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Could hydrogen from chlor-alkali energise Europe's future?

When making chlorine and caustic soda/ potash (chlor-alkali) it is also possible to make hydrogen. This highly flammable gas has many important uses for modern society and, as an energy carrier or chemical 'building block', is seen as a key part of a climate neutral future for Europe.

As a chlor-alkali co-product, efforts are underway to utilise all of the hydrogen produced by our industry but there are technical, safety and financial limitations that need to be addressed. Any hydrogen generated from chlor-alkali compares favourably (with regards to its purity and energy requirements) with other methods of production meaning our sector's hydrogen could contribute to various European and global energy-related challenges.

An important chemistry...

Chlor-alkali chemistry is a key part of many products that make everyday life safer, healthier and more comfortable. From chlorinated disinfectants for healthy water, purified aluminium and polymers such as polyvinyl chloride (PVC) for construction, to polyurethane insulating foams and chemicals for the manufacture of pharmaceuticals, chlor-alkali chemicals are vital. Chlor-alkali materials even play a role in materials for windmills, solar panels and energy efficiency products.

Historically (19th Century), there was a desire for the alkali to make lye for soap, with chlorine as a 'waste' product. However, as production technology evolved, a market for the chlorine chemicals evolved to ensure that nothing was wasted. This 'circular' way of thinking has been carried over into the modern chlor-alkali industry and into the current discussions on hydrogen.

...with important by-products.

When chlor-alkali (chlorine and caustic soda/ caustic potash) is made, hydrogen can be formed as a co-product. This is because water (H_2O) and salt (NaCl or KCl) are 'split', by electrolysis, into the base components chlorine (Cl_2), sodium/ potassium (Na/ K), hydroxide (OH^-) and, potentially, hydrogen gas. Whilst some of these components combine together, hydrogen can be produced at the negative electrode of the electrolysis cell (Figure 1) before being collected for use. Whilst there are obvious applications for the chlorine and caustic components, the hydrogen must also be carefully considered to avoid wasting this valuable resource.

Hydrogen is the most abundant element in the universe but was first 'made' artificially by reacting metals with acids in the 16th century. There are now several technologies to produce this gas, including as a co-product in chlor-alkali production as detailed previously. In modern times though, to meet it's low carbon energy needs, the EU is looking to hydrogen as it is a clean-burning fuel that emits no carbon dioxide (CO_2) when used (especially if it is produced from climate-neutral energy sources). This important gas also has other uses in the chemical industry.

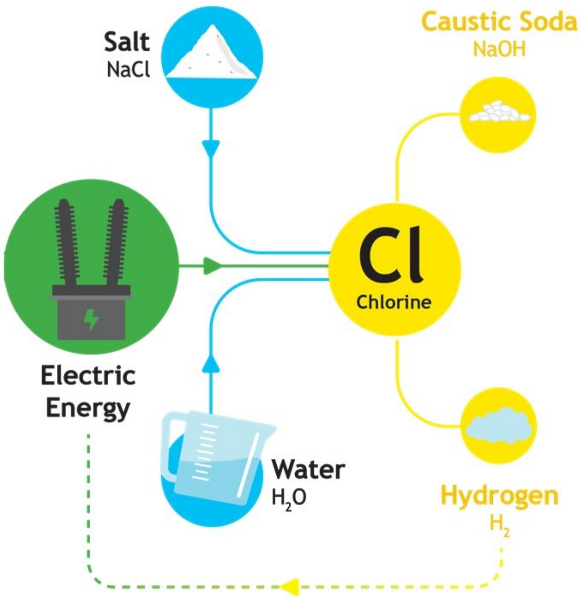

Figure 1. The chlor-alkali production process

The 'value' of hydrogen.

