The Energy Conservation Center、Japan
ECAP34

Global hydrogen Value Chain Solution

November 12th, 2024

Chiyoda Corporation
Yoshimi Okada

- **Who we are**
- **Chiyoda’s efforts for Energy Transition and Decarbonization**

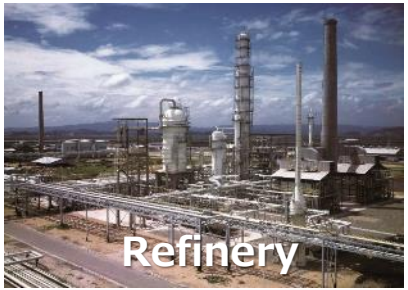
CHIYODA CORPORATION

Who we are :Chiyoda's Philosophy

Chiyoda has been providing pioneering engineering solutions for each generation since 1948, and under our company's philosophy 'Energy and Environment in Harmony', continues our vision of 'serving society through technology'.

From Coal to Oil, Oil to Gas, Gas to Renewables and New Energy

1948–1970 **1971–1990** **1991–2000** **2001–2010** **2011–2020**



1960
Mitsubishi Oil Co., Ltd.
Mizushima grassroots refinery

2004
LNG plants for Qatargas
Operating Company Limited

2018
World's largest battery power storage system project in Hokkaido, Japan

2015-2020
World's first global hydrogen supply chain demonstration project

Chiyoda's Vision for the Future

Engineering that shapes the future of energy and the global environment

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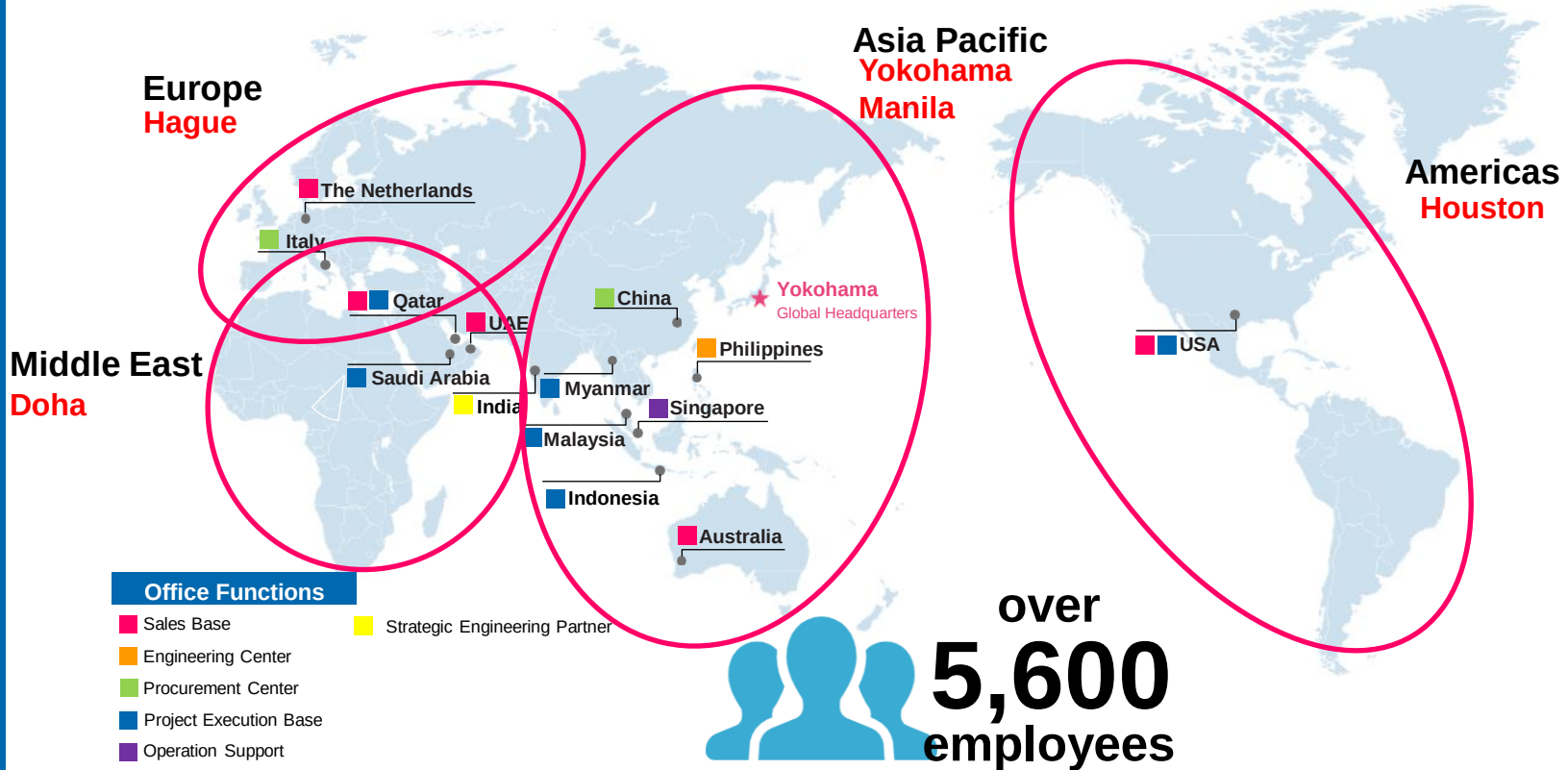
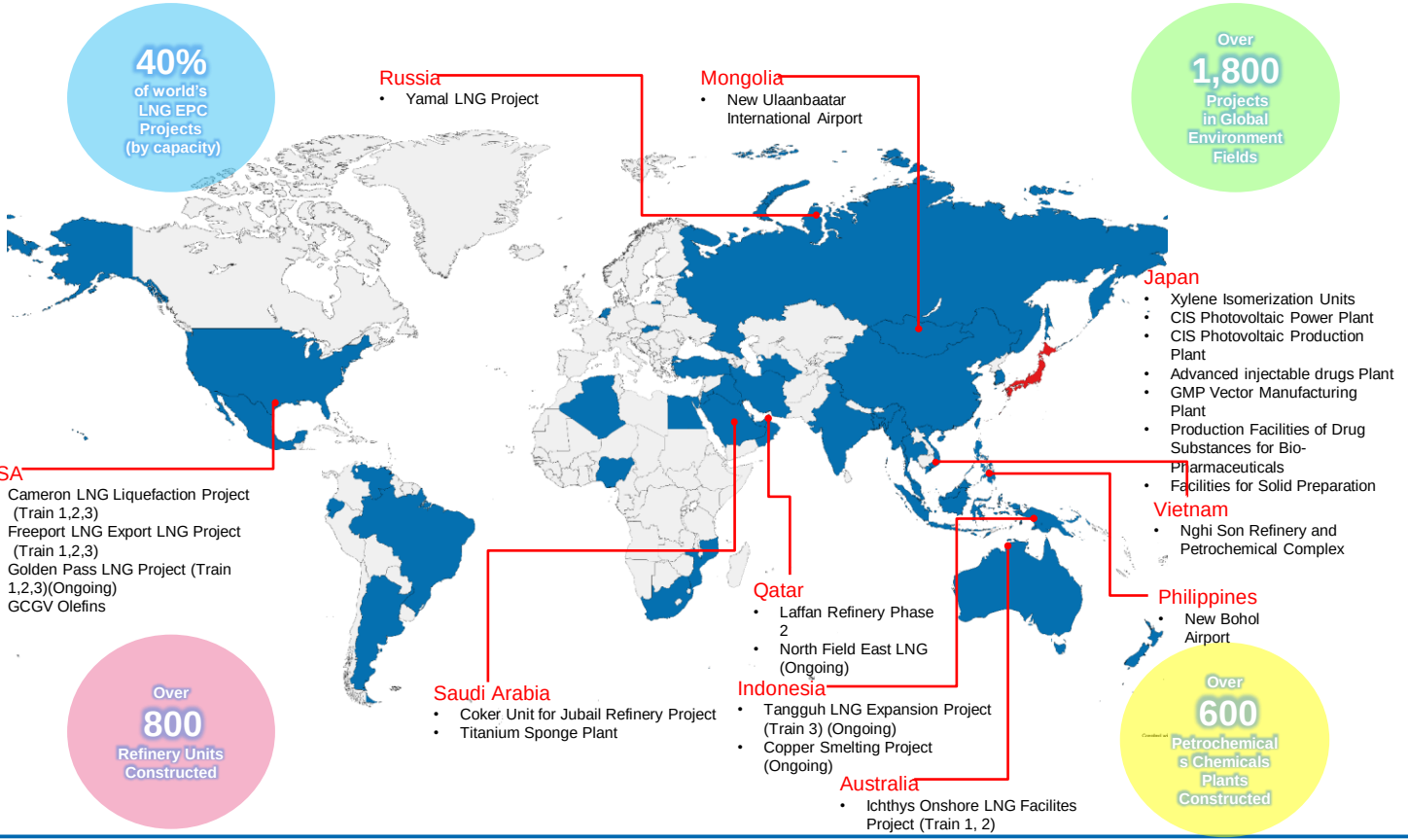
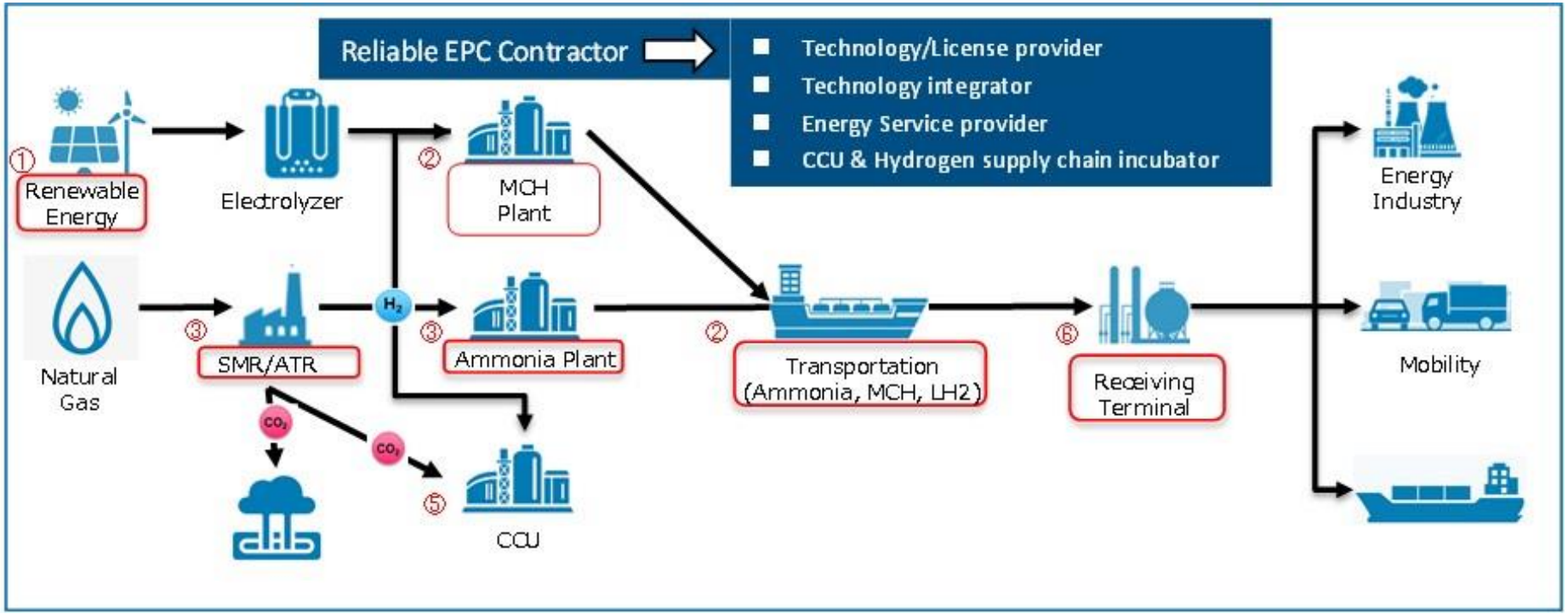
Global Operation (Network and Resources)



