カワる、
サキへ。
Changing forward

For APEC Symposium on Pursuing Decarbonization of Fossil Fuels

# Towards the Realization of International Liquefied Hydrogen Supply Chain

October. 11, 2023

Kawasaki Heavy Industries, Ltd.

Kawasaki
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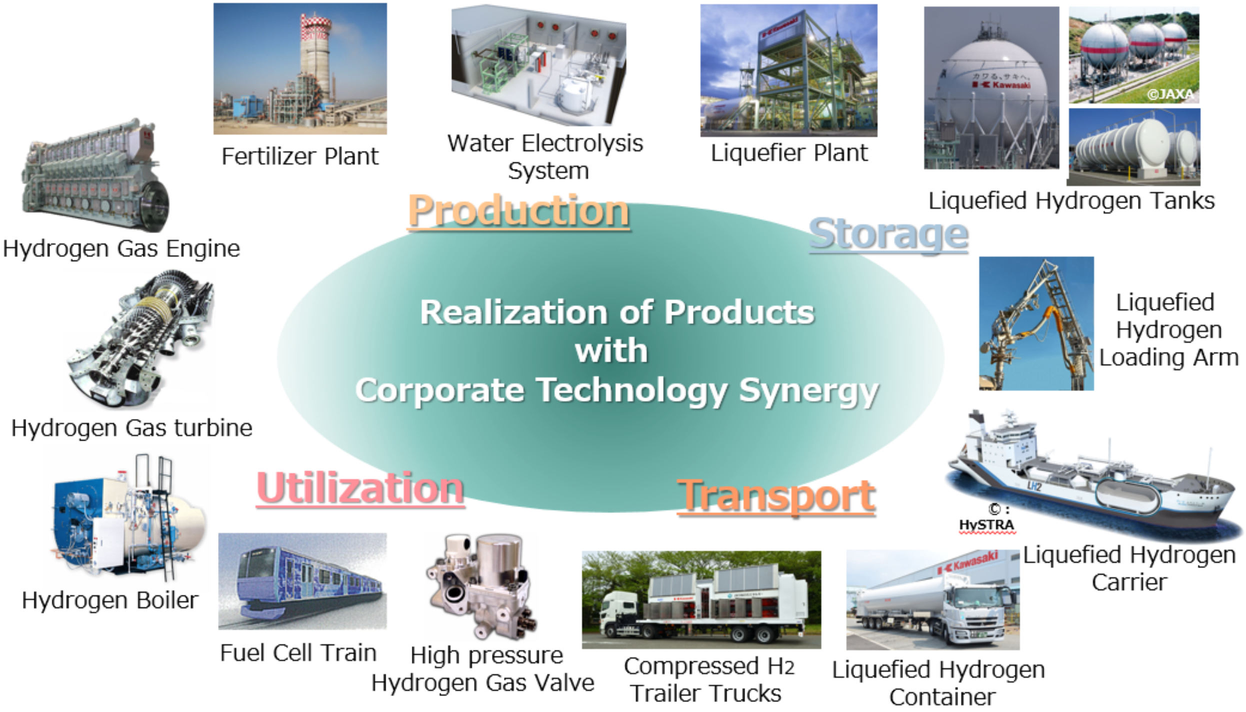
# KHI Group Hydrogen Products

Kawasaki Heavy Industries contributes to decarbonization as **the only company in the world** that has the technology for the entire hydrogen supply chain **to produce, transport, store, and utilize hydrogen.**



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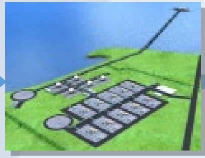
# Concept of a $CO_2$-Free Liquefied Hydrogen Supply Chain

## Hydrogen Producing Economy

Production of hydrogen at low costs from <u>unused resources and/or abundant renewable energy</u>

