November 2, 2021

ENEOS Corporation
Chiyoda Corporation
Queensland University of Technology

ENEOS, Chiyoda, and QUT Successfully Scaled Up an Australian CO_2-Free Hydrogen Supply Chain Demonstration using Direct MCH® ~Filling a FCV with hydrogen derived from renewable energy~

ENEOS Corporation (President: Ota Katsuyuki; "ENEOS"), Chiyoda Corporation (President: Masaji Santo; "Chiyoda"), and Queensland University of Technology (President: Margaret Sheil; "QUT") announced that they had succeeded in expanding the scale of their technological verifications of CO_2-free hydrogen to a practical level for the first time in the world. We commenced technical verifications of the production, transportation, and dehydrogenation of CO_2-free hydrogen in 2018.

In order to store and transport hydrogen, it was previously necessary to store hydrogen produced via water electrolysis in a tank, then convert it to methylcyclohexane ("MCH"), which is a type of organic hydride. The technology developed by ENEOS significantly simplifies this process, by directly producing MCH from water and toluene through the electrochemical synthesis of organic hydride[*2](Direct MCH® [*3]).

In March 2019, ENEOS, Chiyoda and QUT succeeded in directly producing MCH from water and toluene derived from Australian renewable energy, transporting this MCH to Japan, and extracting hydrogen from it. This was the first successful verification of such a technology in the world, but produced only a lab-sized amount of MCH containing 0.2 kilograms of hydrogen. We have expanded the scale of MCH produced to a practical level so that it contains approximately 6 kilograms of hydrogen; they have also extracted hydrogen from this MCH in Japan, and actually used the hydrogen to fill and drive a fuel cell electric vehicle (FCEV).

For the reasons listed below, the technologies of ours used in this technological verification are superior to other technologies for a transportable hydrogen supply chain.

Party	Technology	Features
QUT	Concentrated Photovoltaic Power Generation System	A power generation system that captures sunlight by gathering solar irradiation with a Fresnel lens and adjusting the orientation of solar panels according to the position of the sun; compared to fixed-array solar panels, the system generates a much higher amount of electricity per unit surface area.
ENEOS	Direct MCH®	A high-efficiency electrolysis process that converts toluene directly into MCH, without first converting it into hydrogen; it is capable of reducing facility costs for MCH production by approximately 50%[*4] compared to the conventional process to produce MCH.
Chiyoda	Dehydrogenation technologies	Using independently developed catalysts and dehydrogenation reactors, the technologies generate extremely high hydrogen yields from MCH.

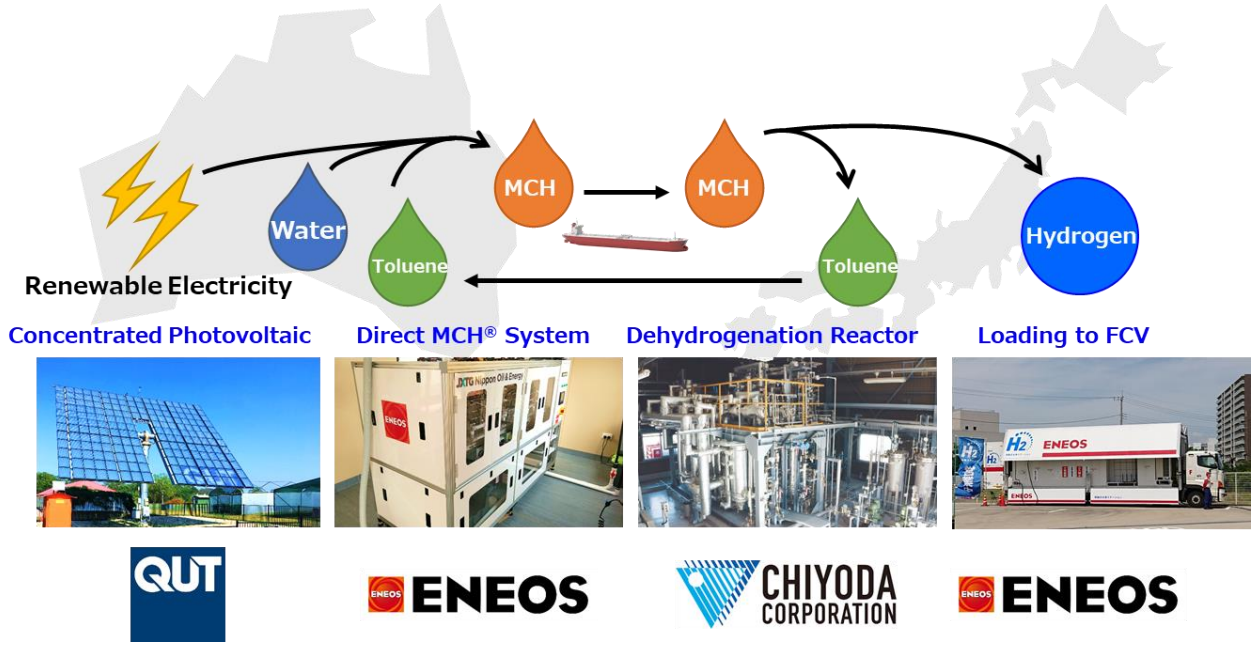
In anticipation of a hydrogen-oriented society, ENEOS intends to further increase production volumes of MCH. The current technological verification is the first stage of an initiative to scale up the electrolyte cell required for its Direct MCH® technology. In 2023, ENEOS plans to complete a medium-sized electrolyzer with an output of 150 kilowatts (with an electrode surface area of about 3 square meters), which will form the basis of a larger-sized electrolyzer. In 2025, the company aims to develop a larger-sized electrolyzer with an output of 5 megawatts. Looking further ahead, ENEOS is engaged in technological development with the goal of establishing CO_2-free hydrogen supply chains by around 2030.