In the modern chemical industry, there are several key uses of chlor-alkali's co-produced hydrogen. These include:

- Burning to produce steam and/or electricity or to heat a furnace. Here, hydrogen is used as a direct energy source. It can be used to make steam to concentrate products or to evaporate/concentrate caustic and make it easier to transport. Hydrogen-derived energy can also be used to heat industrial buildings.

- Application in other chemical reactions. Many chlor-alkali production plants are connected directly to their customers. These customers may also use any hydrogen for a range of chemical reactions to make important products such as:
  - ◊Ammonia (e.g.) as a source of nitrogen for fertilisers for food and fuel crops;
  - ◊Hydrogen peroxide (e.g.) for medicine and paper production;
  - ◊Hydrochloric acid (e.g.) by carefully combining the hydrogen with the chlorine to make an acid that is important for any reaction where pH control is vital;
  - ◊Methanol (e.g.) for the production of carbon containing chemicals and as a fuel, solvent and anti-freeze;
  - ◊Removing sulfur from petrol. When combusted, sulfur in petrol can be released from cars which has been linked to acid rain.

- Direct use in fuel cells to produce electricity. There are some pilot projects to use the hydrogen to run vehicles in the chemical plants, raw material transportation barges, and in transport such as trucks and busses.

However, hydrogen is very difficult to store and must be safely handled (it is explosive and may have an impact on the global climate if accidentally released). As such, unless there is a nearby and almost immediate use for hydrogen (along with safe infrastructure to carry the gas to where it is needed), it must be 'flared' (i.e. burned) to prevent it from building up.

In 2018, Euro Chlor members reported that 87% or the hydrogen they produced was used, however 13% still had to be flared. This 'unused' hydrogen is equivalent to the annual energy requirements of 0.5 million homes, so, as part of the 2050 Euro Chlor Mid Century Strategy, European chlor-alkali is working to ensure that 100% of all co-produced hydrogen is used.

But what are the options for using such hydrogen produced from chlor-alkali?

How about using it in transport?

31% of EU energy consumption is in the transport sector. If Europe were to replace current transport energy sources with hydrogen, 80 million tons of hydrogen would be required. Whilst it may not be desirable to have household cars driving around with tanks full of hydrogen due to safety concerns, it is possible that this hydrogen could be used to make electricity to charge batteries that drive electric vehicles. Work is underway on this technology as the weight of the batteries (e.g. for trucks) must be carefully considered. Additional work must also be undertaken to make battery charging quicker and more efficient. Work would also be needed to take the hydrogen from the chlor-alkali plant to the electricity-producing location.

How about using it to heat buildings?

Heating of buildings accounts for approximately 1/4 of EU energy consumption, equal to over 90 million tons of hydrogen. Using hydrogen to instead run heat pumps is a possibility but requires the buildings to be very well insulated, as well as infrastructure to efficiently carry the 'energy' from the chlor-alkali plant without losing any. Currently, there are EU drives to renovate Europe's buildings to make them more energy efficient which could play an important role in making this a reality.

How about using it as a chemical 'building block'?

Currently around 3.3 million tons of hydrogen are used to make ammonia and methanol, which could be supplemented by hydrogen from chlor-alkali electrolysis. Hydrogen can also be used to replace coal in steel manufacturing (to remove oxygen from iron ore) or to make ethylene and propylene (used to make many important plastics). There may even be a role in making new fuels from CO_2 and hydrogen. Unfortunately, work is also needed here as these processes are not always energy efficient. Chemicals could however be used to 'carry' the hydrogen safely to the places where they are needed. This would prevent the need to carry it in tanks as a gas and reduce the safety risk. Pilot plants for this have already opened in Germany.

How about using it for energy storage?

Hydrogen can be used to store energy and transport it over long distances. When burned, only water vapour is released making it preferable to fossil fuel combustion (which has been linked to climate change). This is especially interesting as hydrogen could be made using energy from renewable and climate neutral sources. Then, as wind and solar power are not always constant, hydrogen could subsequently be used to power any 'gaps' when wind doesn't blow or the sun doesn't shine. Despite this, using electricity to make hydrogen and then liberate it again when needed is currently around 26% efficient and requires careful consideration of the stored gas.

