Hydrogen Energy Ministerial Meeting

SPERA Hydrogen

Hydrogen Supply Chain by LOHC System

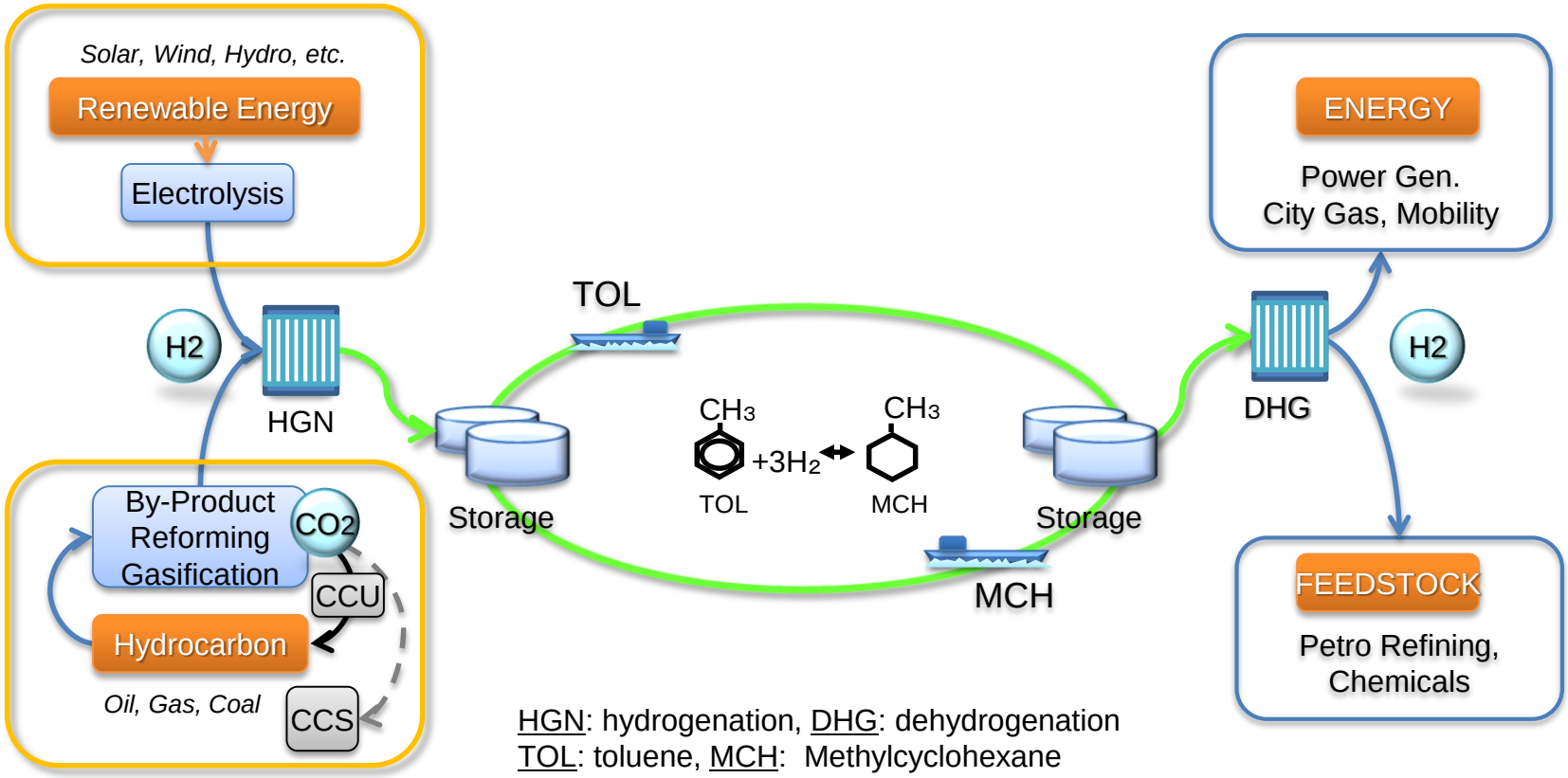
Chiyoda Corporation

October 23, 2018

Contents

1.1 Concept of MCH-LOHC System

- Chiyoda has established an efficient and large scale H2 storage and transportation system.
- Methylcyclohexane (MCH), an H2 carrier, stays in a liquid state under ambient temperature and pressure anywhere (**Liquid Organic Hydrogen Carrier Method**).