Chiyoda's Project Foot Prints



Chiyoda's Approaches to Energy Transition



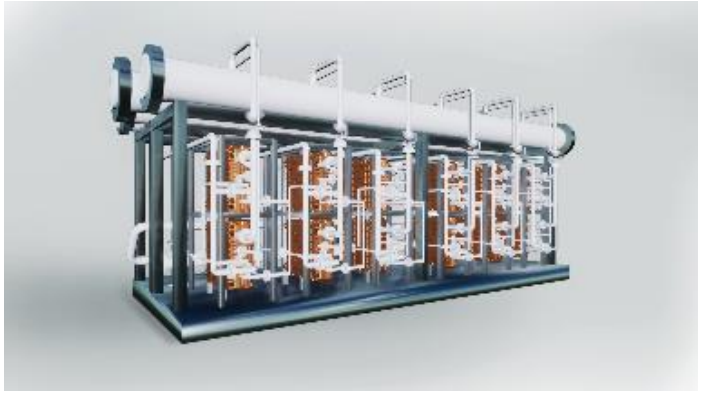
Chiyoda and Toyota Jointly Developing Large-scale Electrolysis System

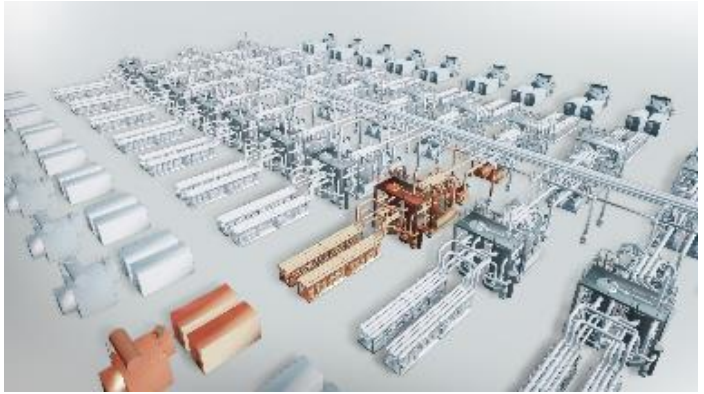
Chiyoda Corporation and Toyota Motor Corporation have agreed to jointly develop a large-scale electrolysis system and construct a strategic partnership and have signed agreement on cooperation.

The goal is to contribute to achieving the government targets for the introduction of electrolysis equipment both in Japan and overseas as part of the Basic Strategy on Hydrogen formulated by the government.

The production and mass production technologies for electrolysis cell stacks using the fuel cell technology held by Toyota and the processing plant design technologies and large-scale plant construction technologies held by Chiyoda will be brought together to develop a large-scale electrolysis system that can be competitive. This will allow adaption to the rapidly expanding hydrogen production markets both inside and outside Japan.

Press Release : https://www.chiyodacorp.com/media/240205_e.pdf

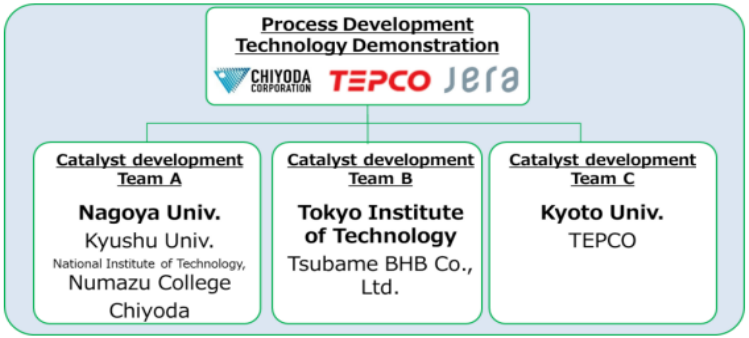




R&D for Ammonia production technology

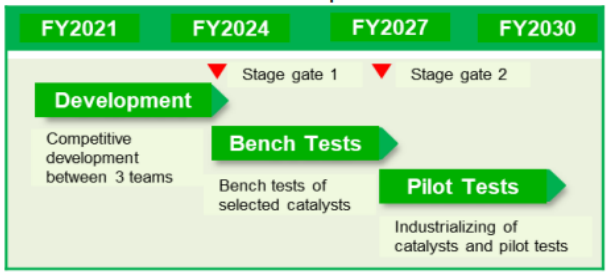
Research and Development of Ammonia Synthesis Catalysts ～NEDO's* Green Innovation Fund～

- Collaboration with Tokyo Electric Power Company Holdings Inc. and JERA Co., Inc.
- Developing Japanese independent technologies to reduce ammonia production costs
- Supporting the establishment of fuel ammonia supply chains



- Project Cost: approximately JPY24 billion
- Project Term: 10 years (FY2021-FY2030)

<Research and Development Schedule>



*New Energy and industrial Technology Development Organization Press release: 220107_e_1.pdf (chiyodacorp.com)

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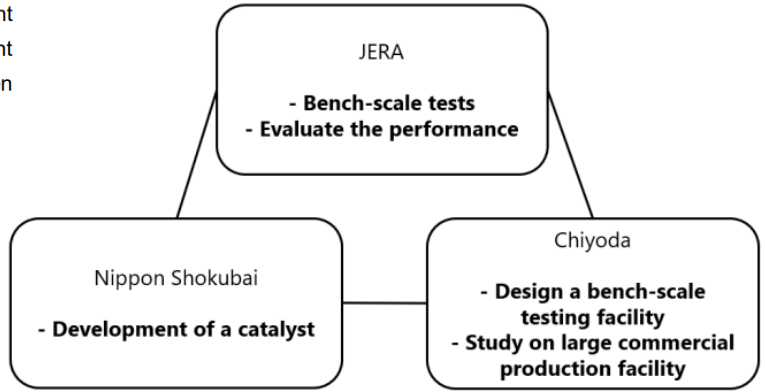
R&D for Ammonia Decomposition technology

