the specification covers only a few impurities such as sulfur compounds and carbon monoxide.

Schnotz explains that product purity measurement is important also for safety. "During the design process, the risk assessment of the electrolyser will have considered the potential for oxygen from the anode to combine with hydrogen from the cathode forming an explosive gas mixture. Measuring traces of oxygen in the pure hydrogen stream and conversely measuring hydrogen in the pure oxygen stream may be appropriate risk mitigations. This is an example of what we look for during an inspection – evidence that the stipulated safety precautions have been incorporated into the final installation."