ENEOS

10th Nov. 2023

Initiatives on Carbon-neutral Technologies at ENEOS

Executive Officer,
Director of the Central Technical Research Laboratory
Yasushi SATO

Long-Term Vision - ENEOS' Role in Japan's Energy Transition

Environmental awareness

- ✓ **Society is certain to move toward carbon neutrality** based on scientific verification and international trends
- ✓ Meanwhile, **leading roles in carbon neutrality** and the **timing of necessary technological breakthroughs are uncertain**

- ✓ Considering policy trends, **the turning point will be around 2030**

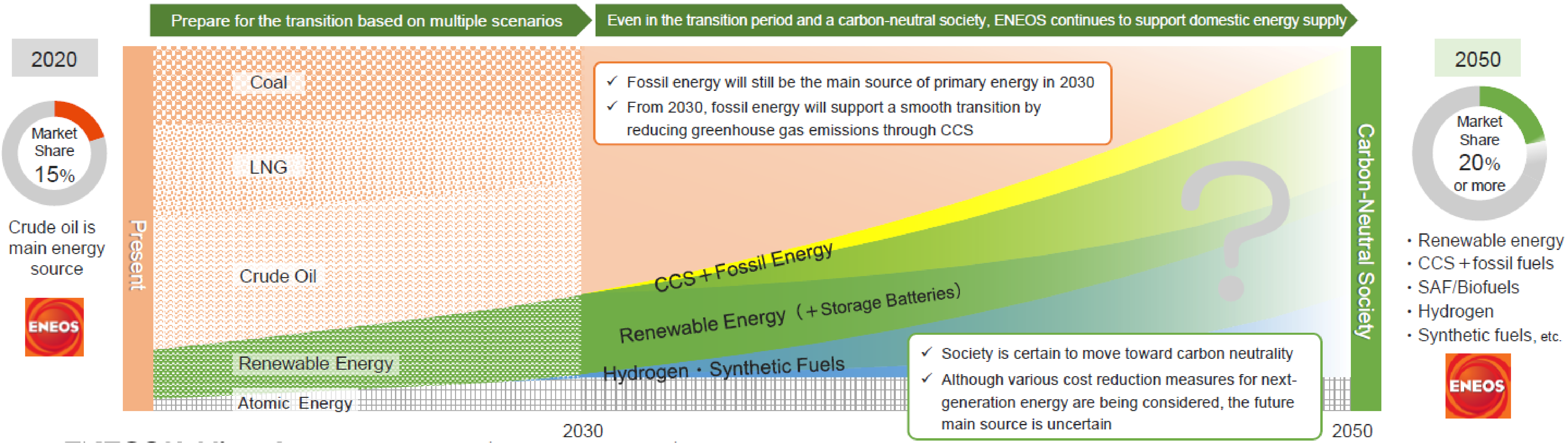
Social issues

- ✓ **Smooth transition toward a carbon neutral society** while fulfilling S + 3E＊

＊Safety, Energy security, Economic efficiency, Environment

ENEOS will **lead Japan's energy transition** and will continue to be a **main player, supplying 20% of Japan's primary energy** (largest market share in SAF, hydrogen and synthetic fuels)

– Future domestic primary energy supply mix (image) –



- ✓ Fossil energy will still be the main source of primary energy in 2030
- ✓ From 2030, fossil energy will support a smooth transition by reducing greenhouse gas emissions through CCS

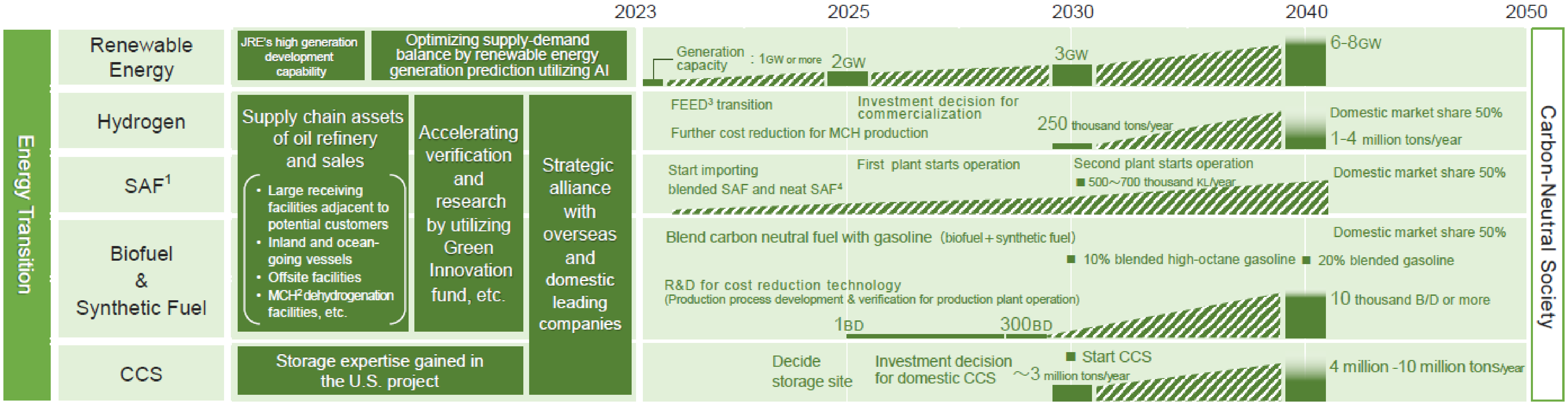
- ✓ Society is certain to move toward carbon neutrality
- ✓ Although various cost reduction measures for next-generation energy are being considered, the future main source is uncertain

- Renewable energy
- CCS＋fossil fuels
- SAF/Biofuels
- Hydrogen
- Synthetic fuels, etc.

Long-Term Vision - Strengths for Tomorrow’s Normal

- ✓ ENEOS has various strengths in main next-generation energies for a carbon-neutral society, and we are taking preemptive measures as a pioneer
- ✓ Furthermore, we possess product lines in core materials for the digital society, advanced recycling technology, and infrastructure / business network support development for a sharing economy

✓ **High resilience** in dealing with **various scenarios** and large **profit-earning potential from 2030** (growth opportunities)



Materials（Advancement of digitization and recycling）

High Performance Materials
（ENEOS Materials）

- One of the world's top shares in fuel-efficient tire materials[5]
- High product development and production capability responding to customer needs

Advanced Materials
（JX Nippon Mining & Metals）

- Top-share product lineup (Core materials for data society)
- High purification and recycling technology cultivated in Mineral Resources and Smelting businesses

ENEOS platform（Advancement in EV and car sharing）

EV Charging

- Strong regionally-rooted nationwide SS network
- Deployed route charging service[6] (Also, more than 6,000 ordinary chargers in Japan)

Fleet Management

- Nation-wide vehicle maintenance network

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1 Sustainable Aviation Fuel 2 Methylcyclohexane: a hydrogen carrier 3 Front End Engineering Design
4 SAF raw materials before mixing 5 Solution polymerization styrene-butadiene rubber 6 ENEOS Charge Plus

from ENEOS’ Carbon neutrality plan

Necessity to transport renewable energy from overseas

It is economically more favorable to import renewable energy in the form of hydrogen and synthetic fuels (energy carriers) from overseas, where renewable energy is abundant and inexpensive.