JERA, Nippon Shokubai and Chiyoda to Start Development of Ammonia Cracking Technology under NEDO's Subsidized Project

TOKYO — 9 June 2023 — JERA Co., Inc. ("**JERA**"), NIPPON SHOKUBAI CO., LTD. ("**Nippon Shokubai**"), and Chiyoda Corporation ("**Chiyoda**") have commenced technology development of ammonia cracking, under the New Energy and Industrial Technology Development Organization ("**NEDO**")'s "Development of Technologies for Building a Competitive Hydrogen Supply Chain" program.

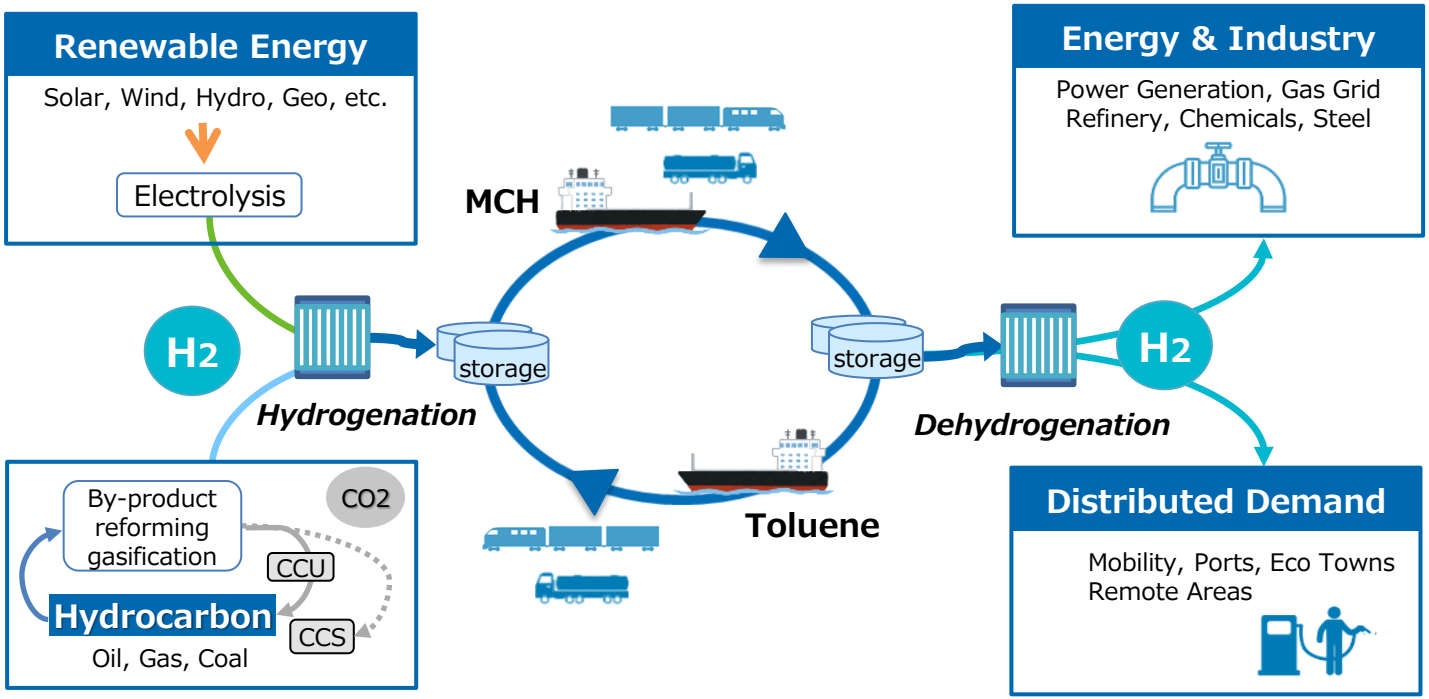
Business promotion system/role of each company



Press Release: 230609_e.pdf (chiyodacorp.com)

SPERA Hydrogen™ System by LOHC-MCH Method

LOHC-MCH System



Characteristics of SPERA Hydrogen™ System by LOHC-MCH method

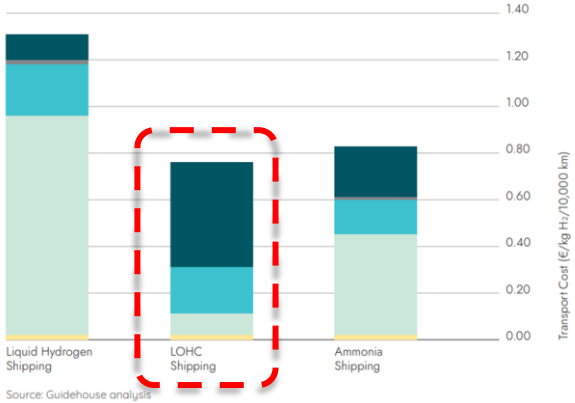
Characteristics of LOHC-MCH

1. Liquid under ambient conditions
2. Chemically stable
3. Low risk and safe
4. Utilizing existing standards and equipment

Requirements for Hydrogen Carriers

- ✓ Easy to handle
- ✓ Can be stored and transported under ambient conditions
- ✓ Ready for commercialization and early commercialization is possible
- ✓ Realistic solutions for the acceleration towards a hydrogen society