**Affordable Renewable Energy**



**Liquefaction/ loading**

**Fossil fuel: Natural gas coal ……**

**CCS (CO2 capture/storage)**

**CO2-Free Hydrogen**

**Production**

**Liquefied Hydrogen Carrier**

**Liquefied Hydrogen Containers**

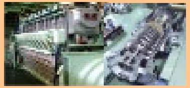

**Liquefied Hydrogen Storage Tanks**

**Transport / Storage**

## Hydrogen Utilizing Economy

**<u>Process Uses</u>**
Semiconductor and photovoltaic cell manufacture
Oil refinement, desulfurization, etc.

**<u>Transport Equipment</u>**
Hydrogen stations
Fuel cell vehicles etc.



**<u>Distributed Power Plants</u>**
Hydrogen gas turbines
Hydrogen gas engines
Fuel cells etc.

**<u>Electrical Power Plants</u>**
Combined Cycle power generators etc.

**Utilization**



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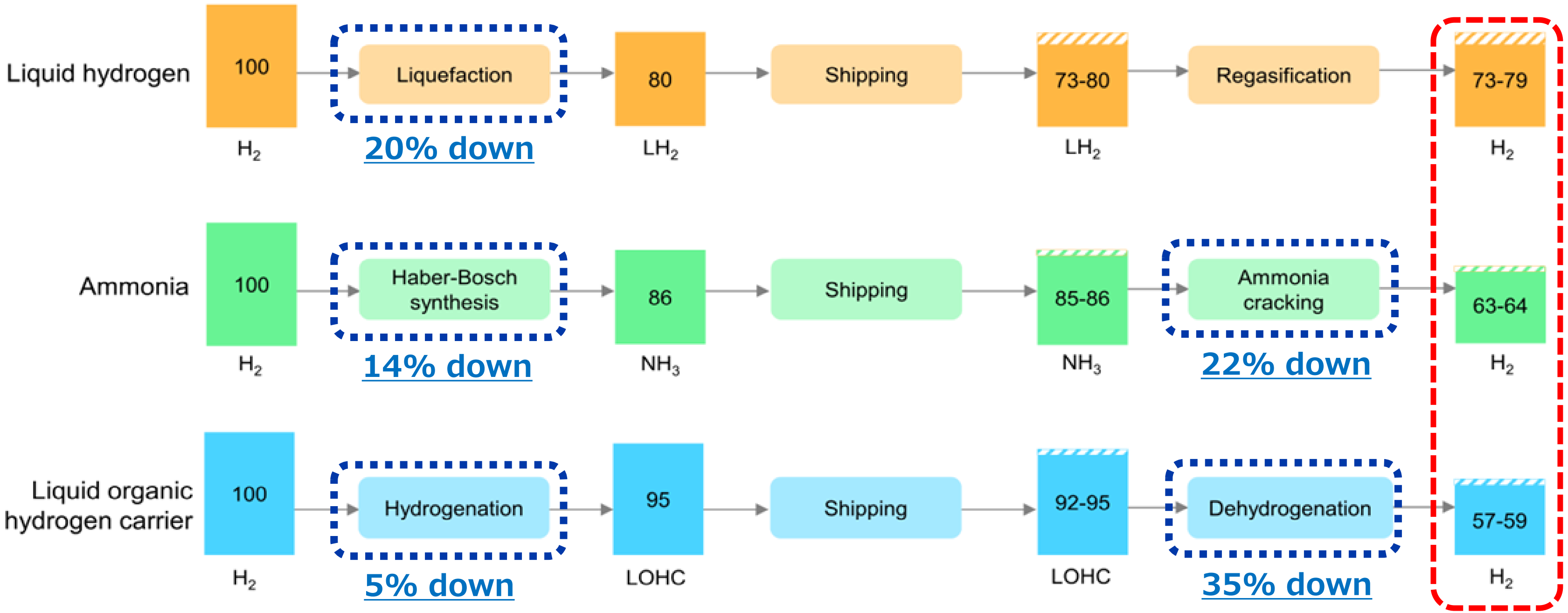
# Hydrogen Carriers and their Characteristics