All of Japan's primary energy supply of 18 EJ/Y to be provided by domestic renewable energy

Solar Power Generation

50 MW/km^2
Utilization rate 0.12

Entire flat land area

Solar Power Generation Cost* :
90 USD/MWh

Imported from overseas (Australia)

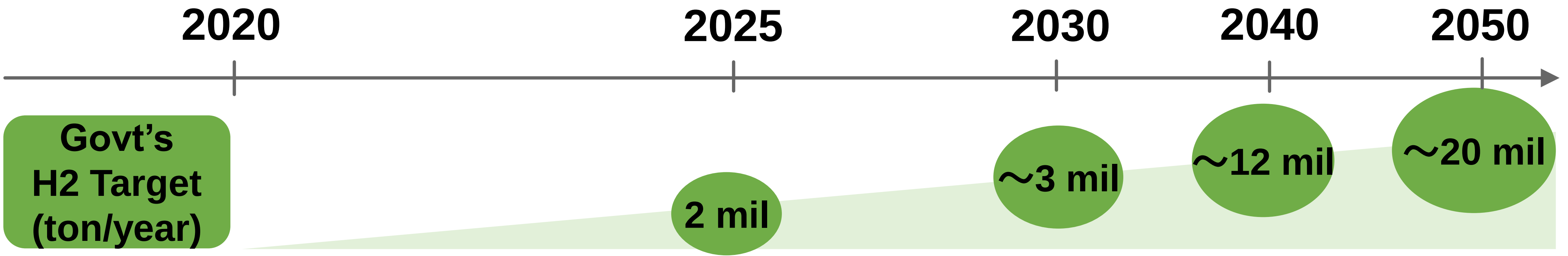
5% of desert

Solar Power Generation Cost* :
40 USD/MWh

*<Source> IRENA, Renewable Power Generation Costs in 2021

Japan's H_2 Supply Target (from Green Growth Strategy Japan)

- Accelerating to build a H2 infrastructure toward 2050
- Supporting companies to establish the supply chain in and outside Japan



(3 million ton of H2: 10GW : 10 Nuclear power plant)

H2 Utilization

R&D, Demonstration → **Commercialization** → **Business Expansion**

Supply to

Manufacturing use

FCVs, FC busses/trucks, Ships, Railways

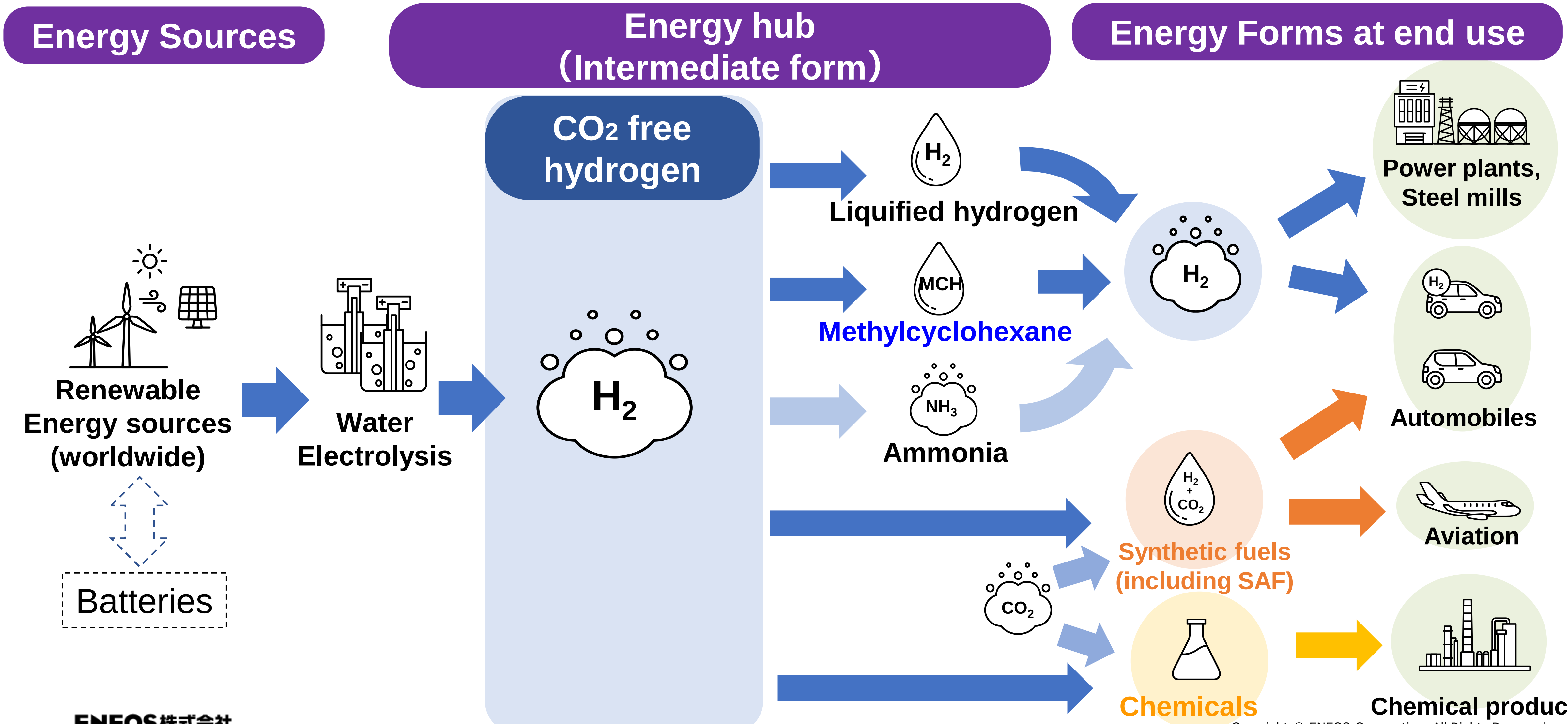
LNG thermal power generations

Power stations, Steel mills

CO_2 free Hydrogen as an Energy hub

reproduction prohibited

CO_2 free Hydrogen can be converted to versatile forms of Energies/chemicals.



Energy Sources

Energy hub (Intermediate form)

Energy Forms at end use

Renewable Energy sources (worldwide)

Batteries

Water Electrolysis

CO2 free hydrogen

Liquified hydrogen

Methylcyclohexane

Ammonia

Synthetic fuels (including SAF)

Chemicals

Power plants, Steel mills

Automobiles

Aviation

Chemical production

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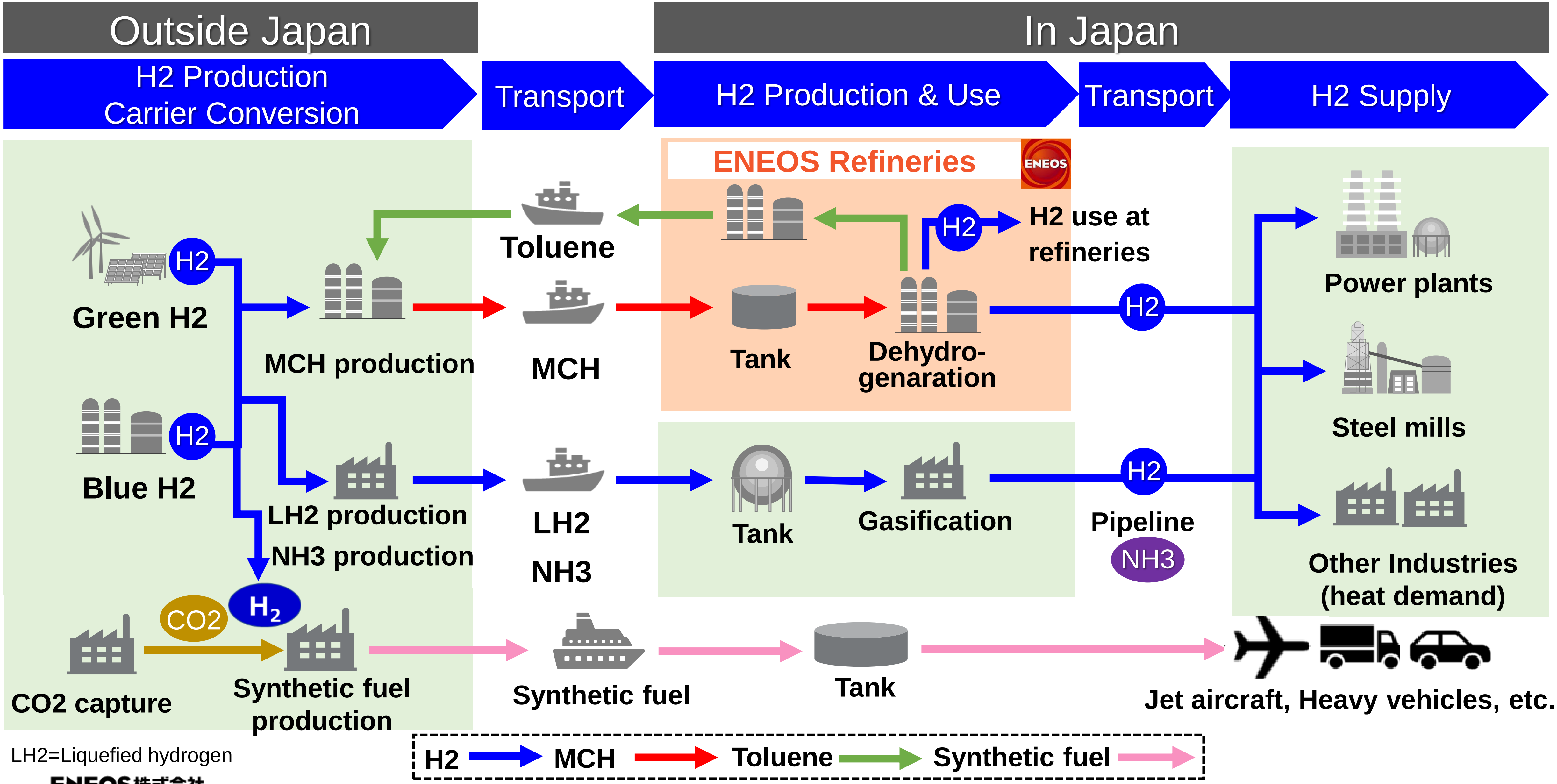
Value Chain of Hydrogen / Synthetic Fuel