HGN: hydrogenation, DHG: dehydrogenation
TOL: toluene, MCH: Methylcyclohexane

Key Technology is New Catalyst of Dehydrogenation.

1.2 Features of MCH-LOHC System

Long term storage & long distance transport	Chemically stable, very minor MCH (H2) loss by long term storage and long distance transport
Easy to handle	Liquid under ambient temperature and pressure Approx. 1/500 in volume
Use of existing oil infrastructure	Physical property is similar to petroleum oil
Reduced risk of H2 storage and transport	Risk for H2 storage and transport is reduced to that of petroleum oil.
Combination of proven technologies	Combination of conventional equipment except for new catalyst for dehydrogenation.

1.3 Features of MCH-LOHC System

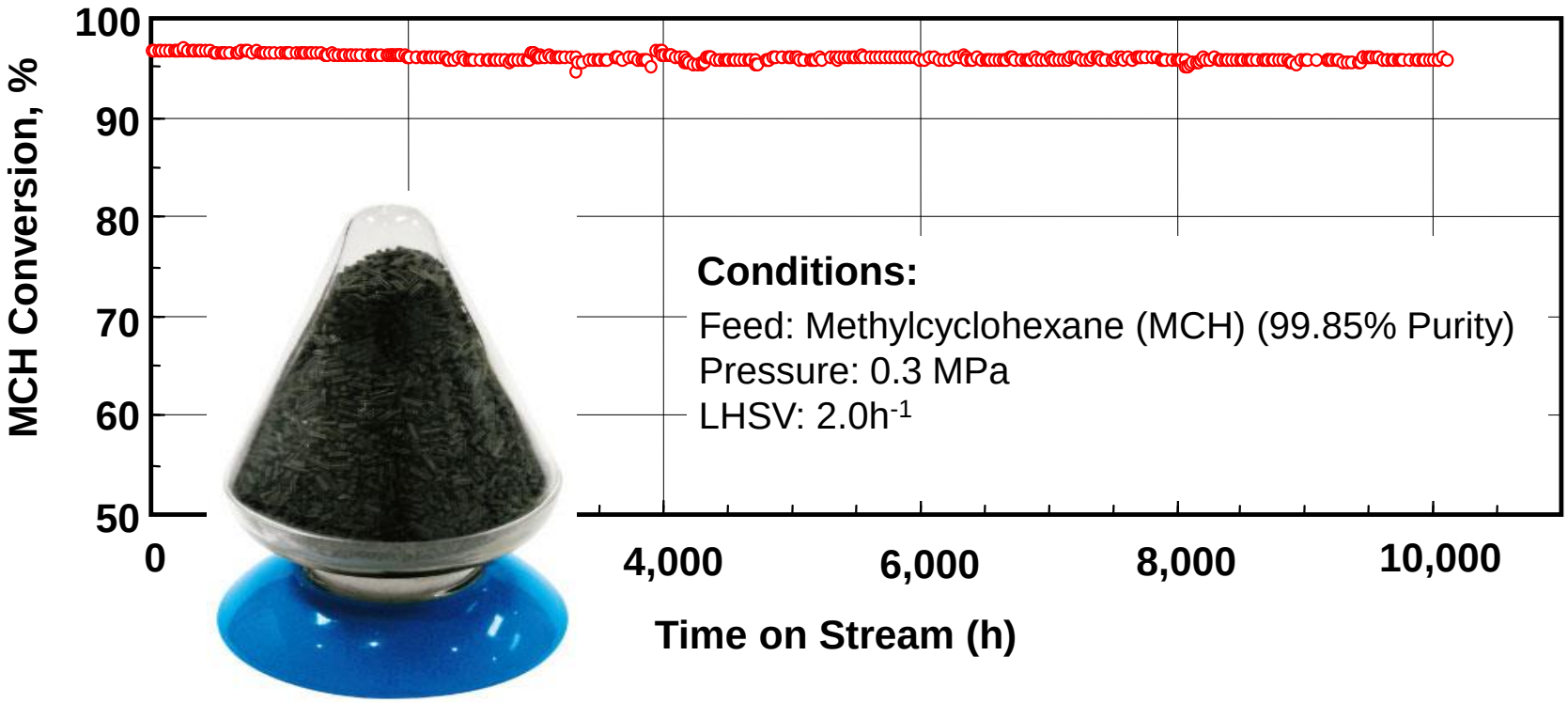
Utilization of Existing Infrastructure

Hydrogen stored
in liquid state
in conventional tanks

Hydrogen transported
by conventional tankers,
pipeline, tanker trucks

2.1 Development of Dehydrogenation Catalyst

Performance of the Catalyst on Laboratory Scale



Performance

- **MCH conversion: >95%, Toluene selectivity; >99.9%, H_2 yield: >95%**
- **H_2 generation rate: >1,000 Nm^3-H_2/h/m^3-cat. (1,000 Ncm^3-H_2/h/cm^3-cat.)**
- **Catalyst life: >10,000h**

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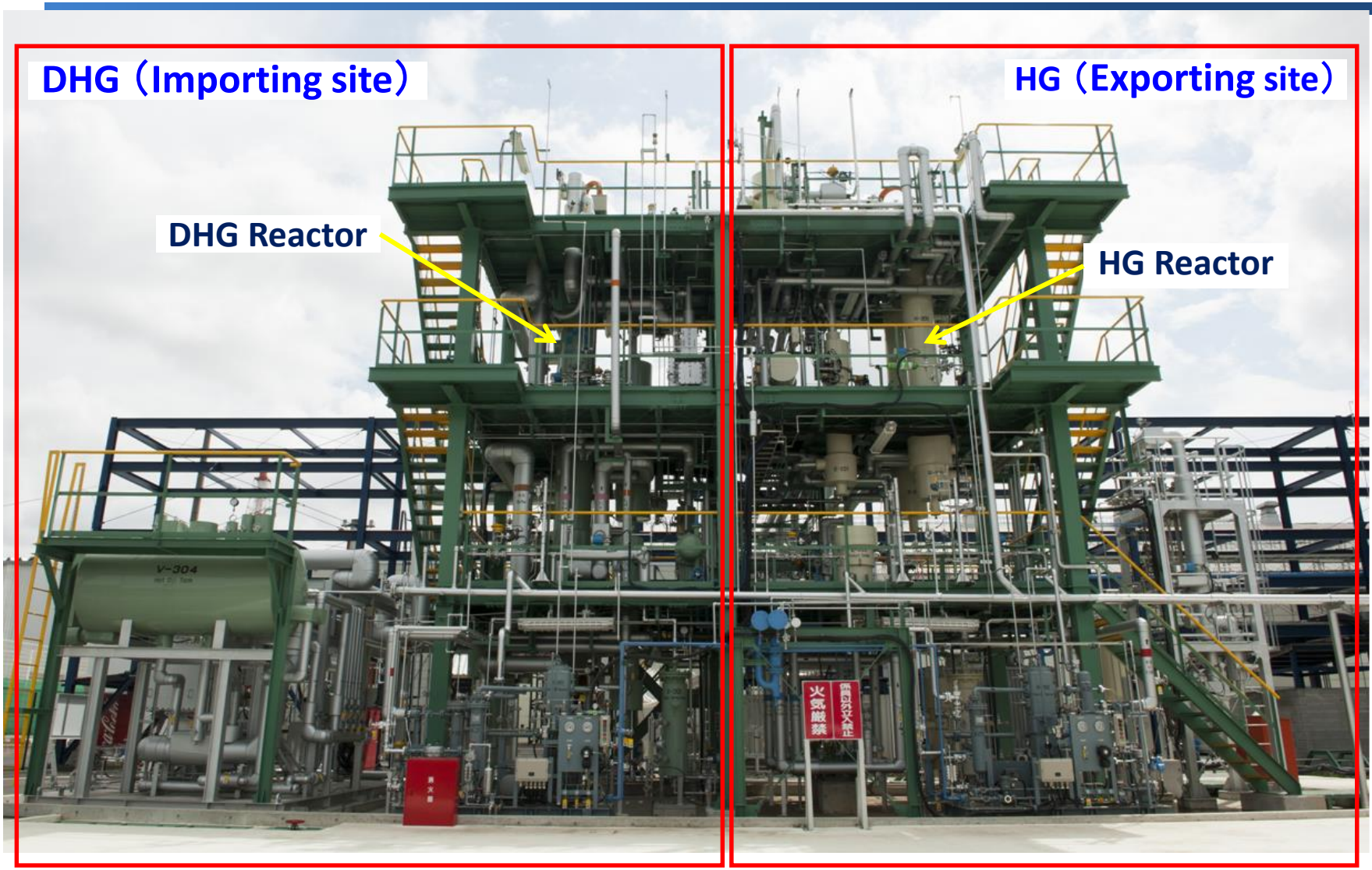
2.2 Demonstration Test of MCH-LOHC Process