| | Ammonia ($NH_3$) | Organic Hydride (MCH) | Liquefied Hydrogen |
|---|---|---|---|
| Volume (vs. gaseous form) | 1/1300 | 1/500 | 1/800 |
| Conditions for liquefaction | -33°C, atmospheric pressure | Atmospheric temperature and pressure | **-253°C**, atmospheric pressure |
| Toxicity | **Toxic, corrosive** | **Toxic with toluene** | None |
| Direct usage | Mixed combustion in coal-fired power generation, etc. (pure hydrogen must be separated) | Not possible (hydrogen separation is required) | Allow to evaporate, then use as-is |
| Transportation infrastructure | Can be transported using existing technology (chemical tankers etc.) | Can be transported using existing technology (chemical tankers etc.) | Domestic distribution is Widely spread on an industrial scale |
| Issues facing expanded usage | **Development of dehydrogenation equipment / direct use technology** | **Reduction of energy loss in hydrogen separation** | **Development of large-volume cryogenic transportation technology** |

*Estimated by Kawasaki with reference to Agency for Natural Resources and Energy's "Direction of Hydrogen-Related Projects Research and Development as well as Full Implementation," April 2021 edition, etc.

# Hydrogen Carriers Energy Efficiency

Energy available along the conversion and transport chain in hydrogen equivalent terms, 2030






Notes: $LH_2$ = liquefied hydrogen; $NH_3$ = ammonia; LOHC = liquid organic hydrogen carrier. Numbers show the remaining energy content of hydrogen along the supply chain relative to a starting value of 100, assuming that all energy needs of the steps would be covered by the hydrogen or hydrogen-derived fuel. The Haber-Bosch synthesis process includes energy consumption in the air separation unit. Boil-off losses from shipping are based on a distance of 8 000 km. For $LH_2$, dashed areas represent energy being recovered by using the boil-off gases as shipping fuel, corresponding to the upper range numbers. For $NH_3$ and LOHC, the dashed area represents the energy requirements for one-way shipping, which are included in the lower range numbers.

Resource: IEA Grobal Hydrogen Review 2022



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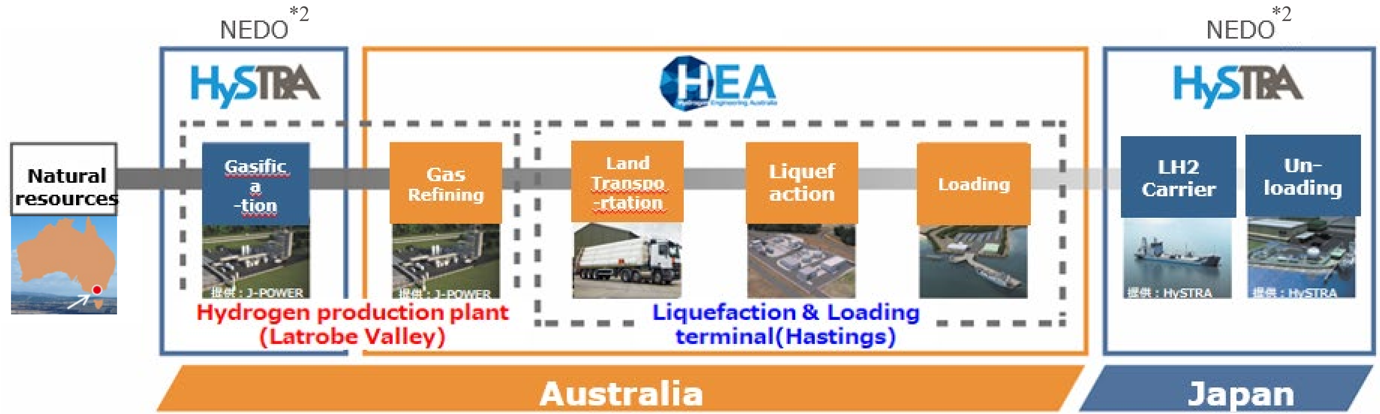
# Japan-Australia Pilot Project (HESC[*1] Project)

- Promoted with Japanese and Australian government, Kobe city, and private sector partners
- Aiming to establish a stable and large-scale hydrogen supply chain system around 2030, the pilot project **demonstrated technology by building a 1/100 scale of commercial supply chain**




**HySTRA** — Supported by the Ministry of Economy, Trade and Industry (METI) and NEDO

【CO2-free Hydrogen Energy Supply-chainTechnology Research Association】

Iwatani Corporation, Kawasaki Heavy Industries, Shell Japan, J-Power, Marubeni, ENEOS, KLINE
(As of March 2023)