reproduction prohibited



Outside Japan

H2 Production
Carrier Conversion

Transport

In Japan

H2 Production & Use

Transport

H2 Supply

Green H2

Blue H2

MCH production

LH2 production

NH3 production

Toluene

MCH

LH2

NH3

ENEOS Refineries

Tank

Dehydro-genaration

H2 use at refineries

Tank

Gasification

Pipeline

NH3

Power plants

Steel mills

Other Industries (heat demand)

CO2

H_2

CO2 capture

Synthetic fuel production

Synthetic fuel

Tank

Jet aircraft, Heavy vehicles, etc.

H2 → **MCH** → **Toluene** → **Synthetic fuel** →

LH2=Liquefied hydrogen

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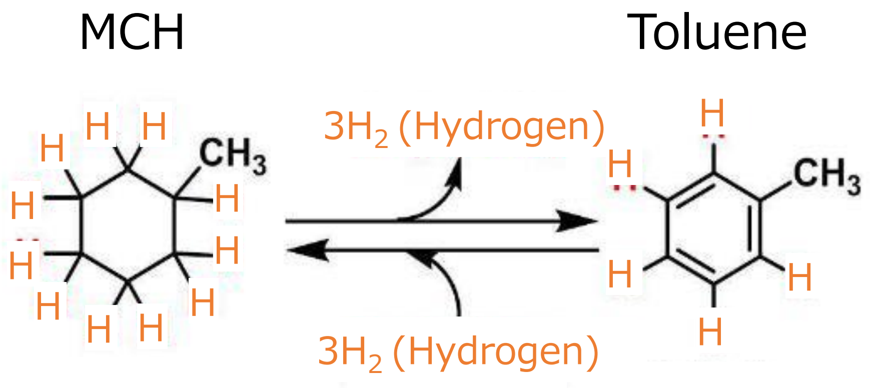
Comparison of CO_2-free hydrogen carriers

Liquid hydrogen, MCH, and ammonia have their own advantages and disadvantages.

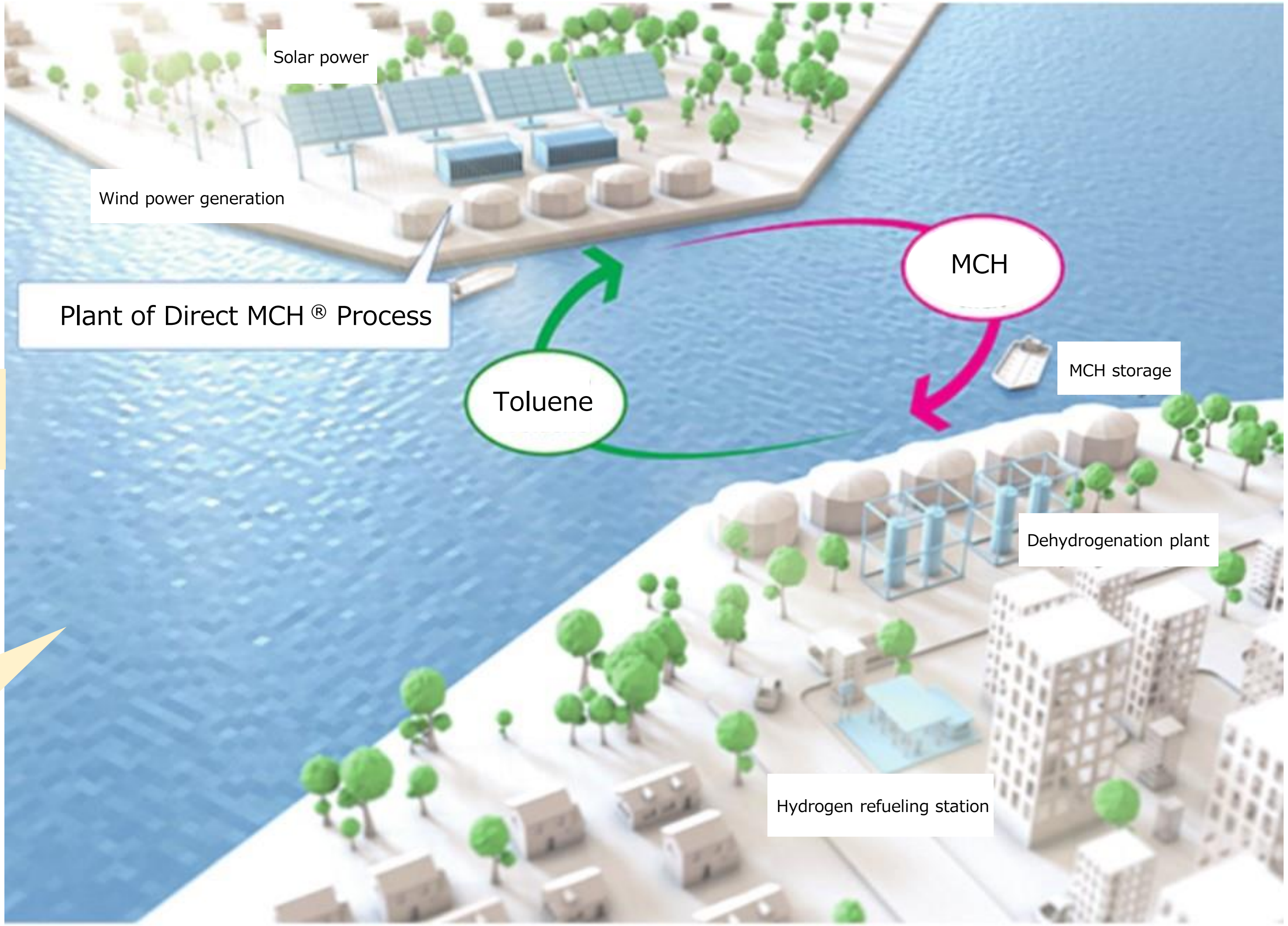
		Liquid Hydrogen	MCH	Ammonia
Properties	**H2 storage density**	**70.8 kg-H2/m3** **(1300kWh/m3 including tank)** △	**47.3 kg-H2/m3** **(1700kWh/m3 including tank)** ○	**121 kg-H2/m3** **(2400kWh/m3 including tank)** ○
	Toxic	**Low** ○	**Low** ○	**High** △
	Storage temp. (transportation)	**-253degC** △	**Ambient temp.** ○	**-33degC** ○
	H2 extraction	**Easy** ◎	**Need heat** △	**Need heat** **(Direct Combustion)** ○
Infrastructure	**Local production**	**Liquefaction :** Need development for large-scale liquefaction technology. △	**Chemical Hydrogenation :** Commercial size plant technology available **Direct MCH :** Further cost reduction ○	**Ammonia Production** Commercial size plant technology available ○
	Transport	**Liquid Hydrogen Transport :** Need development and build new large transport vessels △	**Toluene·MCH Transport :** Existing tankers available ◎	**Ammonia Transport :** Existing LPG tanker conversion ○
	Tank	**Liquid hydrogen tank :** Large tanks require technology development and new construction △	**Toluene·MCH Tank :** Existing tanks available ◎	**Ammonia Tank :** Existing LPG tank conversion ○
	H2 extraction	**Vaporization :** Simple vaporization equipment ◎	**Dehydrogenation of MCH** Existing refinery equipment available ◎	**Ammonia dehydrogenation** Hydrogen Utilization : Need installation of dehydrogenation unit. △ Power generation and marine fuel : Direct use. ○