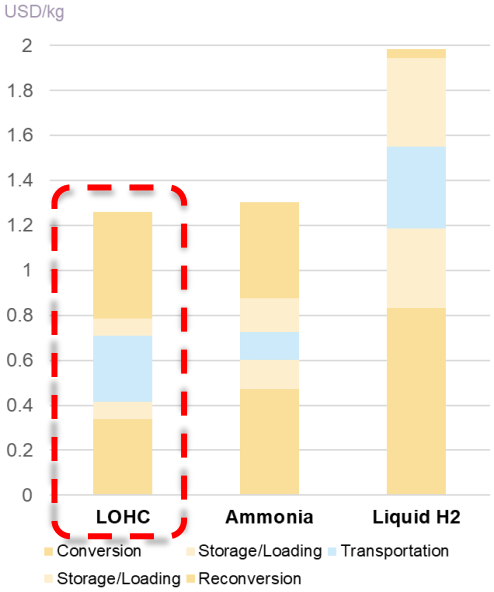
Cost comparison by 3rd parties

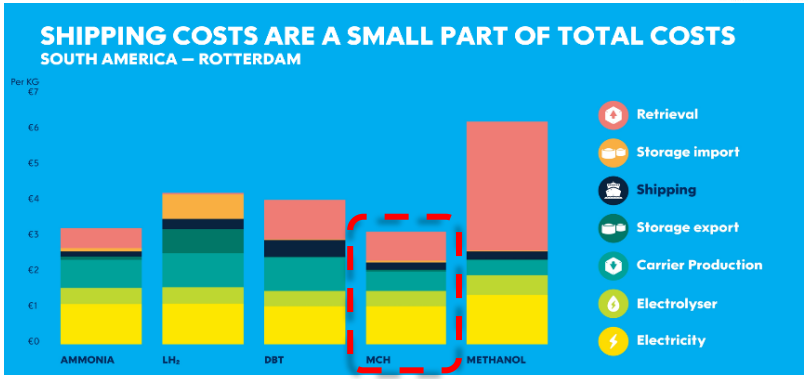


Source : European Hydrogen Backbone [2021]

Source : Hydrogen value chain analysis comparing different transport vectors – Wood 2021

Figure 1 – Qatar to UK Shipping Route





- The H_2 supply cost includes H_2 production cost.
- The results shows that LOHC method is the lowest cost.
- The cost is not including the effect of converting conventional facilities or ships.

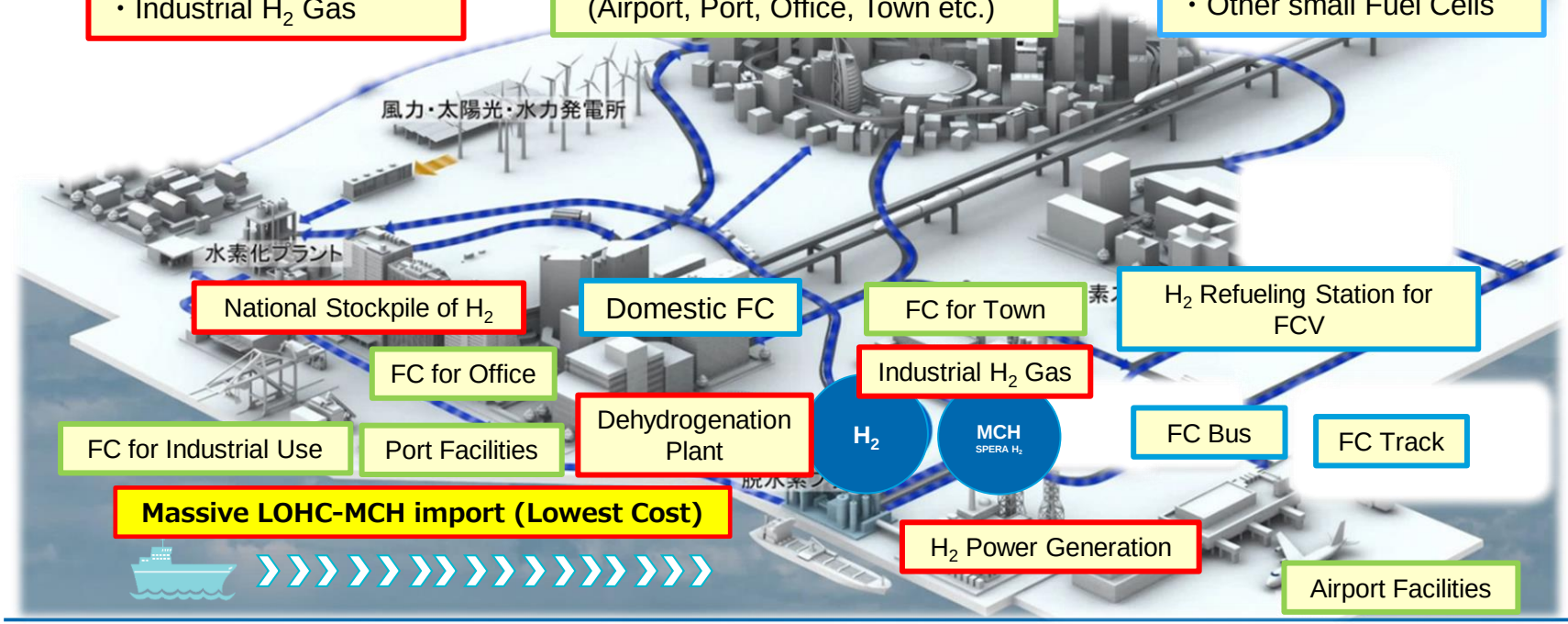
Source : Keynote speech CEO Port of Rotterdam Authority, at the 2nd World Hydrogen Summit

