Webinar - Kobe City
Hydrogen Twin Cities: H2 Kobe - Hydrogen is Here

Kawasaki Hydrogen International Liquefied Hydrogen Supply Chain

Kawasaki
Powering your potential

Kawasaki Heavy Industries, Ltd.

30 January 2024

Company Profile

Kawasaki Heavy Industries, Ltd.

Incorporated	October 15, 1896
Head Offices	**Tokyo Head Office** 1-14-5, Kaigan, Minato-ku, Tokyo 105-8315, Japan Tel. +81-3-3435-2111 / Fax. +81-3-3436-3037 Map > **Kobe Head Office** Kobe Crystal Tower, 1-3, Higashikawasaki-cho 1-chome, Chuo-ku, Kobe, Hyogo 650-8680, Japan Tel. +81-78-371-9530 / Fax. +81-78-371-9568 Map >
President	Yasuhiko Hashimoto
Paid-in Capital	¥104,484 million (As of March 31, 2023)
Number of Shares Issued	167,921,800 (As of March 31, 2023)
Net Sales	¥1,725,609 million (Fiscal year ended March 31, 2023)
Number of Employees	38,254 (As of March 31, 2023)

Kobe Head Office

Tokyo Head Office

More detailed information, please refer to our website.

https://global.kawasaki.com/en/corp/profile/index.html

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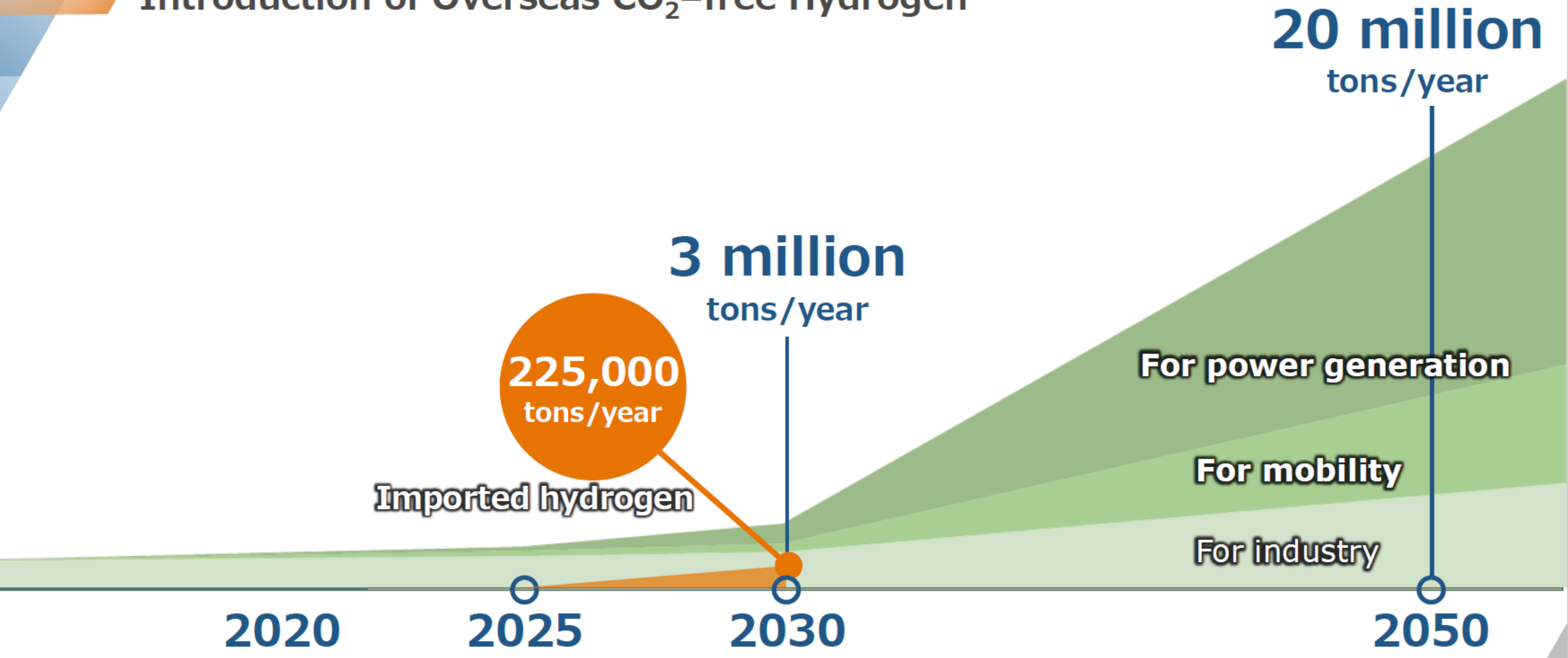
Introduction of Overseas CO_2–free Hydrogen