MCH system - for effectively transporting hydrogen



Both are colorless at room temperature and normal pressure and are **easy-to-handle liquids,** similar to gasoline

- ✓ **Enables effective use of existing distribution infrastructure** such as tanks and shipping vessels
- ✓ Enables re-purposing existing oil tanks and storing hydrogen as an MCH **making it also effective for ensuring energy security.**



<Source> ENEOS R&D HP

Oversea H2 Supply Chain Projects

ENEOS is exploring both blue and green H2 in Australia, Southeast Asia and Middle East, with anticipation that green H2 would be required in the long term

Southeast Asia

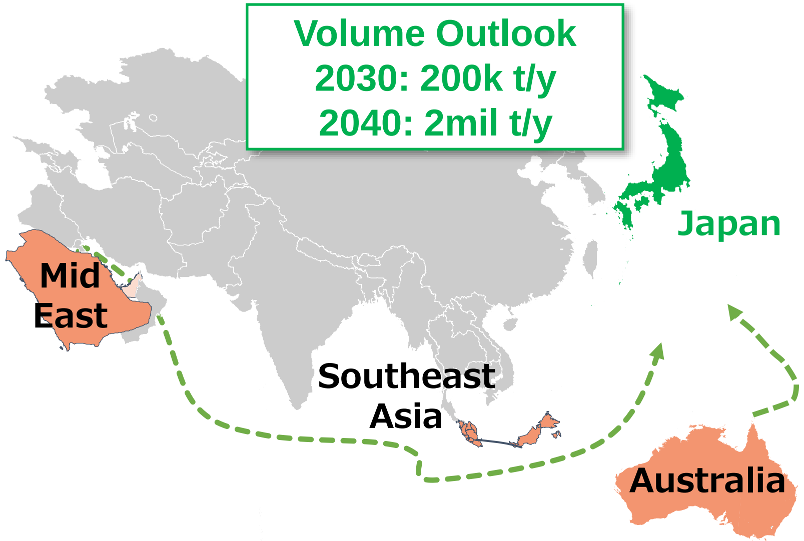
Blue H2 **Green H2**

- ■ Partners : Sumitomo & SEDC, PETRONAS
- ■ Scopes : Green H2 production from local hydro power / use of co-product H2 at petchem plants, convert to MCH and ship to Japan
- ■ Location : Malaysia

Australia

Green H2

- ■ Partners: NEOEN, Origin
- ■ Scopes : Produce green H2 from renewable energies, convert to MCH and ship to Japan
- ■ Location : QLD, SA



Volume Outlook
2030: 200k t/y
2040: 2mil t/y

Middle East

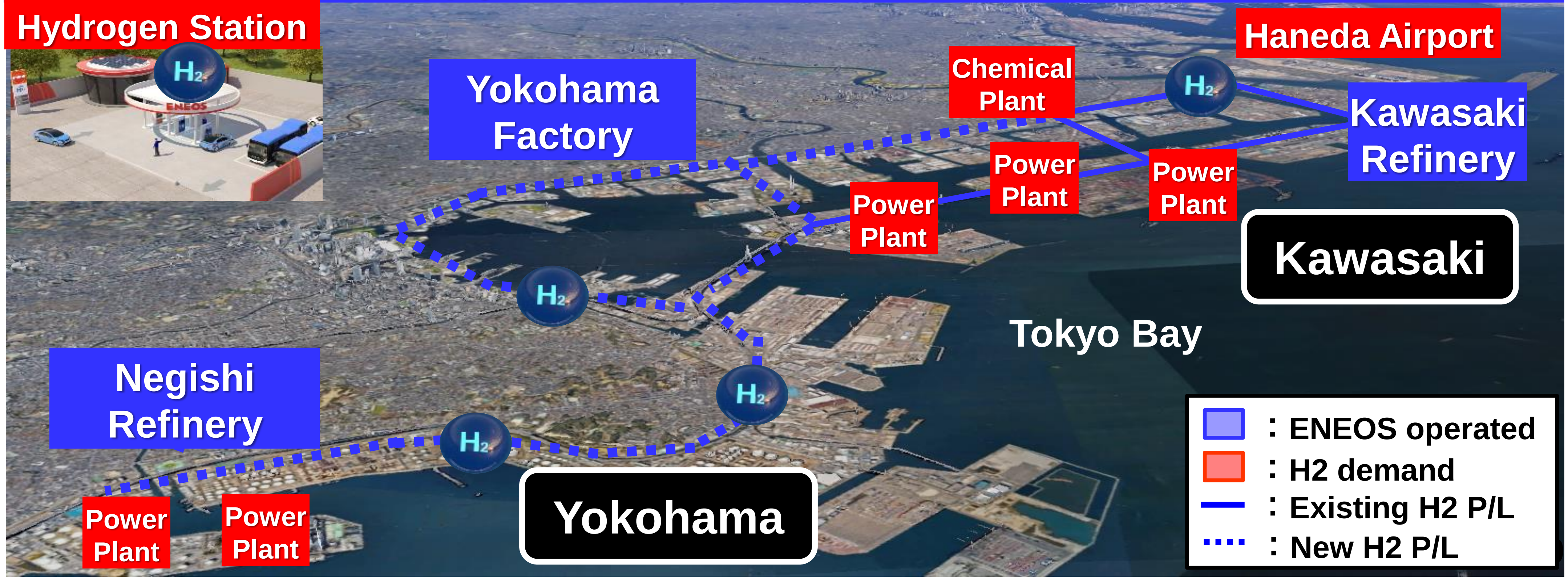
Blue H2

- ■ Partners : Saudi Aramco, ADNOC
- ■ Scopes :
  - - H2 productions from fossil fuels (NG, LPG) with CCS / use of by-product H2
  - - Evaluating H2 carriers
- ■ Location : Saudi Arabia, UAE

