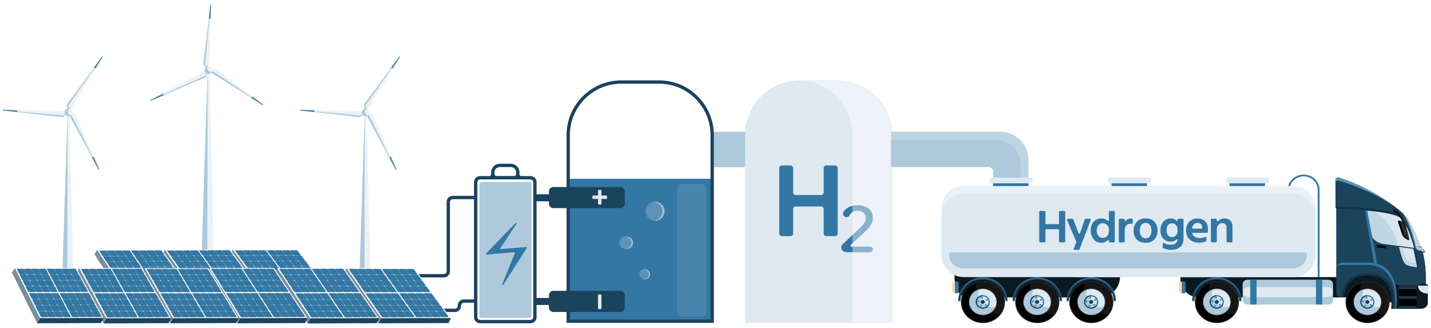

RENEWABLE HYDROGEN

Quest explores how solar and wind energy can be used to produce 'green hydrogen'

Opponents of investment in renewable energy often point out that solar and wind energy is not a reliable or consistent power source. Sunshine and wind naturally vary throughout the day, so some kind of energy storage is required, typically in the form of batteries. Back-up power is also needed for longer periods of insufficient sunshine or wind, and currently that comes from coal-fired, nuclear or gas-based power plants.

In future though, both energy storage and back-up power could be provided by 'renewable hydrogen' emanating from wind farms or photovoltaic power plants. At times of excess supply, the electricity from these renewable energy installations could be passed to an electrolyser, where hydrogen is produced through electrolysis – using an electrical current to induce a chemical reaction that splits compounds or elements into smaller parts. In this case, electrolysis would be used to split water into hydrogen and oxygen. The hydrogen could then be stored until it is needed at peak demand periods to generate electricity in a hydrogen fuel cell or hydrogen internal combustion engine. Alternatively, the hydrogen could be used in vehicles running on these technologies.

Adoption of hydrogen technologies is partly dependent on the ability to store and transport hydrogen safely and efficiently, so this has become a key focus area of research worldwide. Hydrogen is the lightest gas in the universe, with an enormous volume under atmospheric pressure, so its density must be increased in order to store and transport it. The three options for storage are (a) as a compressed gas in high-pressure tanks, (b) as a liquid in cryogenic tanks that keep the temperature at around −253°C and (c) as a solid or liquid in another material, through adsorption or chemical reaction.

In South Africa, the HySA Infrastructure Centre of Competence, co-hosted by North-West University (NWU) and the CSIR, conducts research and development on hydrogen production, storage and delivery. The CSIR team has largely focused on developing porous materials-based storage technologies, such as metal-organic frameworks and carbon nanostructures, as well as high-pressure composite cylinders for lightweight applications, for use in portable power systems and fuel cell vehicles.

At NWU, much of the emphasis has been on water electrolysis stack development and on chemical carriers, including ammonia, formic acid and LOHC. The latter stands for Liquid Organic Hydrogen Carrier, and it refers to organic compounds capable of reversible hydrogenation and dehydrogenation – in other words, those that can absorb and release hydrogen through chemical reactions. In an LOHC system, a hydrogen-lean organic compound is loaded with hydrogen in a catalytic reaction for hydrogen storage; when the hydrogen is needed another catalytic reaction converts this hydrogen-rich compound back to the hydrogen-lean one, releasing hydrogen in the process.

Hydrogen production pathways

Grey hydrogen: Currently, over 95% of H_2 produced worldwide comes from fossil fuels, mostly via steam methane reforming (SMR) of natural gas, which releases CO_2 into the atmosphere.

Brown/black hydrogen: Gasification of either lignite (brown) or bituminous (black) coal produces syngas, comprised mostly of H_2 and carbon monoxide (CO), with CO_2 released in the process.

Blue hydrogen: The same processes as for grey/brown/black hydrogen, but the CO_2 is captured and stored, reducing the environmental impact.

Green hydrogen: Hydrogen produced by the electrolysis of water. If the electricity used in the electrolysis is produced from renewable energy sources, there are no CO_2 emissions.

HySA

HySA Infrastructure's solar-to-hydrogen facility on the NWU Potchefstroom campus relies on a 55 kW photovoltaic (PV) installation and an electrolytic hydrogen-generation system.

One of the best LOHCs identified to date is dibenzyltoluene, so the NWU team – led by Prof. Dmitri Bessarabov, who is also the Director of HySA Infrastructure – has investigated the potential of Marlotherm SH, a heat-transfer fluid produced by Sasol. It is a mixture of dibenzyltoluene isomers and is used in various industries for indirect heating of reactors, polymerisation vessels, distillation columns, as well as in heat exchangers and heat-recovery systems. The advantage of dibenzyltoluene as an LOHC is that it is stable when stored for long periods under ambient temperature and pressure conditions. It can also be distributed via existing pipelines, tankers and petrol stations used for liquid fuels, but unlike petrol and diesel it has low toxicity and is non-flammable and non-explosive.

After conducting tests on lab-scale hydrogenation and dehydrogenation systems, the HySA NWU team successfully commissioned a pre-commercial scale hydrogenation plant using this LOHC technology in collaboration with Framatome GmbH. The plant is linked to the HySA NWU solar-to-hydrogen facility, which comprises a 55 kW photovoltaic installation and an electrolytic hydrogen-generation system, with facilities to test various fuel cells provided by manufacturers or to conduct research projects by students.

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The Cofimvaba Science Centre in the Eastern Cape, officially opened on 6 October 2021, has an electrolytic hydrogen-generation system coupled to a 35 kW solar PV system and a 5 kw hydrogen fuel cell installed by HySA Infrastructure.

HySA

The HySA NWU team conducted extensive tests using this laboratory-scale hydrogenation system to assess the performance of dibenzyltoluene as a Liquid Organic Hydrogen Carrier (LOHC).

Apart from this 'power-to hydrogen' system, research is also carried out on 'power-to-methane' technology, which combines the hydrogen with carbon dioxide (CO_2) in a catalytic Sabatier reaction to form methane (CH_4). This gas is in high demand for its uses in industry and as a fuel for heating, lighting and (when burned in gas- or steam-turbines) electricity generation. Interest in methane-fuelled vehicles is also growing – according to a *Forbes* webpost from 8 November 2020, there are already 23 million such vehicles worldwide, although these 'fill up' with methane from underground natural gas sources, landfills or food waste processing facilities.

The HySA NWU team is currently participating in the EU-funded SherLOHCk project, which aims to reduce the system cost for LOHC technology to 3€/kg for large-scale applications. Their specific input will be contributing towards the fundamental understanding of catalyst activities for dehydrogenation reactions.

For more information about the HySA NWU facilities, visit https://hysainfrastructure.com/our-facilities/nwu-facilities/
There is a link to a 360-degree virtual tour. Click on the navigation bar on the left for specific facilities, or click on the round mirror on the opening screen to tour the building from the entrance.

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