OPINION

Prospects and limitations for a hydrogen economy in South Africa

Many countries around the world, including South Africa, are weighing up the prospects and limitations of the production and distribution of "green hydrogen" as part of a greener energy economy. So writes Bo Barta.

In South Africa, the process of building up a hydrogen economy is closely associated with the decarbonisation of energy generation, which is based primarily on the coal-fired power station. This process is being focused in South Africa on extensive development of renewable energy, mainly by the on-shore wind and solar radiation by means of solar photovoltaic (PV) and concentrated solar power (CSP) technologies.

The other technologies and resources available and suitable in South Africa are hydropower, biomass, tidal and wave energy generation, which seem rather unattended and omitted from the future production and export of green hydrogen.

Table 1: Essential background about green hydrogen production by electrolysis in South Africa

By definition: **1 kg of hydrogen requires allocation of 8,94 kg (or 9 litres) freshwater** and overall reverse osmosis (RO) of sea or brackish water requires between 5 and 3,5 kWh of energy. NB: The **energy needed for splitting of water into hydrogen and oxygen** can be determined by following equation: **$\Delta G = n*F*E_{rev}$**; where: n = no. of electrons involved; F = 96 500 (Faraday's constant); E_{rev} = reversible voltage = $\Delta G/nF$ = 1,23 V.
Notes: (i) The water electrolysis powered by renewable energy sources (e.g., sun, wind, hydropower, tide/wave or even by biomass) can be integrated into a distributed energy system to produce green hydrogen for end use or as an energy storage medium. Alkaline water electrolysis is the most common technology used, but the production equipment is relatively complicated, including electrolyser, pressure regulating valve, lye filter and circulation pump, storage device, hydrogen purification and gas detection device and other modules. The density of hydrogen is 1/14 of air. (ii) The hydrogen production by electrolysis of freshwater, besides needing electricity, will utilise water in the consumptive manner, therefore subjected to all legislative requirements of the National Water Act (Act 36 of 1998). If the green hydrogen is exported, the production is classified as "virtual water" (e.g., export of citrus, vine, beer, etc.)

The hydrogen gas can be extracted from water by the process in electrolysing preferably of the freshwater or generated by steam reformation of the hydrocarbons (e.g. coal, oil, etc.). The product, so-called "grey hydrogen", which if combined with the carbon monoxide, can produce a synthetic gas (or syngas by Fischer-Tropsch technology) has been produced in South Africa for decades by the coal-to-gas giant, Sasol.

By international standards, the grey hydrogen can be labelled as "blue hydrogen" which is methane or coal derived, but the production process is accompanied with the carbon capture (e.g., in the defunct sealed mines, etc.). Any hydrogen generation processes described will need a reliable supply of electricity, which is rather inadequate and unreliable in South Africa at present. Unless both the reliability and stability improve the production of green hydrogen will be not guaranteed. The supplies from the RE sources are subject of intermittency without storage.

The entire South African economy is dependent on one only electricity generator and distributor represented by Eskom Holdings (Pty) Ltd. This entity generates and provides electricity supplies from the national electricity grid which is labelled internationally as the largest greenhouse gases (GHG) emitter on the African continent, due primarily to coal-fired generation. To rectify this situation and if South Africa would like to become a significant producer of green hydrogen as well as carbon-neutral fuels and other chemicals, it needs to synchronise the development of all types of renewable energy resources with the development and beneficiation of its platinum group metal reserves and appropriate conversion of the industrial synthetic-fuels production. However, the serious limitations to such development and conversion of the South Africa's economy are manifesting from where come from the large quantities of water of relevant quality as well as the renewable energy supplies to reduce dependency on the coal-fired generation.

South Africa is recognised as a water stressed country, and it has not much freshwater to spare for electrolysis, however, the country does have access to an abundance of seawater. This seawater has to be desalinated prior to entering the electrolyser, which becomes an expensive extra step with regard to primarily the electricity requirements. To date, research in this sphere suggests that a thin semi permeable membrane replacing the reverse osmosis (RO) membrane is placed in the electrolyser, this means by a principle that the seawater pushed through electrolyser does not require the RO membrane, but an electrolyser provides the RO function itself. Nevertheless, the price of such process is at present exorbitant in South Africa and the research is not fully concluded. Presently, a well-established electrolysis process is based on the Proton Exchange Membrane (PEM), which is making use of platinum iridium and hydrogen fuel cells (platinum is a catalysator) in water electrolysis which is depending on the cooling efficiency of adopted system. The PEM water electrolysis hydrogen technology can be connected to hydropower, wind, solar and other renewable/alternative (e.g., nuclear) sources of energy for the required energy inputs. Internationally, the green hydrogen technology (i.e., PEM electrolysis) supplier is Nel Hydrogen in Norway (info@nelhydrogen.com).