Study of Hydrogen Utilization in Japan

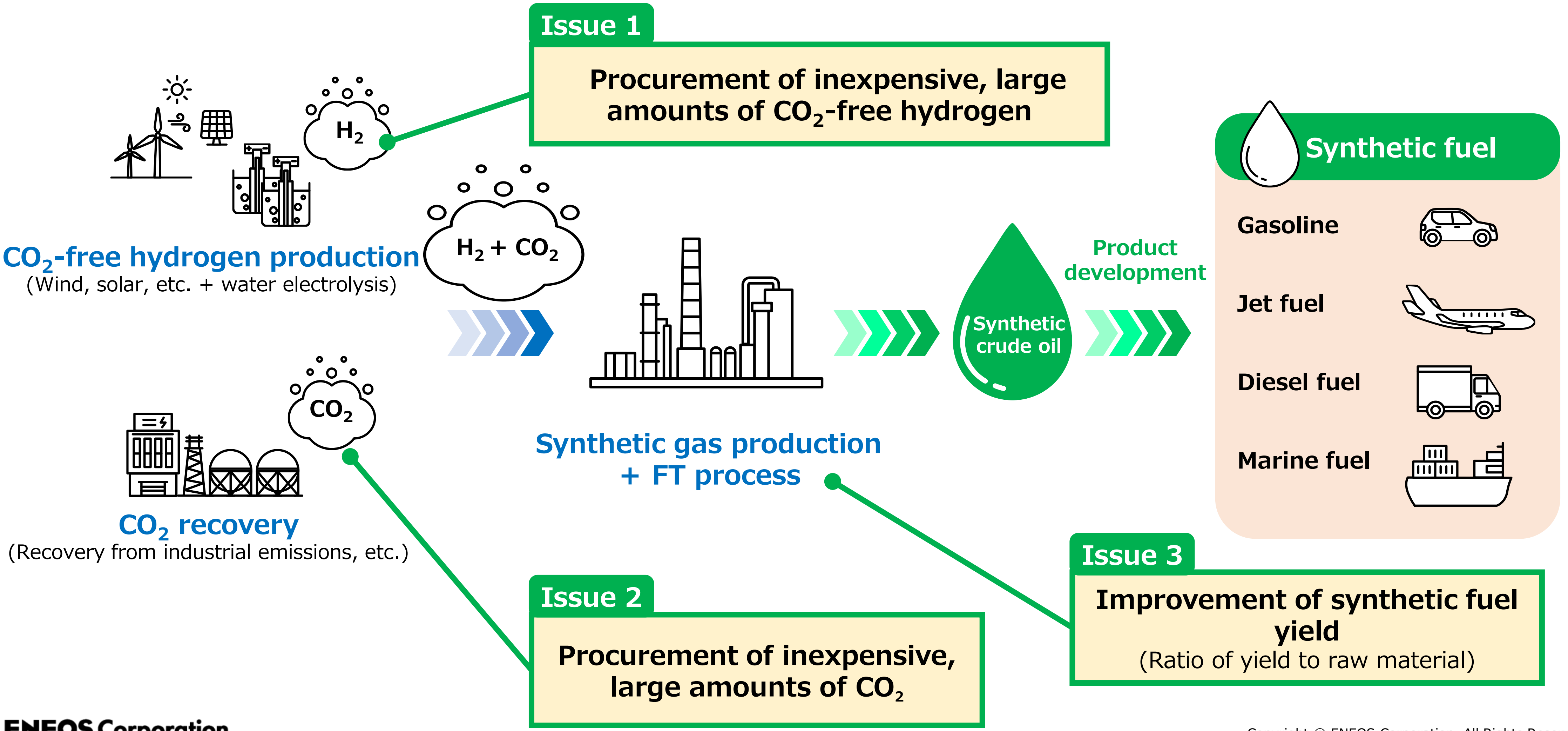
- ENEOS also conducts joint studies with various local governments and companies to expand hydrogen use in the future.
- We recently signed agreement with Yokohama and Kawasaki Cities to seek opportunities to use hydrogen in the west side of Tokyo Bay through pipelines.

Image of hydrogen supply infrastructure in the Kawasaki-Yokohama waterfront



Synthetic Fuels -Challenges for commercialization

For each of these issues, the solution cannot be achieved by individual companies alone, pointing to the need for discussions involving the national government and society.



Issue 1

Procurement of inexpensive, large amounts of CO_2-free hydrogen

CO_2-free hydrogen production
(Wind, solar, etc. + water electrolysis)

CO_2 recovery
(Recovery from industrial emissions, etc.)

Synthetic gas production + FT process

Synthetic crude oil

Product development

Synthetic fuel
- **Gasoline**
- **Jet fuel**
- **Diesel fuel**
- **Marine fuel**

Issue 2

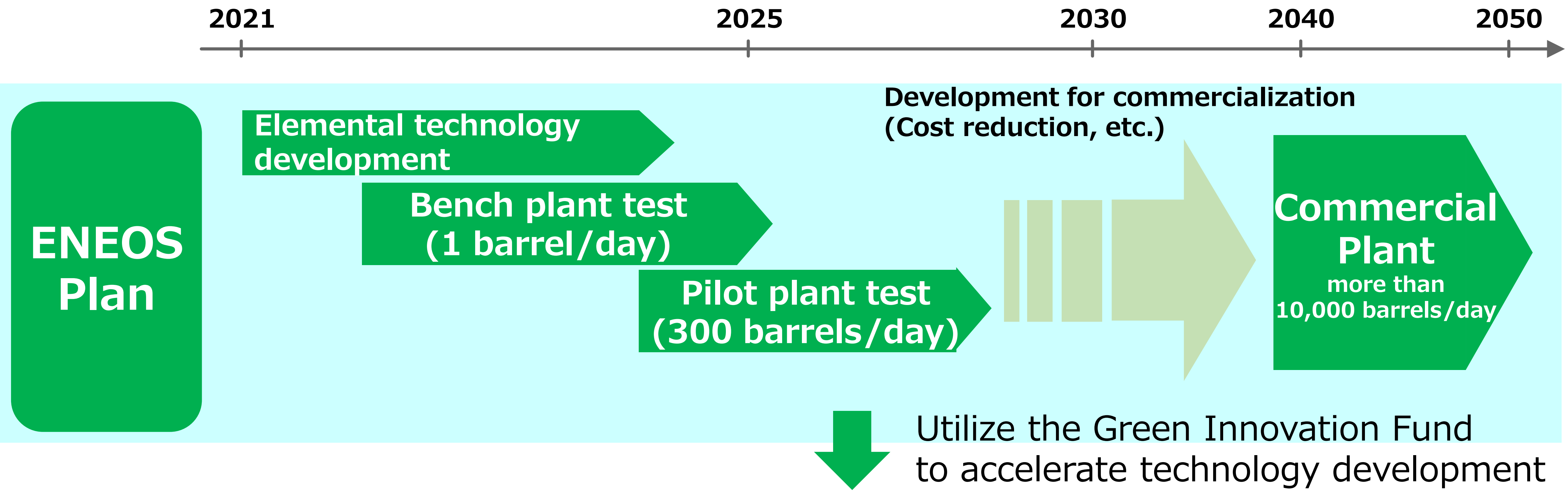
Procurement of inexpensive, large amounts of CO_2

Issue 3

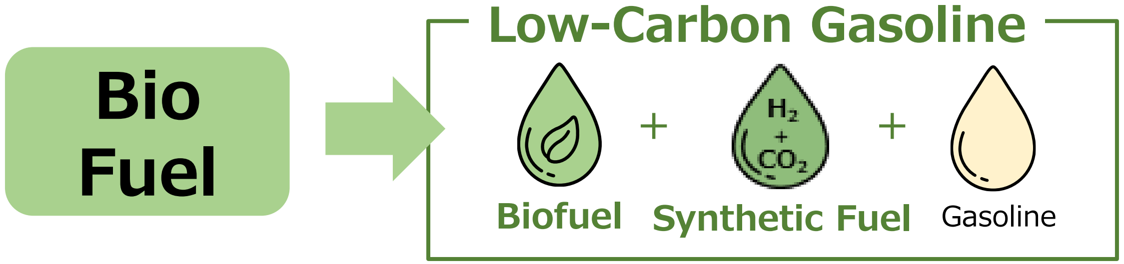
Improvement of synthetic fuel yield
(Ratio of yield to raw material)

Synthetic Fuel Roadmap

Establish high-efficiency, large-scale synthetic fuel production technology by 2030, then expand its implementation and reduce production costs.
ENEOS aims to quickly realize carbon neutralization through the use of biofuel and synthetic fuel.



Utilize the Green Innovation Fund to accelerate technology development

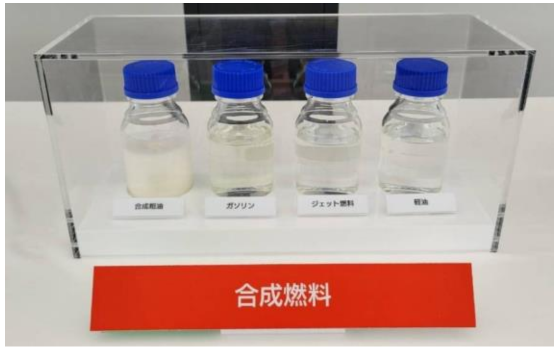


To be rolled out gradually from around 2027 beginning with supply to limited regions

Activities to Raise Social Awareness

Conducted a driving demonstration with TOYOTA to widely publicize the first Japanese-made synthetic fuel.