*Estimated by Kawasaki with reference to Ministry of Economy, Trade and Industry's "Future Hydrogen Policy Issues and Direction of Responses: Interim Summary (Draft)," March 2021 edition

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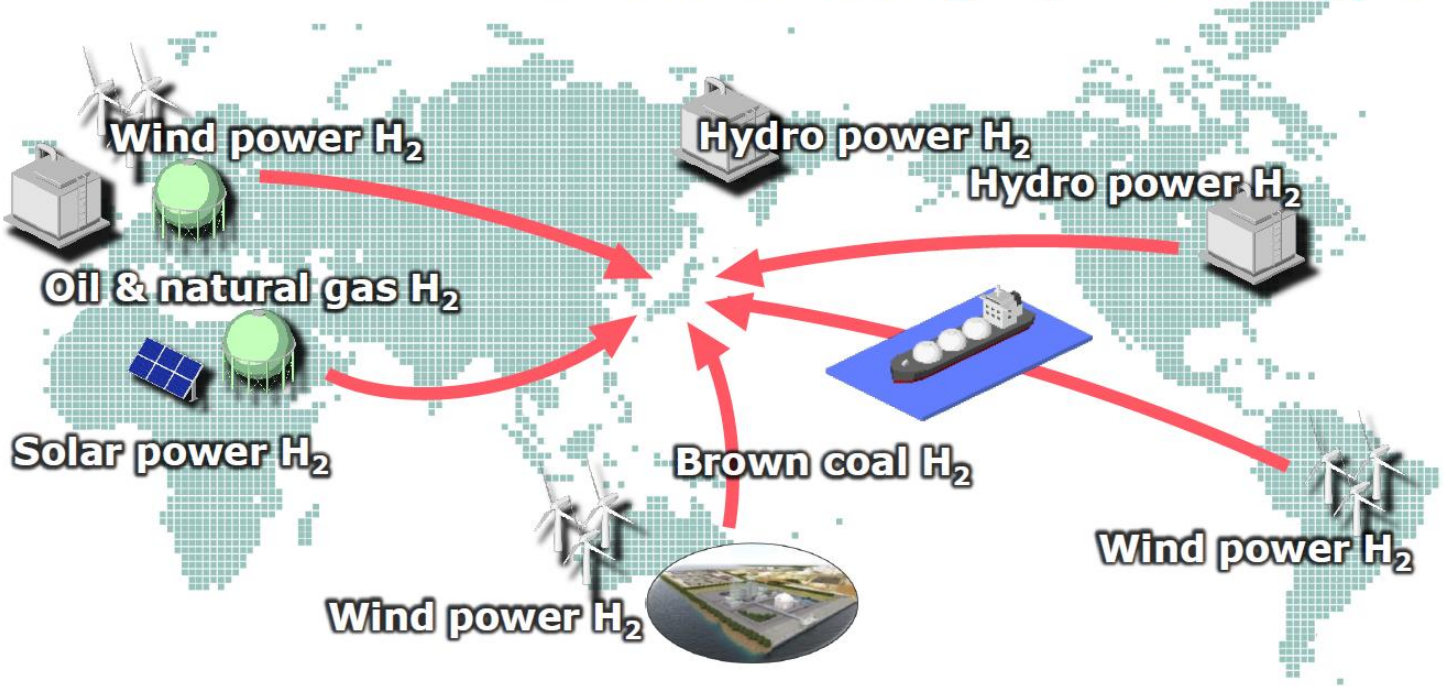
Economic Security

