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Bringing hydrogen to Singapore for clean fuel

To accelerate the commercial use of hydrogen (H2) as a renewable energy source in Singapore, Nanyang Technological University (NTU) and various industry collaborators are working on improving the efficiency of extracting hydrogen from liquid organic hydrogen carriers (LOHCs). LOHCs are organic compounds that can be chemically induced to store and release hydrogen, making them a convenient way to transport hydrogen from overseas production facilities without having to liquefy the gas by extreme cooling and high pressure.

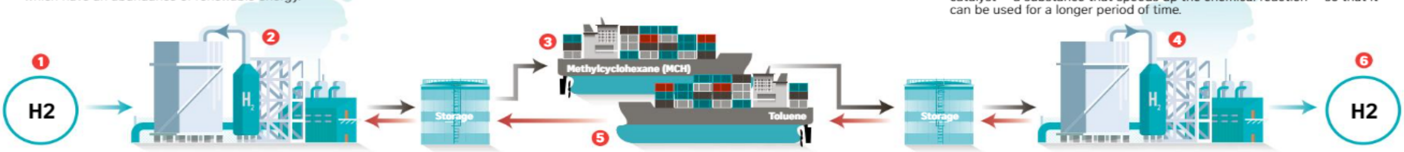
One company, Chiyoda Corp, has already developed its own hydrogen storage and transport technology. This is how it works:

CLOSED-LOOP GREEN H2 TRANSPORT

1 **H2**
Green hydrogen is produced by splitting water into hydrogen and oxygen using electricity from renewable sources, like wind and solar power, which ensures that no carbon dioxide is emitted in the process – making the gas a clean fuel. This can be done in countries such as Australia and Chile, which have an abundance of renewable energy.

3 **Transport**
MCH is a liquid at ambient temperature and pressure, and can be safely stored and transported using petroleum tankers.

4 **Dehydrogenation**
In Singapore, the hydrogen is released from MCH via a chemical reaction known as dehydrogenation. Researchers at NTU aim to reduce the cost of the hydrogen extracted, by improving the efficiency of the reactor needed for the dehydrogenation process and improving the stability of the catalyst — a substance that speeds up the chemical reaction — so that it can be used for a longer period of time.



2 **Hydrogenation**
During this process, hydrogen is added to an organic liquid compound, toluene, forming another liquid compound known as methylcyclohexane (MCH).

5 **Reusing raw materials**
Toluene, the by-product of the dehydrogenation process, can be repeatedly recycled as a raw material for producing MCH.

6 **H2 fuel**
Trials include testing the viability of hydrogen-powered vehicles with PSA Corp. Eventually, hydrogen can be used in sectors such as power generation, transport and town gas.

Source: NANYANG TECHNOLOGICAL UNIVERSITY, CHIYODA CORPORATION STRAITS TIMES GRAPHICS

Low-carbon hydrogen fuel tech could be used nationwide by 2030

Cheryl Tan

New technology to transport and extract low-carbon hydrogen fuel to Singapore is being developed in the Republic and could be implemented on a national scale as early as 2030.

This means the clean fuel could soon play a bigger role in everyday life – from powering vehicles to power generation.

Companies such as port operations group PSA Corp are looking to adopt hydrogen as a fuel for their vehicles to lower their carbon footprint, while energy company City Energy is hoping to use green hydrogen for town gas production.

A consortium, comprising Nanyang Technological University (NTU), the National University of Singapore (NUS), Japanese engineering firm Chiyoda Corp and other industrial players, could bring about a steady supply of hydrogen into Singapore and accelerate its commercial use here.

This can be done by using liquid organic hydrogen carriers, or LOHCs, which are organic compounds that can be chemically induced to store hydrogen for transport. Once the LOHCs reach their destination country, the hydrogen is extracted for use.

Dr Xu Rong from NTU's School of Chemical and Biomedical Engineering told The Straits Times that low-carbon hydrogen could first be produced overseas using electricity generated from renewable resources such as solar and wind energy, before it is transported to Singapore using LOHCs.

"The production could be done in countries like Australia and Chile where renewable energy is in abundance, and diversifying the sources of Singapore's energy imports ensures the lowest cost and minimal supply risk of renewable energy," said Dr Xu.

Singapore has announced plans to trial the import of low-carbon or clean electricity from Malaysia, Indonesia and Laos. The Republic plans to import 30 per cent of its energy from low-carbon sources by 2035.

Green hydrogen, which is produced by splitting water into hydrogen and oxygen by using renewable electricity, emits no carbon dioxide during the production process.

OBTAINING CLEAN FUEL

The production could be done in countries like Australia and Chile where renewable energy is in abundance, and diversifying the sources of Singapore's energy imports ensures the lowest cost and minimal supply risk of renewable energy.

DR XU RONG, from Nanyang Technological University's School of Chemical and Biomedical Engineering, on how low-carbon hydrogen could first be produced overseas using electricity generated from renewable resources.

Hydrogen does not emit any carbon dioxide when it is burned, thereby making it a clean fuel.

A promising type of LOHC used by Chiyoda involves adding hydrogen to an organic compound known as toluene, which produces another liquid compound known as methylcyclohexane (MCH).

MCH can be easily transported from overseas production facilities in conventional petroleum tankers as it remains in its liquid state at ambient temperature and pressure.

Without a carrier like MCH, the hydrogen will need to be pressurised and cooled to minus 253 deg C, then transported as liquid hydrogen in tankers that maintain an environment needed for it to stay in its liquid state.

Once the MCH reaches local shores, the hydrogen is extracted via another chemical reaction known as dehydrogenation, leaving behind toluene as the by-product. The toluene can then be recycled as a raw material for producing MCH.

This technological innovation developed by Chiyoda is known as Spera Hydrogen.

To reduce the cost of hydrogen for commercialisation, Dr Xu and her team have been looking at improving the performance of the catalyst – a substance that speeds up the chemical reaction – and the reactor needed for the dehydrogenation process.

For example, improving the stability of the catalyst such that it has a longer lifespan could help to drive down costs.

Low-carbon hydrogen currently costs more than US$3 (S$4.10) a kg. Its price must drop to about US$2 a kg to be comparable to hydrogen generated from fossil fuels, said Dr Xu. The extracted hydrogen can be used in various sectors, such as transport, and town gas and power generation.

For hydrogen-powered vehicles, extremely pure hydrogen – of more than 99.9 per cent purity – is required, said Dr Xu. The presence of contaminants could affect the performance of the fuel cell.

Once the cost of hydrogen production and transport has been reduced to a certain target in laboratory settings, the technology will then be trialled on a larger scale with PSA, one of the industry players in the consortium, Dr Xu said.

"This test-bedding is important because we want to ensure the operational feasibility of this technology in Singapore."

In collaboration with all industrial members of the consortium, Professor Iftekhar Abubakar Karimi from NUS' Department of Chemical and Biomolecular Engineering will be leading a study on integrating hydrogen transport and extraction technology with the processes on Jurong Island, such as for the power generation and petrochemical industries.

The research projects will help the consortium to semi-commercialise the hydrogen technology from 2025 or 2026, and fully commercialise it from 2030.

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