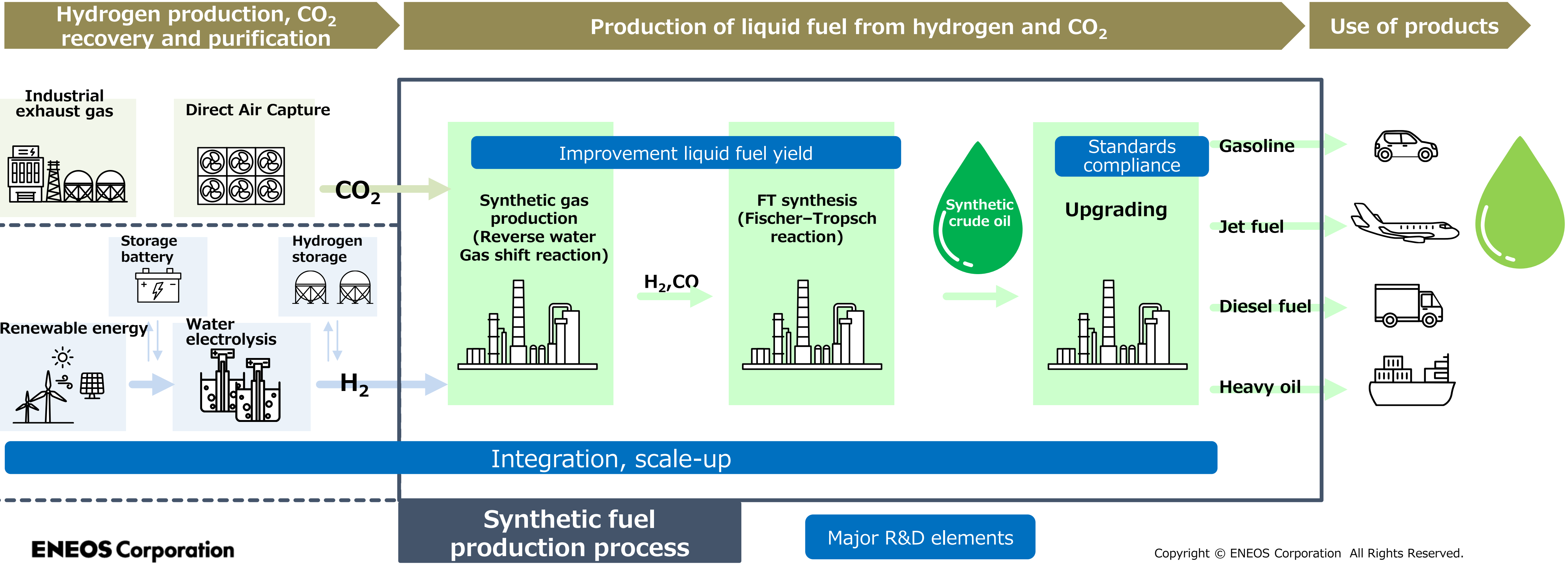
28th May 2023@ Fuji Speedway Mobilita



In addition to the presidents of ENEOS and TOYOTA, several members of the Japanese Diet and more than 50 members of the press attended, drawing a great deal of attention.

Improvement of synthetic fuel yield

We will promote the development of a production manufacturing process for upgrading to different fuel products by using a series of technologies for producing synthetic fuels consisting of
(1) a reverse water gas shift reaction to produce synthetic gases by reducing CO2 to hydrogen,
(2) FT synthesis to produce synthetic crude oil from synthetic gases, and
(3) the hydrotreating, cracking, etc. to produce several kinds of fuels.



ENEOS Corporation

Raw material needed for commercial scale production

For a production scale of 10,000 barrels per day:

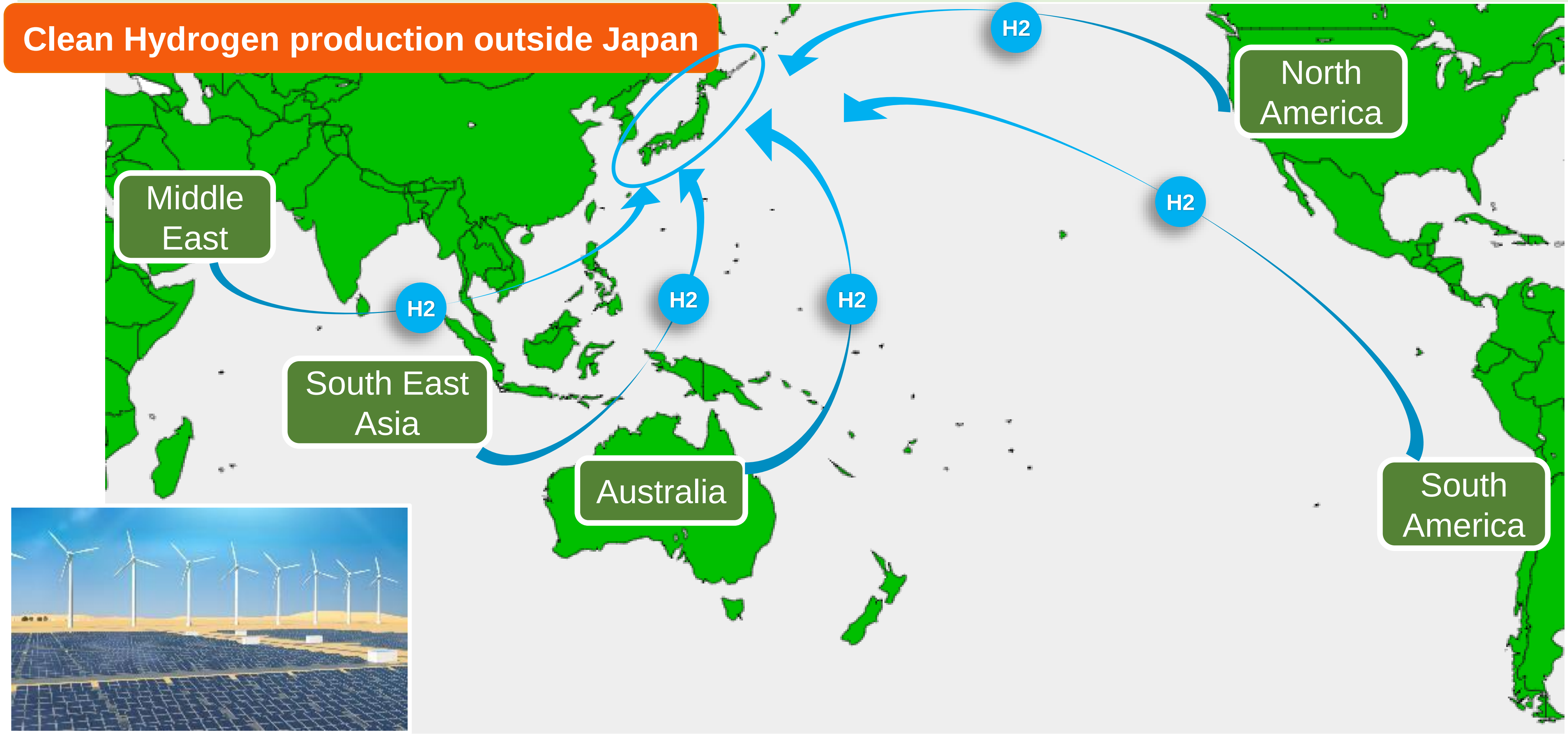
Required CO_2-free hydrogen amount	200,000 metric tons/year
Required renewable energy volume (Estimate)	PV panels equivalent to the area of around 500 Tokyo Domes (5km x 5km)
Required CO_2 volume	1-2 million metric tons/year
Location for CO_2 recovery (Estimate)	0.7-GW-class LNG power plant Equivalent to the total CO_2 volume in the exhaust gas

The introduction of innovative CO_2 capture technologies such as DAC*, which collects atmospheric CO_2, is also under consideration.