**HEA** — Supported by Australia and Victoria government

【Hydrogen Engineering Australia】

Kawasaki Heavy Industries, J-Power, J-Power Group, Iwatani Corporation, Marubeni, Sumitomo Corporation AGL (Australian Energy Company)
(As of March 2023)

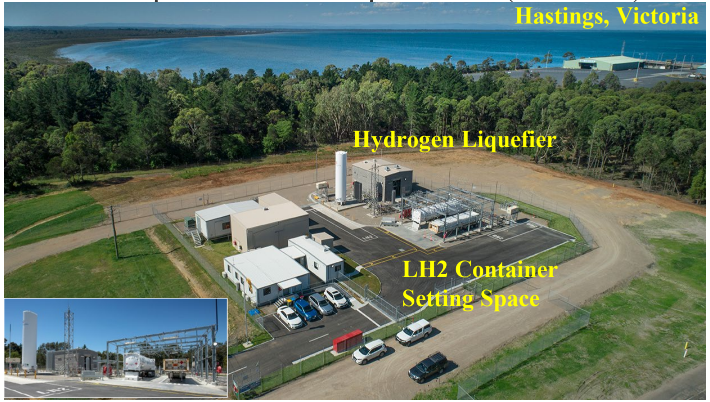
*1: HESC(=Hydrogen Energy Supply Chain) Project

*2: FY 2015 to FY 22: NEDO issue-setting industrial technology development expense subsidy program "Demonstration Project for Building a Large-Scale Maritime Transport Supply Chain for Hydrogen Derived from Unutilized Brown Coal"

# Status of the Pilot (HESC) Project

## Hydrogen Production (Australia)


## Land Transportation and Liquefaction (Australia)




## Maritime Transportation


Liquefied Hydrogen Carrier

| | | | |
|---|---|---|---|
| Length | 116m | Speed | 13knot |
| Width | 19m | Cargo | 1,250m3 |
| Crew | 25person | Propulsion | Diesel Electric |

## Unloading and Storage (Japan)


| principal particulars | |
|---|---|
| liquefied hydrogen storage tank | 2,500 m3<br>19 m in diameter<br>spherical vacuum double shell |
| loading system | Diameter 6" in vacuum double insulation<br>emergency release mechanism |
| BOG Management | BOG compressor<br>BOG Holder<br>vent stack |
| Other Equipment | Receiving equipment from tank Truck etc. |



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# World’s First International Shipping of Liquefied Hydrogen

- **World's first demonstration of hydrogen transport and cargo handling by liquefied hydrogen carrier**

First voyage from Japan to Australia (Dec. 24, 2021)


"Suiso Frontier" Australia arrival ceremony (Jan. 21, 2022)

Japan-Australia Pilot Project Completed (Apr. 9, 2022)


**At the ceremony to complete the demonstration of the Japan-Australia hydrogen supply chain**

**Prime Minister Kishida attended the meeting.**

# Commercialization Demonstration Project

■ Adopted as a Green Innovation Fund project for commercial supply chain construction in 2030.

■ **Began a commercialization demonstration project which implements technology for enlargement.**