(1) Demonstration Plant - Reaction Section



Operating period: Apr. 2013～Nov. 2014

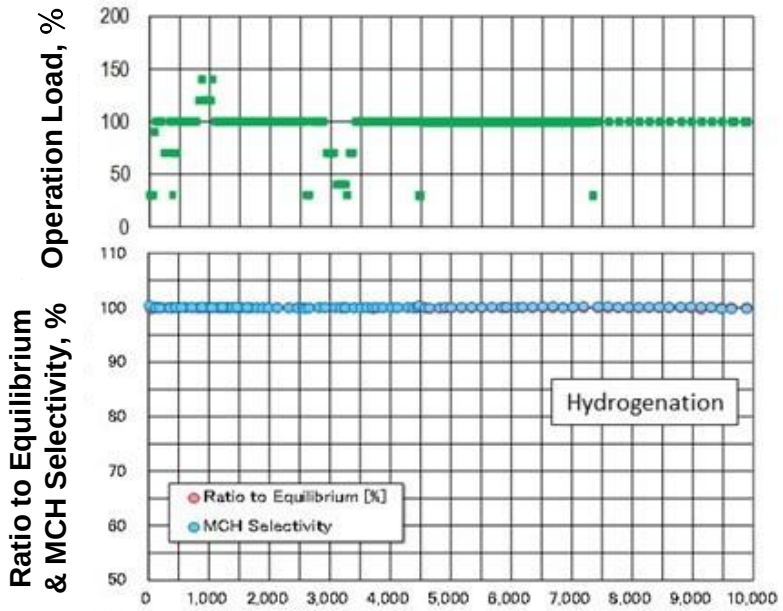
H_2 consumption / generation：50 Nm^3/h

2.3 Demonstration Plant of MCH-LOHC Process

(2) Performance

Hydrogenation of Toluene

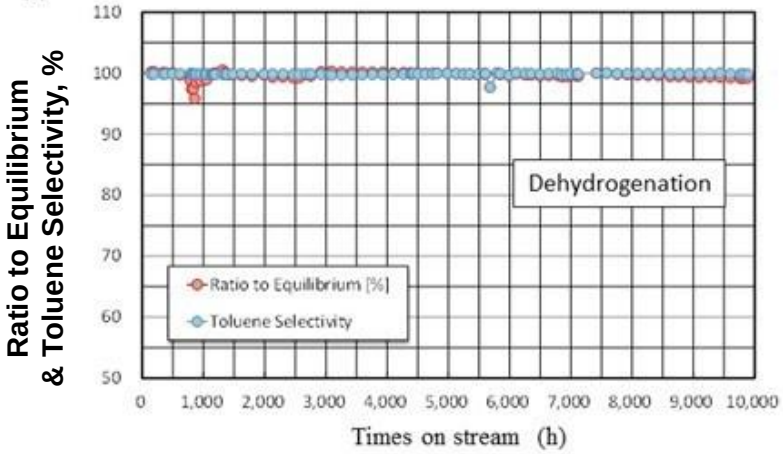
- MCH Selectivity



Yield of H_2 Storage: > 99%

Dehydrogenation of MCH

- Toluene Selectivity



Yield of H_2 Generation: > 98%

Operating period: Apr. 2013～Nov. 2014（approx. 10,000h）

H_2 consumption / generation：50Nm^3/h

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3.1 Global Hydrogen Supply Chain Demonstration

Organization and Schedule

Using LOHC technology, Chiyoda and its partners established the Advanced Hydrogen Energy Chain Association for Technology Development (AHEAD), and started the world's first global hydrogen supply chain demonstration project toward 2020.