Integrated Hydrogen Supply Chain Concept

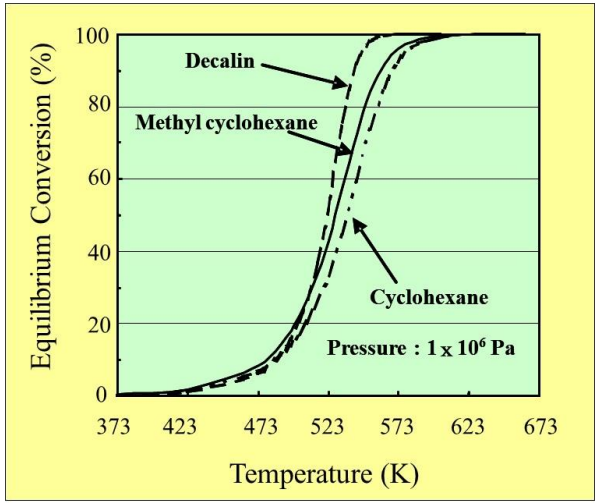
Large-Scale Use (1MW-1GW)
- H_2 Power Generation
- National Stockpile of H_2
- Industrial H_2 Gas

Middle-Scale Use (10kW-1MW)
- Fuel Cells for Industrial Use
- Fuel Cells for Infrastructures (Airport, Port, Office, Town etc.)

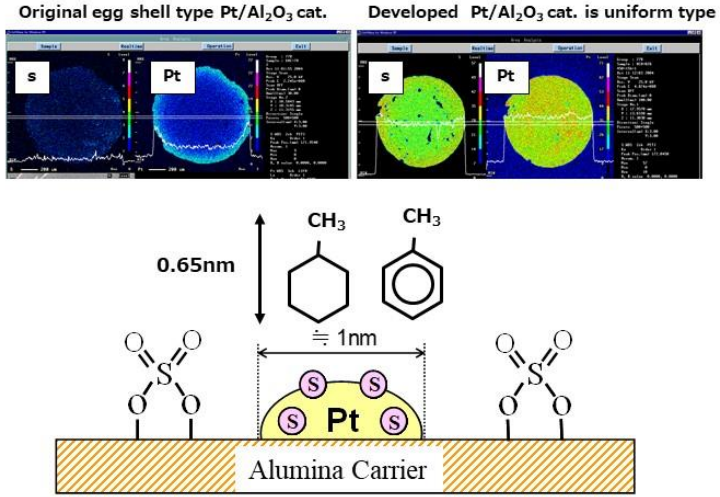
Small-Scale Use (1kW-10kW)
- FCV, FC BUS, FC Track
- Domestic Fuel Cell
- Other small Fuel Cells



Dehydrogenation Catalyst Development (2002-2009)



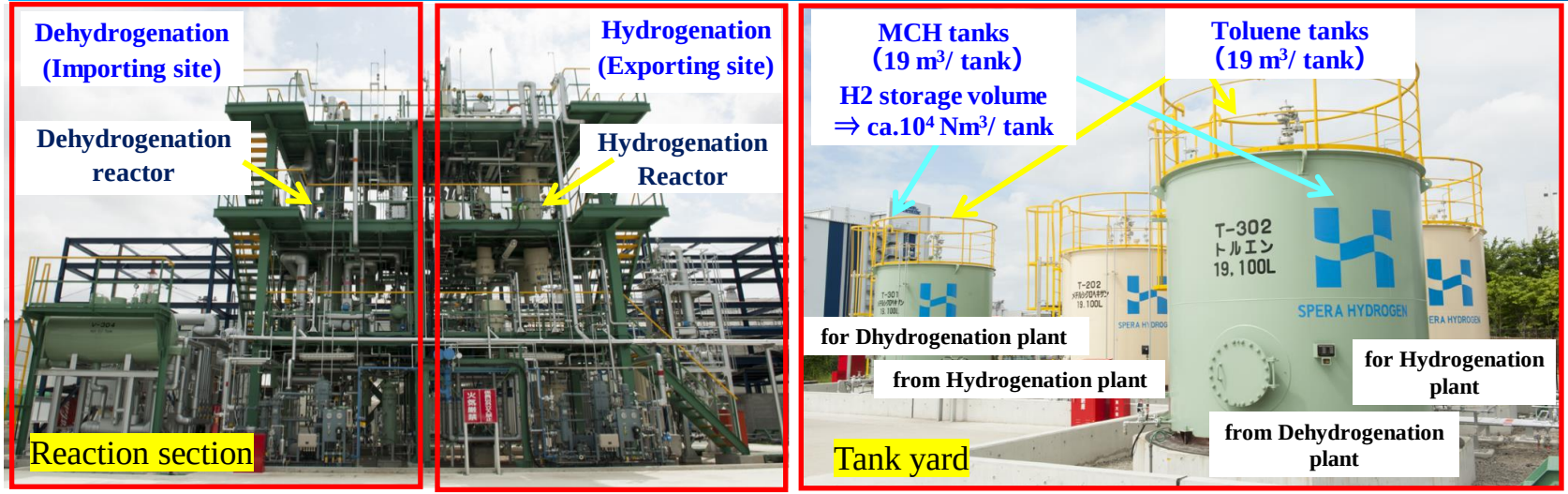
Chemical Equilibrium of Dehydrogenation



Estimated Catalyst Surface Model

- ☆ Chiyoda succeeded to develop a novel dehydrogenation catalyst.
- ☆ The catalyst is the world's smallest class of single-nano platinum particles which diameter is ≒ 1 nm.
- ☆ It has an estimated 400 times higher activity than conventional platinum catalysts (≥2-3 nm).
- ☆ The conventional platinum catalysts require a temperature of 500°C or higher for dehydrogenation of 99% or higher, but the developed dehydrogenation catalyst can achieve a yield of 99% or higher under the theoretical conditions of chemical equilibrium.