ENEOS, Chiyoda, and QUT will continue their industry-academia collaboration with the goals of developing and implementing commercial-scale technologies for the production of CO_2-free hydrogen at the earliest opportunity, and of contributing to the realization of carbon neutrality in Japan by 2050.

*1 Normal temperature, normal pressure liquid with a mass of 1/500 of hydrogen gas. It is characterized by ease of handling in storage and transport.
*2 Direct MCH electrochemical synthesis is a method of producing MCH directly from water and toluene, derived fromrenewable energies or other sources of electricity.
For further details about Direct MCH electrochemical synthesis, please see the following news release:
<Succeeded in the world's first technical verification to produce "CO2-free hydrogen" at low cost | News Release | ENEOS Corporation>
*3 Direct MCH® is a registered trademark of ENEOS Corporation.
Part of the development of this technology was carried out in partnership with Professor Shigenori Mitsushima of National University Corporation YOKOHAMA National University, and De Nora Permelec Ltd.
*4 “Approximately 50%” is the estimated cost, calculated by ENEOS, for when the technology is at scale in the future.

Reference

Technological verification process and image



1. QUT generates power using its Concentrated Photovoltaic Power Generation System
2. Using the 100-percent renewable electricity generated from 1., a 2-kilowatt electrolyte cell system that incorporates Direct MCH® technologies is used to produce MCH in Australia
3. This MCH—which contains approximately 6 kilograms of hydrogen, enough to fill one FCV—is transported to Japan
4. Chiyoda dehydrogenates the MCH and purifies the resulting hydrogen so that it meets the ISO 14687 international standard
5. The CO_2-free hydrogen is used to fill an FCEV at the ENEOS Tokyo Itabashi Hydrogen Station, and it is verified that the FCV can actually be driven