Advanced Hydrogen Energy Chain Association for Technology Development

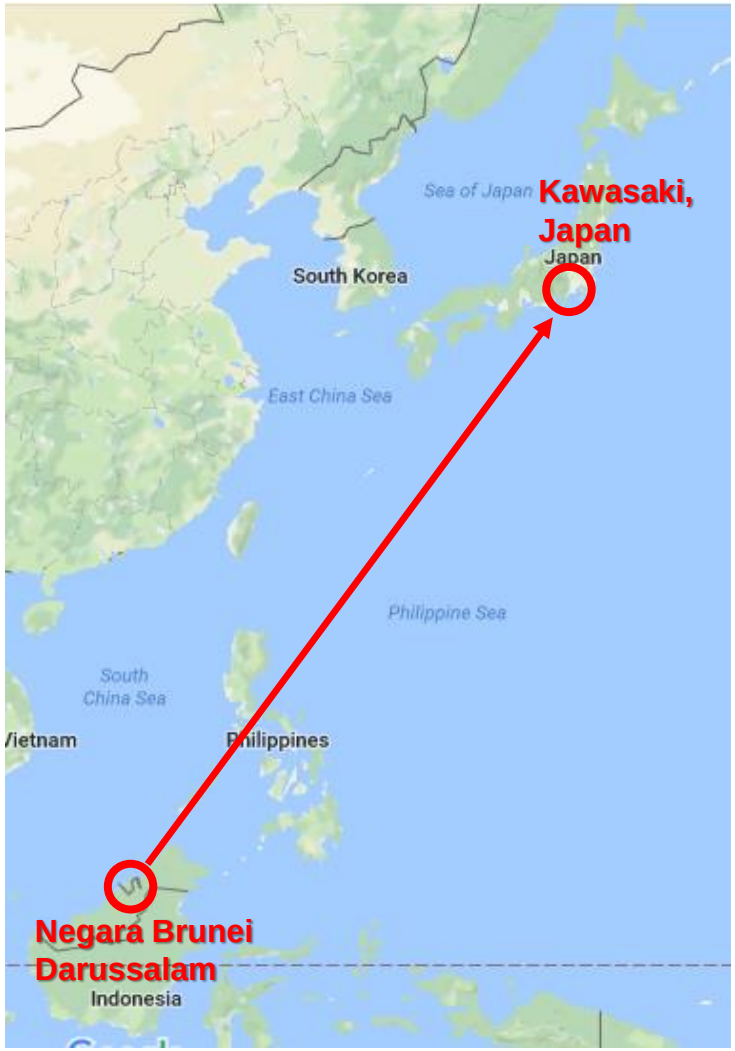
CHIYODA CORPORATION　Mitsubishi Corporation　MITSUI & CO.　NYK LINE NIPPON YUSEN KAISHA

< Schedule >

2015	2016	2017	2018	2019	2020
Phase 1: FS and basic design		Phase 2: Design, construction, commissioning			Demonstration

3.2 Global Hydrogen Supply Chain Demonstration

Project Outline



Project Scale

Supply of 210 tons (max) of hydrogen in 2020, equivalent to filling 40,000 fuel cell vehicles (FCV).

Hydrogen Supply

Hydrogen will be produced by steam reforming from the processed gas derived from the natural gas liquefaction plant of Brunei LNG Sdn. Bhd.

Hydrogen Demand

Fuel for the Keihin Refinery Thermal Power Plant, an affiliate of TOA OIL Co., Ltd.
TOA OIL Co Ltd. is owned by SHOWA SHELL SEKIYU K.K..

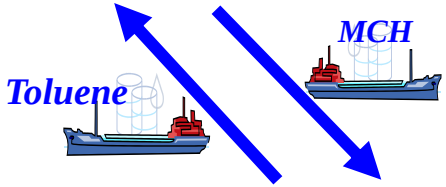
NEDO Support

2/3 of this project is funded by NEDO (New Energy and Industrial Technology Development Organization, the funding agent of the Ministry of Economy, Trade & Industry).

3.3 Global Hydrogen Supply Chain Demonstration

HG and DHG Plants

Brunei H_2 Production and Hydrogenation Plants



Kawasaki Dehydrogenation Plant

3.4 Global Hydrogen Supply Chain Demonstration

Hydrogen Value Chain – Project Status in Brunei

Ground breaking ceremony was held on April 21, 2018, and the guest of honor was Deputy Minister of the Ministry of Energy and Industry, together with 150 other guests.