*DAC: Direct Air Capture

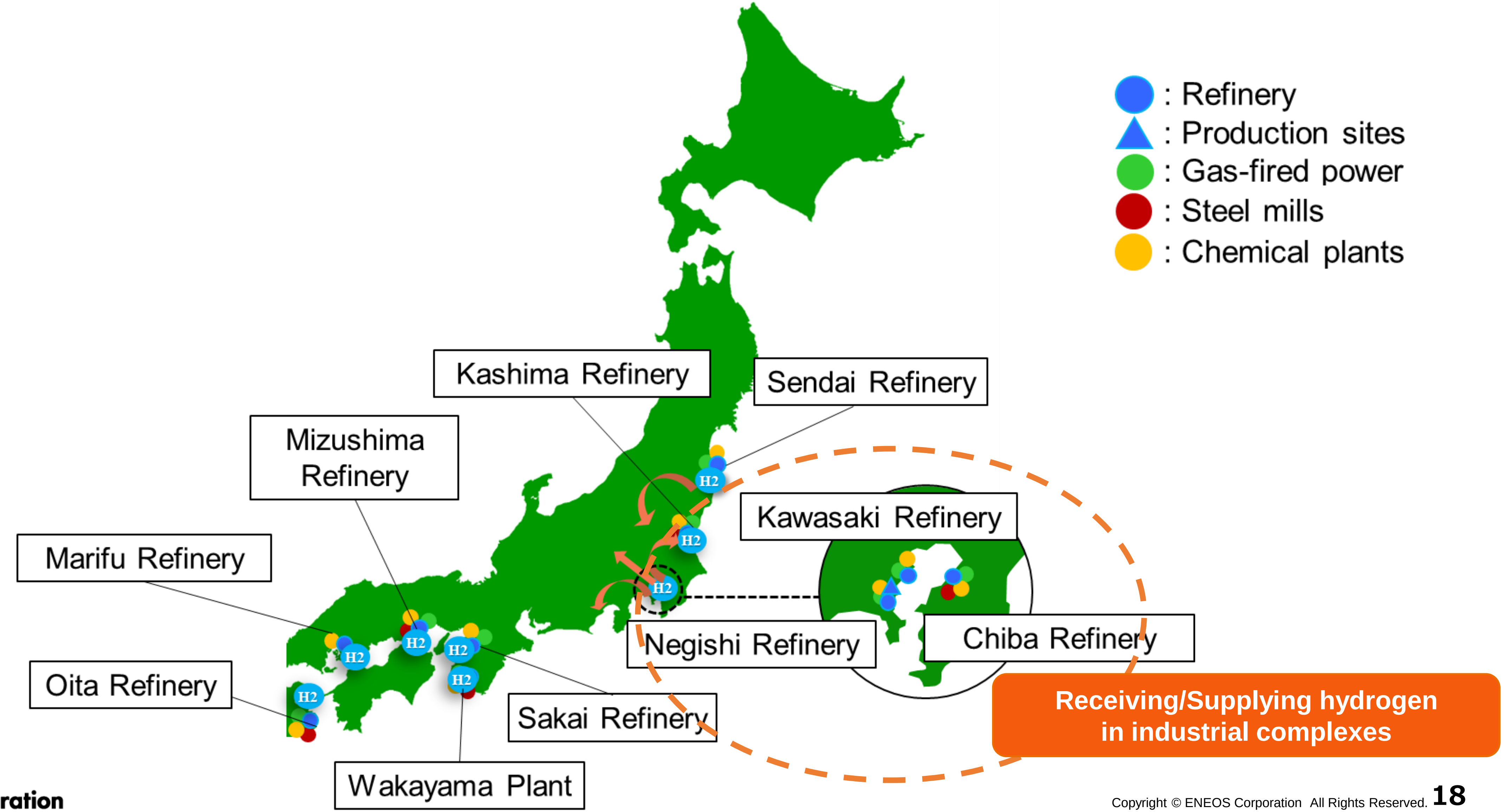
ENEOS Clean Hydrogen Supply Chain (transport from overseas)

- Securing global supply sources
- Our supply chain technology and know-how will guide us for smooth transition



ENEOS Clean Hydrogen Supply Chain (domestic receiving/storage)

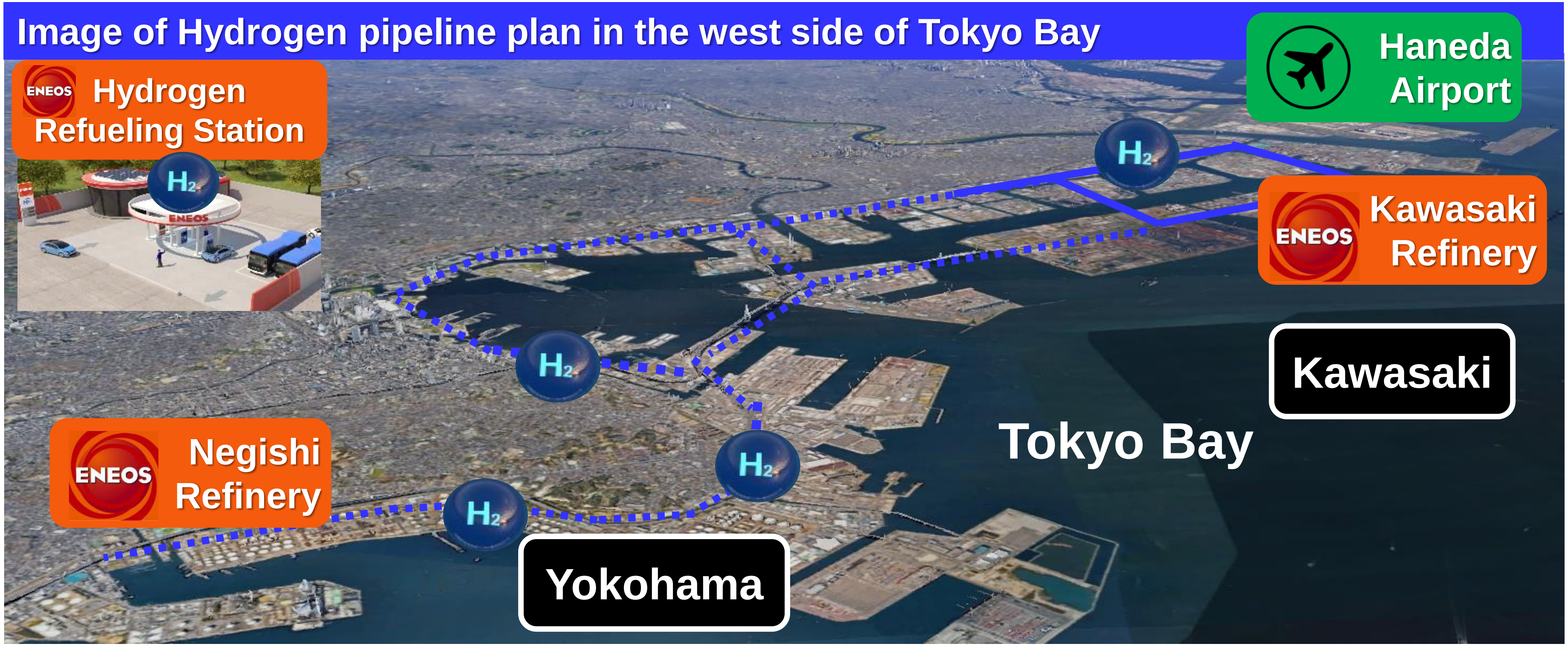
- Fully utilize existing petroleum/petrochemical assets and networks