Innovative new technologies may help to connect chlor-alkali hydrogen sources with users and further improve efficiencies and address safety concerns. These are particularly important if this gas is to be used as an energy carrier for the future of Europe. Europe's chlor-alkali industry will remain in close discussions to ensure that all hydrogen produced is used and applied correctly.

Alternatives to chlor-alkali for hydrogen production

Chlor-alkali represents just 3.5% of the total amount of hydrogen produced in Europe. Currently, most of the hydrogen (approximately 90%) is produced from fossil fuels.

An alternative technology to produce hydrogen is via the direct electrolysis of water. Here, water is split into hydrogen and oxygen. To make 1 kg of hydrogen in this way requires 60 kWh of electricity when the oxygen is vented to atmosphere. However, when all the oxygen is used for other processes, the electricity requirement for 1kg of hydrogen drops to 3.5 kWh. In comparison, to make 1 kg of hydrogen from chlor-alkali you only require 1.3 kWh of electricity. This is because you obtain additional, fully utilised, products (chlorine and caustic) which 'split' any energy costs further.

Assuming there are any greenhouse gas emissions associated with the electricity production, it is clear that (e.g.) less CO_2 would be emitted from the production of hydrogen from chlor-alkali than from water electrolysis. This means that this technology compares favourably to both fossil fuel-based and water electrolysis-based production. More information on this can be found in the Euro Chlor infographic.

Chlor-alkali derived hydrogen is of the highest purity and uses less electricity and emits less CO_2 to produce 1kg of hydrogen than (e.g.) water electrolysis. It is hoped that the volume of 'unused' chlor-alkali hydrogen will decrease over time as demand for hydrogen increases, and more application solutions become available. Any environmental footprint may also be further reduced given the drive for more climate neutral electricity across Europe.

A hydrogen strategy for Europe

With the evolution of proposals for a European 'Climate Law', work has begun to reduce the amount of greenhouse gases being emitted to make hydrogen power more viable. When produced from climate neutral energy, hydrogen could play an important role as an energy carrier for Europe. Indeed, hydrogen is seen as being essential for global efforts on climate neutrality and in implementing the Paris Agreement. As such, a regulatory framework to address the use of hydrogen is expected.

Whilst historical efforts to utilise this gas may have failed before due to costs, technologies and lack of regulatory ambition, investments are now being made to boost hydrogen production and use across the continent. Due to such interest, it is predicted that the share of hydrogen in the EU energy mix will increase from <2% to 14% by 2030 with investments in renewable hydrogen in the order of upto 470 bn EUR by 2050. Financing frameworks to support this are also being readied.

Many different sources and types of hydrogen remain under investigation but, when produced with climate neutral electricity, hydrogen is considered to be a 'green' energy carrier. Given the fact that, compared to other sources, less energy is required and vital chemicals are produced (i.e. chlorine and caustic soda/ caustic potash), it could be argued that if climate neutral electricity is used, chlor-alkali hydrogen production is 'green' too and could play an important role.

In cooperation with hydrogen-experts at Cefic (European Chemical Industries Council), Euro Chlor will continue to monitor these developments and contribute to discussions as appropriate. More detailed information on hydrogen and chlor-alkali will then be presented at www.eurochlor.org.

Hydrogen remains a vital part of chlor-alkali and could play a key role in Europe's future.

More information?

Cefic Hydrogen Information

Euro Chlor Hydrogen web page

Euro Chlor Hydrogen Technical Infographic

Euro Chlor Communications
Rue Belliard 40 (box 15)
B—1040 Brussels
Tel. +32.2.436.95.08.
eurochlor@cefic.be

Find out more about chlor-alkali at www.eurochlor.org

A Sector Group of cefic