Commercialization Demonstration Overview and Scale Image

**Green Innovation Fund**

**Participants**

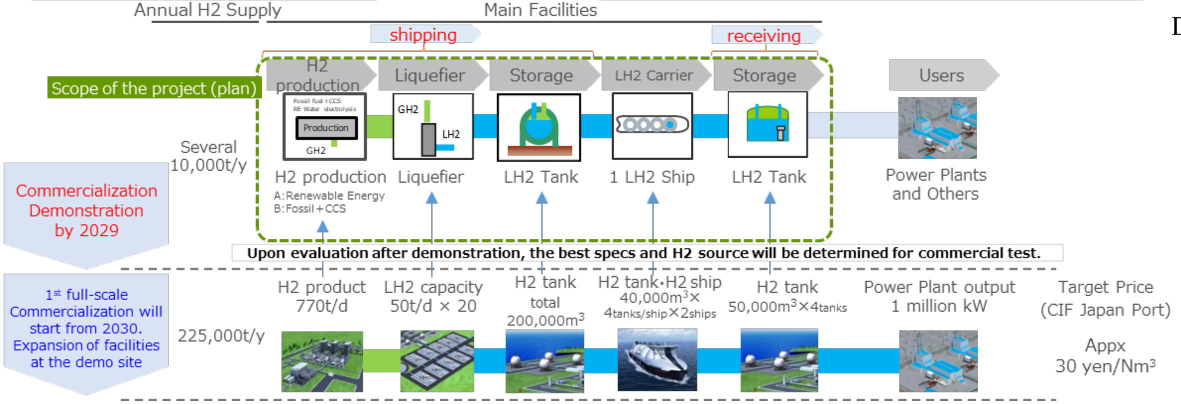
Japan Suiso Energy, Ltd. (JSE), ENEOS Corporation and Iwatani Corporation

**Investment**

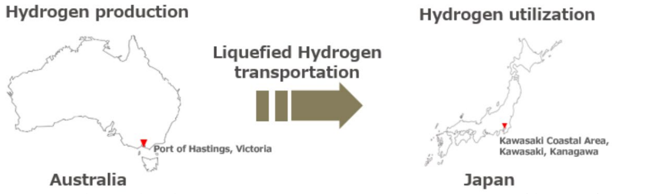
Total Investment* : Appx. 2.7 billion US$
Government support** : Appx. 2.0 billion US$

*Including the development of an innovative technology to further enhance liquefaction efficiency worked by Kawasaki.
**Including the amount of incentive reward. Expected to be rationalized in accordance with the progress of the project through stage-gate process.
1US$=110¥

**Overview**




Demonstration Location




Hastings, Victoria

Kawasaki Coastal Area, Kawasaki, Kanagawa



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# Development of Scaling Up on LH2 Technology

**Pilot Ship Tank: 1,250m$^3$**


X 32

**Commercial Ship Tank: 40,000m$^3$**

(4 tanks, 160,000m3 in total)


**Pilot Terminal Tank: 2,500m$^3$**


X 20

**Commercial Terminal Tank: 50,000m$^3$**

(Interface equipment, such as Loading arm and Compressor, are also under development)

# Progress and scale of commercial demonstration of Liquefied Hydrogen Supply Chain

■ Reduce hydrogen costs by increasing the size of equipment

**2021**

**Pilot Demonstration**


**1,250m³**

Proven for 40 years

**Spherical tank: 2,500m³**

Demonstrated feasibility of hydrogen production from brown coal and long-distance maritime transportation

(About 1/100 of the commercial level)

*Equivalent to about 5,000 households' power consumption

CIF JPY 170/Nm³

×128 ×20

**~2030**

**Commercialization Demonstration**

**160,000m³**

**Cylindrical tank: 50,000m³**

Determine the feasibility of commercialization, including economic efficiency, by setting the size of equipment to commercial scale

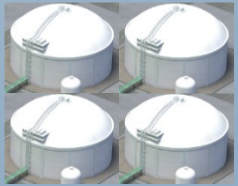
(One step away from commercialization)

CIF JPY 30/Nm³

**From 2031**

**Commercialization**

**160,000m³ x 2 carriers**



**Cylindrical tank: 50,000m³ x 4** (plan)

Profitable business which economically independent from installation to operation

*Equivalent to approx. 400,000 households' power consumption

**Around 2050**

…

…

CIF JPY 20/Nm³

*CIF cost

# Summary

- Kawasaki aim to realize commercial scale of liquefied hydrogen carriers and various equipment through commercial demonstration planning in the mid-2020.

- Kawasaki does not limit hydrogen sources to 'fossil fuels,' to support the hydrogen introduction described in the "Green Growth Strategy through Achieving Carbon Neutrality in 2050" decided by Japanese government.

- In establishing an international supply chain for liquefied hydrogen, Kawasaki will contribute to the realization of hydrogen costs and installed volumes that are competitive with fossil fuels in 2050 by cooperating with the demand side of hydrogen power generation, which is expected to generate large-scale demand.