Roadmap for future development of Direct MCH® technologies

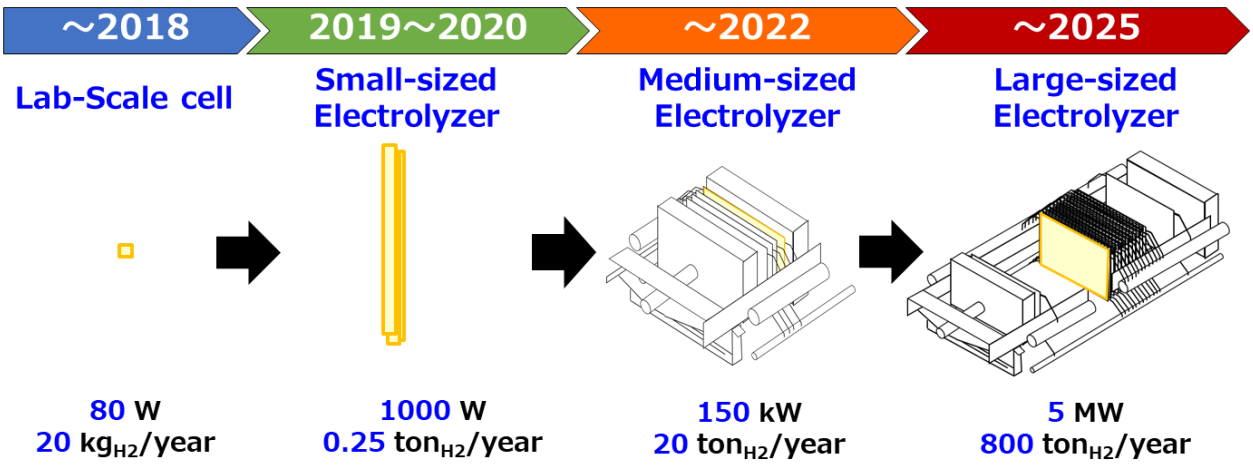
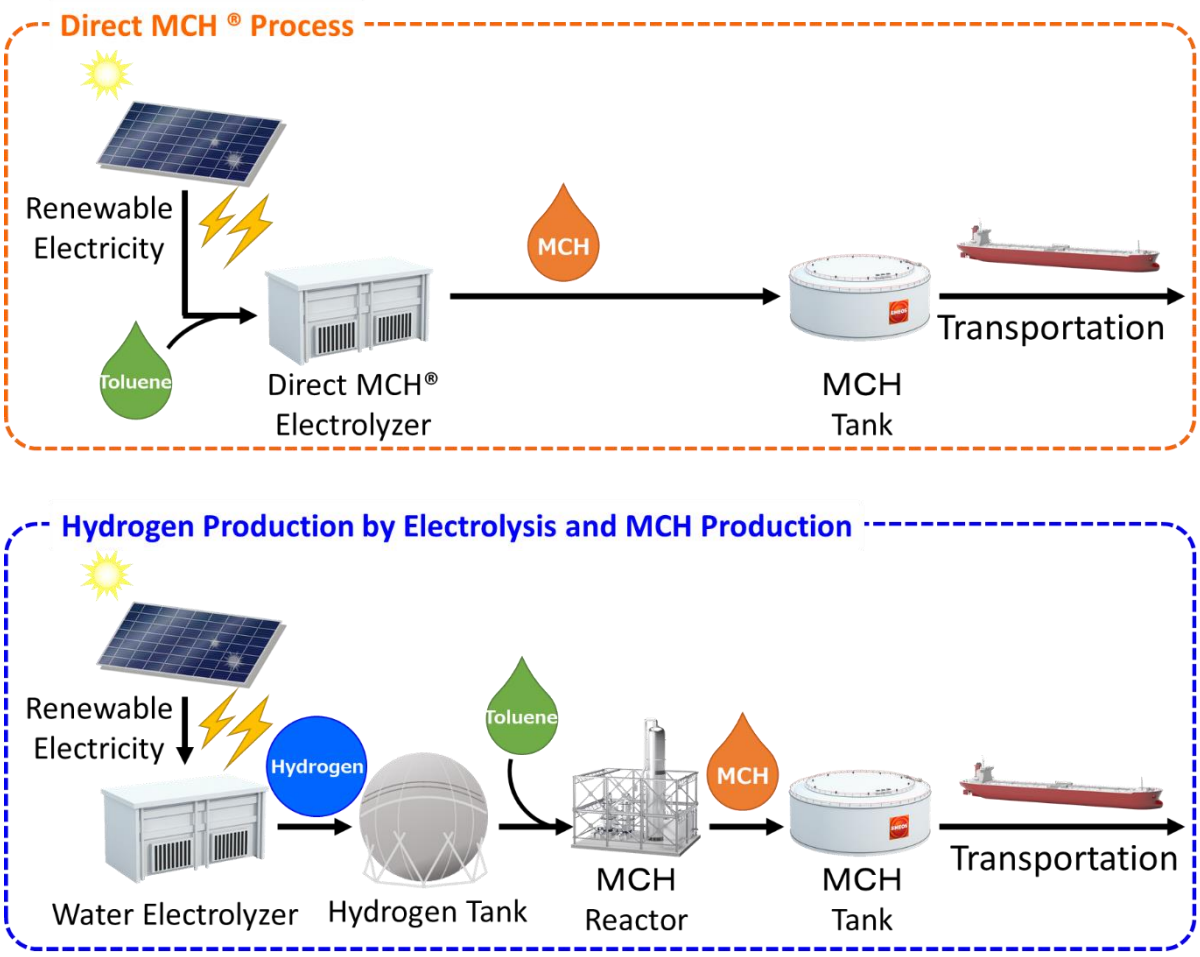
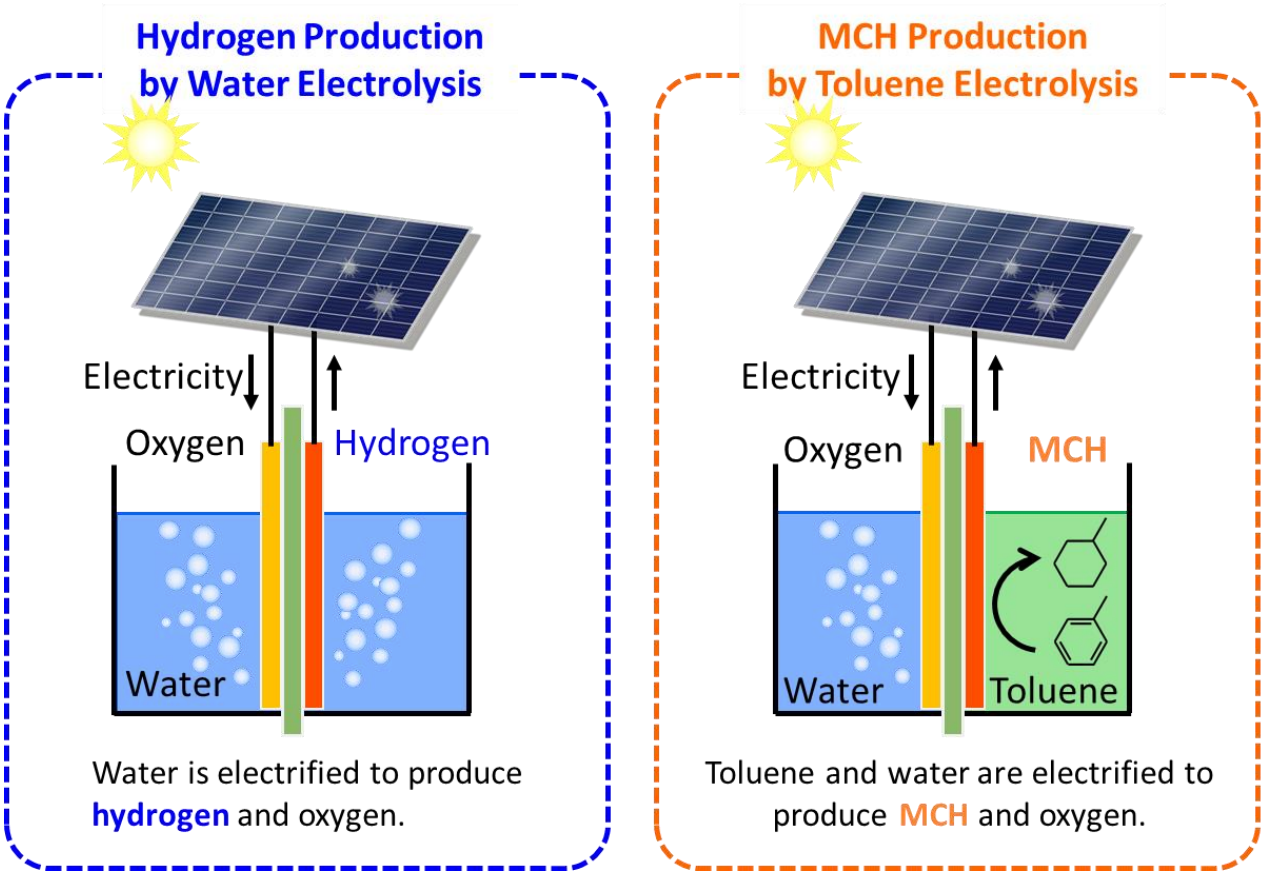


Image of process simplification by Direct MCH®



Overview of Direct MCH electrochemical synthesis (Direct MCH®)



Hydrogen gas has low energy density, requiring large volumes of space for storage, and must therefore be liquefied at -253˚C. For this reason, developing technologies to transport hydrogen is of the utmost urgency.

ENEOS independently developed Direct MCH® technology uses electrochemical reactions, similar to water electrolysis, to produce MCH directly, by causing toluene, an organic substance, to add hydrogen. Since MCH is a liquid at normal temperature, it can be transported in a similar way to oil; and since Direct MCH® does not require hydrogen gas to be produced as an intermediate step, it has the potential to significantly reduce costs associated with the production of CO_2-free hydrogen.

Media contacts:

ENEOS Corporation	PR Department PR Group	Email: pr@eneos.com
Chiyoda Corporation	IR, PR & CSR Section	Email: irpr@chiyodacorp.com
Queensland University of Technology	Ian Mackinnon Professor	+61-7-3138-7656