Technical Demonstration with Pilot Plant (2013-2014)



Pilot Scale : 50Nm^3-H_2/h for hydrogenation / dehydrogenation

Demonstration operation : April 2013～Nov. 2014 (≒10,000hr)

Performance Hydrogenation : Toluene Conversion >99%, MCH Selectivity >99%, MCH yield >99%

Dehydrogenation : MCH Conversion >98%, Toluene Selectivity >99%, Toluene Yield >98%

Chiyoda completed technical demonstration of a pilot plant in 2014, which achieved totally around 10,000hrs of the pilot plant operation. Processes technology for the system was established

International Hydrogen Supply Chain Demonstration (2020)

Hydrogenation@Brunei

MCH

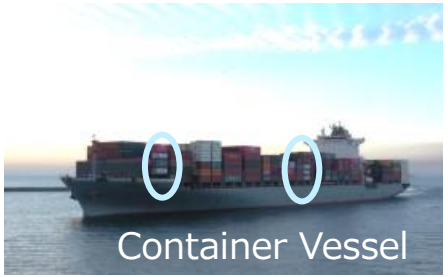
TOL

Inland Transportation

MCH

TOL

Ocean Transportation



Dehydrogenation @Japan

MCH

H_2

TOL

H_2 mixed Power Gen.

MCH : Methylcyclohexane
TOL : Toluene

Utilize hydrogen for GT fuel from Dehydrogenation as World first

Global H2 Supply Chain Projects①

Progressing a hydrogen import hub and a hydrogen highway project in Europe*

Commercial scale hydrogen import to Rotterdam, The Netherlands

Port of Rotterdam · koole TERMINALS · CHIYODA CORPORATION · Mitsubishi Corporation

Scotland to Rotterdam hydrogen highway project

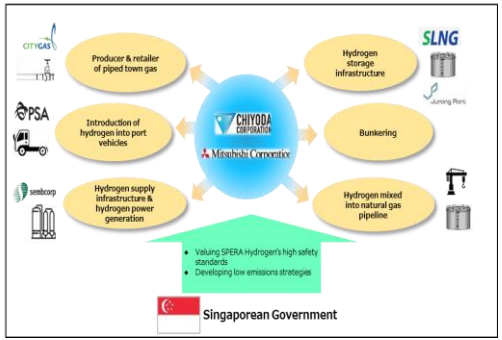
* Source: https://www.portofrotterdam.com/sites/default/files/2021-06/hydrogen-economy-in-rotterdam-handout.pdf

Global H2 Supply Chain Projects②

Asia : Singapore

MOU signed in March 2020

- City Energy
- Sembcorp
- PSA
- Jurong Port
- SLNG
- Mitsubishi Corporation
- Chiyoda



Site Visit by Mr. Lawrence Wong,
Deputy Prime Minister of the Republic of Singapore

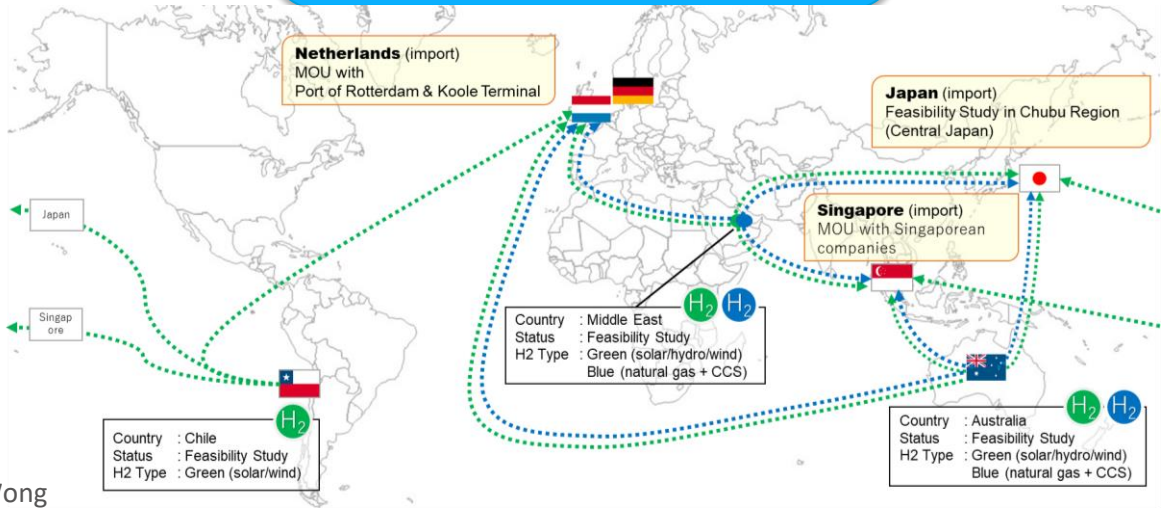
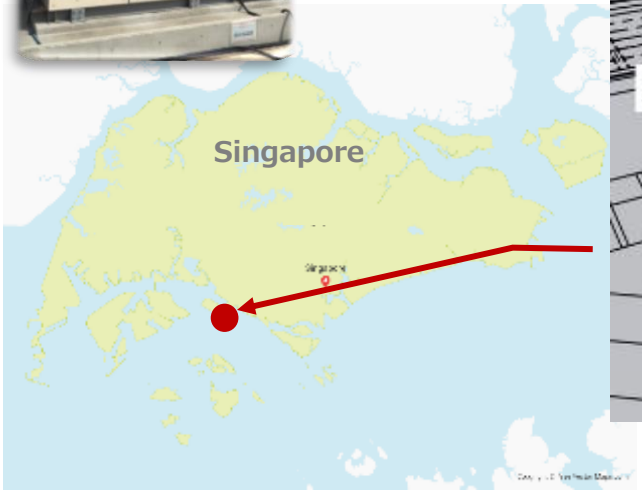
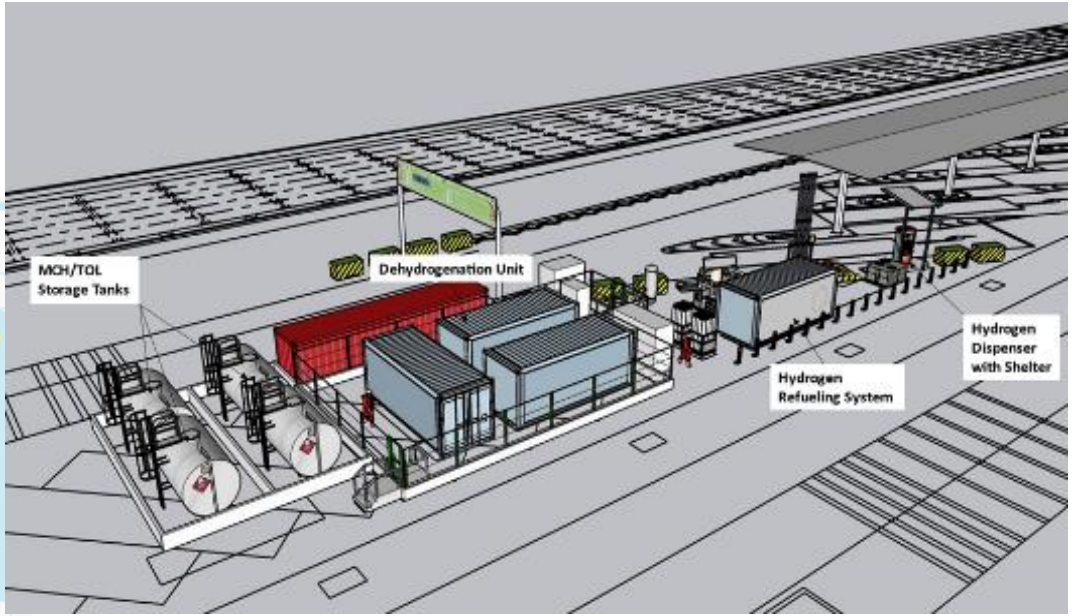