For the obvious reasons outlined above, the South African near-future options in producing green hydrogen are limited to primarily splitting good quality freshwater, which is mainly stored in existing medium and large dam impoundments. Several of those are underutilised as the allocations to the mining, urban/industrial and agricultural users are gradually reducing on account of the technological and social-economic changes within such sectors. It is estimated that about 30 dams (i.e., from a total of 5 100 man-made impoundments) can be equipped by a small to large electrolysis plants to produce the green hydrogen in a hybrid configuration of hydropower and floating solar PV rafts to reduce extensive evaporation as a positive trade-off. There are a few potential locations to focus on, mainly on existing dam storages close to and supplying presently the coastal metropolitan municipalities, which in the near to medium future will have to invest into a significant desalination processes to cover increasing demand for potable water and to cope with the consequences of the climate change increasingly manifesting in the Southern Africa sub region.

According to the ***Hydrogen Strategy and Investor Roadmap*** (HS&IR) introduced in South Africa in 2021, the country's yearly production of green hydrogen for local and import uses is envisaged in order of 3,8-million tonnes by 2050 (1 tonne = 1000 kg) – this appears to be a very low estimate and it is questioned. Thus, the freshwater requirements will be in order of some 34 million m^3 per annum. Such use of freshwater will be highly consumptive subjected to South Africa's legislative requirements in allocation of relevant permits and if the green hydrogen will be exported, such water to be classified as the virtual water as is for instance water used and exported of the agricultural products. In South Africa, the water required for the generation of the green hydrogen by electrolysis could be available from gradually discontinued Eskom dry-cooling coal-fired power stations. The availability of freshwater for the generation of green hydrogen to be exported is a subject of more detailed investigation, particularly at the likely locations of large electrolyser installations. From the survey of public domain information sources on the implementation and development of green hydrogen infrastructure the following might be of interest and is presented in Table 2.

Table 2: Known development of green hydrogen installations in selected countries as in 2020

Project location	Description	Remark
Australia (Victoria)	10 MW electrolysis facility to produce green hydrogen at the wastewater treatment plant by 2023	Hydropower generation of electricity
Australia (Queensland)	3 000 MW green hydrogen electrolysis facility project is being designed for the export of green hydrogen	RE technology in generation of electricity
Australia (Tasmania)	A hydropower powered 250 MW ammonia plant installation producing ultimately some 250 000 tonnes/year for the domestic and international export	Hydropower generation of electricity
Canada (Quebec)	An electrolysis installation of 88 MW in capacity to produce green hydrogen of some 11 100 tonnes/year and some 88 000 tonnes/year of oxygen	RE technology in generation of electricity
DRC (Africa)	Kamoa Copper Mine is hydroelectricity powered from of hydropower installations of combined capacity of 240 MW to be producing the green copper output of some 600 000 t/year	Hydropower generation of electricity
Germany	A green hydrogen hybrid configuration project including installation of electrolysis plant of 100 MW in capacity planned for commission in 2025	RE technology in generation of electricity (wind and solar)
North Wales (UK)	a hydrogen modular reactor (HMR) of 3 000 MW using wind energy generation designed to produce some 3-million kg of green hydrogen by 2027	RE technology in generation of electricity (wind)
South Africa (Limpopo)	Anglo American Platinum developing a pilot plant of initial solar PV capacity of 3,5 MW to produce 1 ton/day of green hydrogen to power the fuel cells for running large haul trucks	RE technology in generation of electricity (solar PV)
South Africa (Limpopo)	10 MW solar power plant at the Zonderreinde PGMs mine intended to produce green metals; another 100 MW solar PV installation is planned at Mogalakwena mine in the Limpopo Province to be operational by the end of 2023	Both planned installations will be using RE solar PV sources in generation of electricity
South Korea	A liquefied hydrogen facility is being constructed for urban/domestic supply of some 30 000 tones/year	Renewable energy source of electricity
Sweden	A hydrogen storage facility of some 100 m3 is being installed at the rock cavern some 30 m below the ground to be commission by 2024	Renewable energy source of electricity
Switzerland	A hydropower plant on the Rhine River of 2,5 MW in capacity is being installed for the production of some 350 tonNes/year of green hydrogen.	Hydropower generationof electricity
Note: The financial outlay is very seldom given for the consideration of the public domain on the project development, but from limited information available it may be established that one MW of electrolyser capacity in South Africa might be in order of Rand 35 to 40 million (2020 basis). The production of green hydrogen on the background of international market prices amounts to Rand 70 per one kg at present.		