Receiving/Supplying hydrogen in industrial complexes

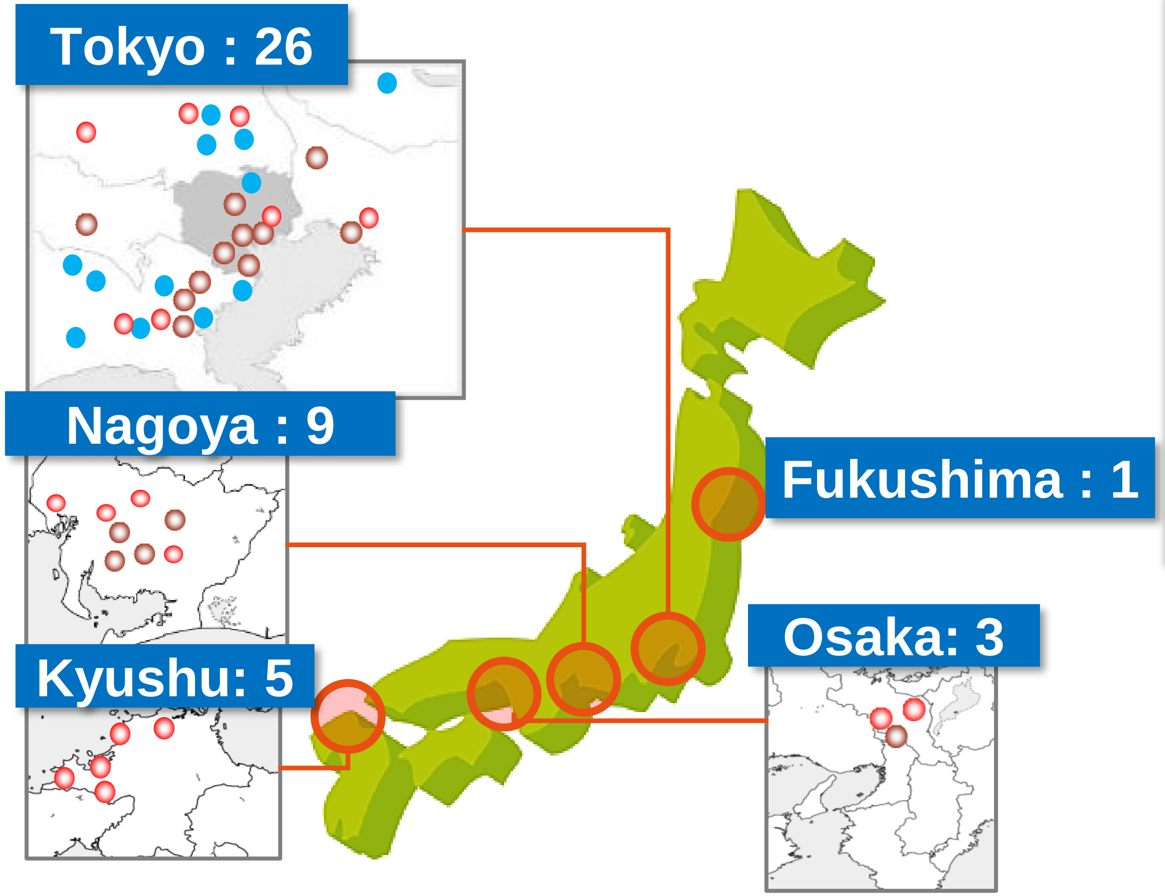
Study for Hydrogen Utilization Base in Japan

- Large-scale Hydrogen consumers aggregate in the west side of Tokyo Bay
- Developing Hydrogen pipeline plan to connect with the Large-scale consumers



Hydrogen Refueling Station Network for FC vehicles and buses

- ENEOS opened 1st hydrogen station in 2014
- Operate 44 stations in Fukushima, Tokyo, Nagoya, Osaka and Kyushu area

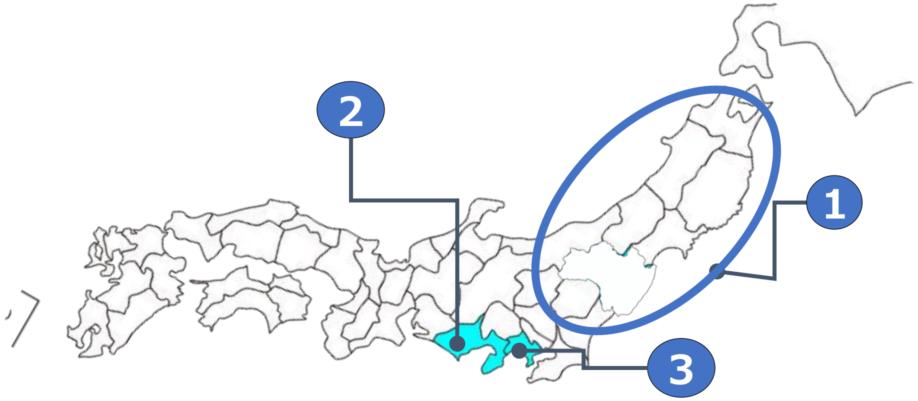


ENEOS's 44 Hydrogen Refueling Stations

Additional three locations are in line

ENEOS Clean H_2 Station Business

- Renewable H2 stations are in operation/underway with extra functions



① Integrated H2 station

・For various **FC mobility vehicles** (FC train, FC trucks etc.)

■ Partnership with **JR-East**

② Woven H2 station @Susono City

・H2 supply to **Woven City** from H2 station

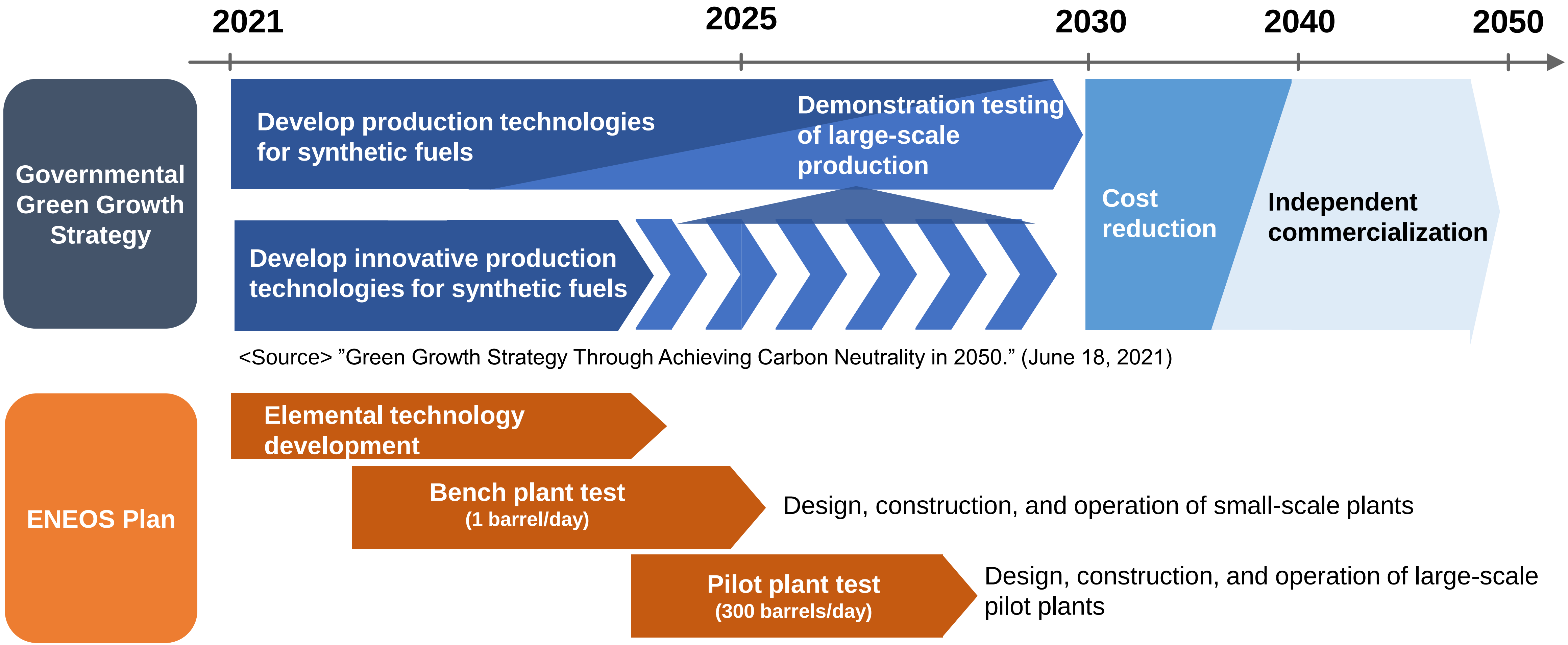
■ Partnership with **Toyota**

③ Green H2 station@Yokohama

・H2 Station with **PV panel**
・**Commercial sale** of green H2

Synthetic Fuels Roadmap

- In line with national government policies, we will reduce costs in the 2030s.
  *The cost of synthetic fuels during the commercialization phase is assumed to be the cost that includes its environmental value.


2021 2025 2030 2040 2050

Governmental Green Growth Strategy

Develop production technologies for synthetic fuels

Demonstration testing of large-scale production

Develop innovative production technologies for synthetic fuels

Cost reduction

Independent commercialization

<Source> "Green Growth Strategy Through Achieving Carbon Neutrality in 2050." (June 18, 2021)

ENEOS Plan

Elemental technology development

Bench plant test (1 barrel/day)

Design, construction, and operation of small-scale plants

Pilot plant test (300 barrels/day)

Design, construction, and operation of large-scale pilot plants