Photo Source: Linked-in of Mr. Lawrence Wong

Global Hydrogen Supply Chain Projects : Singapore Project

In addition to the global H2 supply chain, Chiyoda and its partners are executing the engineering work for MCH Hydrogen Refueling Station demonstration project aiming to start operation in 2024, which plans to demonstrate hydrogen charging for port utility FC trucks.





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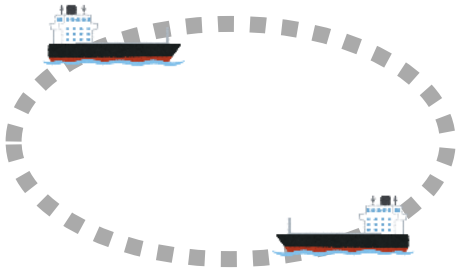
Collaboration between Axens and Chiyoda

Strategic commercial cooperation agreement with Axens enables one-stop service to customers and supports hydrogen transport technology by MCH

AX-CYD License Commercial Package

Axens
Powering integrated solutions

- Hydrogenation (HGN)
- Licensor's expertise



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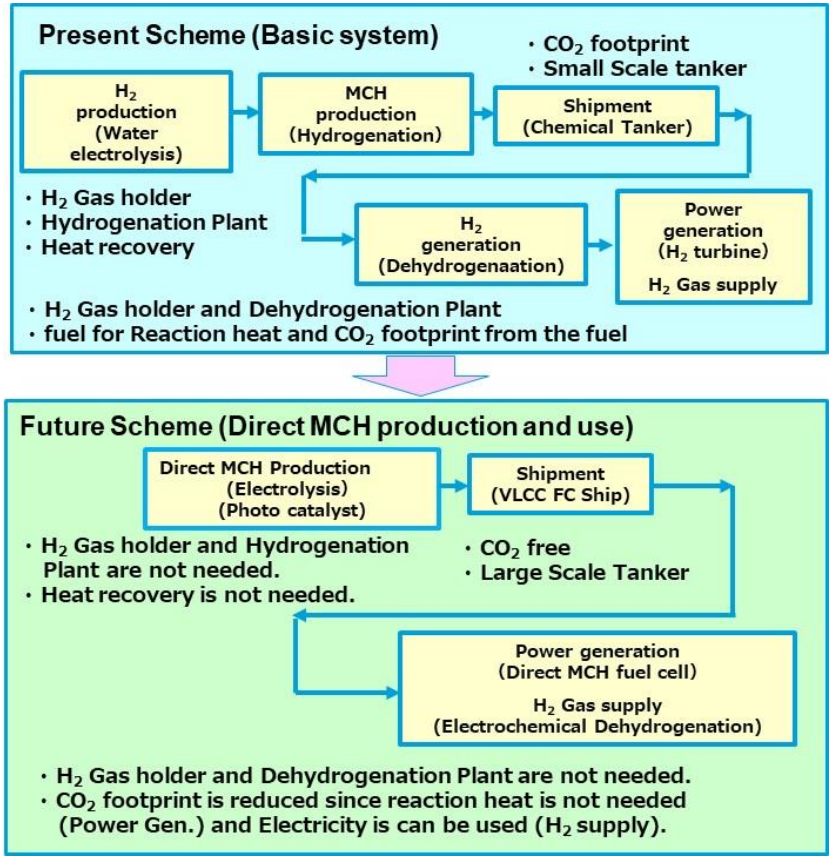
- Dehydrogenation (DHG)
- Engineering expertise

Technical Innovation for Cost Down and Carbon Footprint Reduction



- The LOHC-MCH method can be advanced to reduce costs and its footprint dramatically by technological innovation principally, since it is chemical method.
- Specifically, it is possible with combination of the direct production of MCH from water and toluene and the direct utilization of MCH for power generation or hydrogen gas supply.
- The direct production of MCH for storage and transportation without generating hydrogen gas by electrolysis or photocatalysis can eliminate the need for hydrogen gas holders and hydrogenation plants.
- Fuel cell power generation using MCH directly eliminates the need for a dehydrogenation plant and heat source for endothermic reactions.
- The electrochemical dehydrogenation of MCH can generate hydrogen gas from grid electricity without the need for a dehydrogenation plant.
- The combination of direct production and direct utilization can challenge the cost target of 20 ¥/Nm3 untill 2050, and can reduce the footprint to almost zero.

Thank you for your kind attention

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