Fabrication of Process Module at Module Yard
(as of August 2018)

Process and Pipe rack Module Foundation
(as of August 2018)

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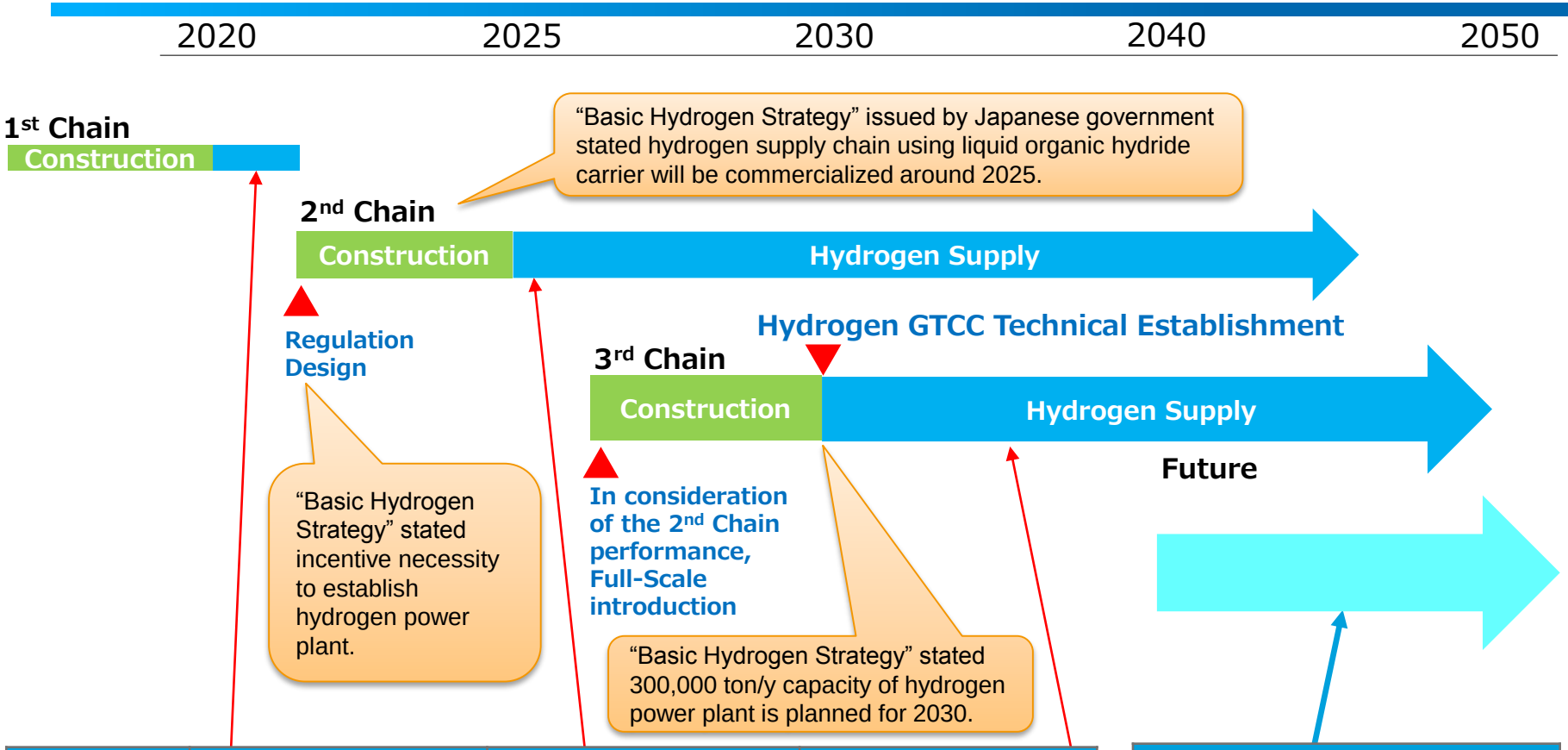
4.1 Hydrogen Supply Scenario Proposed by Chiyoda



	1st Chain (Demonstration)	2nd Chain	3rd Chain
H2 Volume	Max. 210 ton/year	50,000 – 90,000 ton/year (80-150,000Nm³/h)	300,000 ton/year (500,000 Nm³/h)
Supply Destination	Gas Turbine	Multi-Fuel GTCC (H2: 20vol%)	Hydrogen GTCC (H2: 100%)

Future
As per demand
Hydrogen GTCC(100%) Industrial Use, etc.

THANK YOU