Hydrogen can be procured from a wide range of countries and energy sources

➤ Guaranteeing Japan's energy security

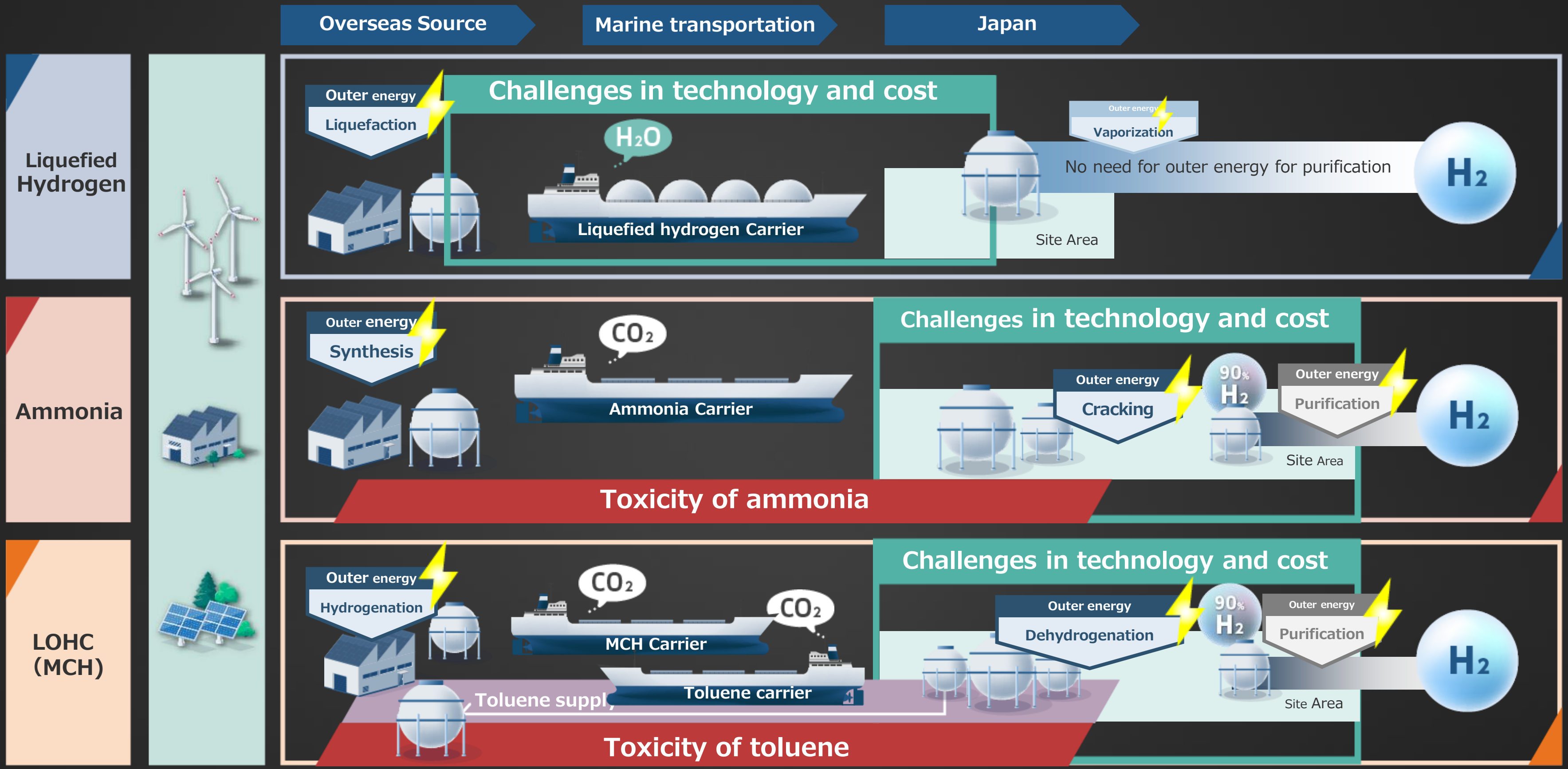


Methods of Transporting Hydrogen to Japan

	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.

Why Kawasaki Heavy Industries Chooses Liquefied Hydrogen



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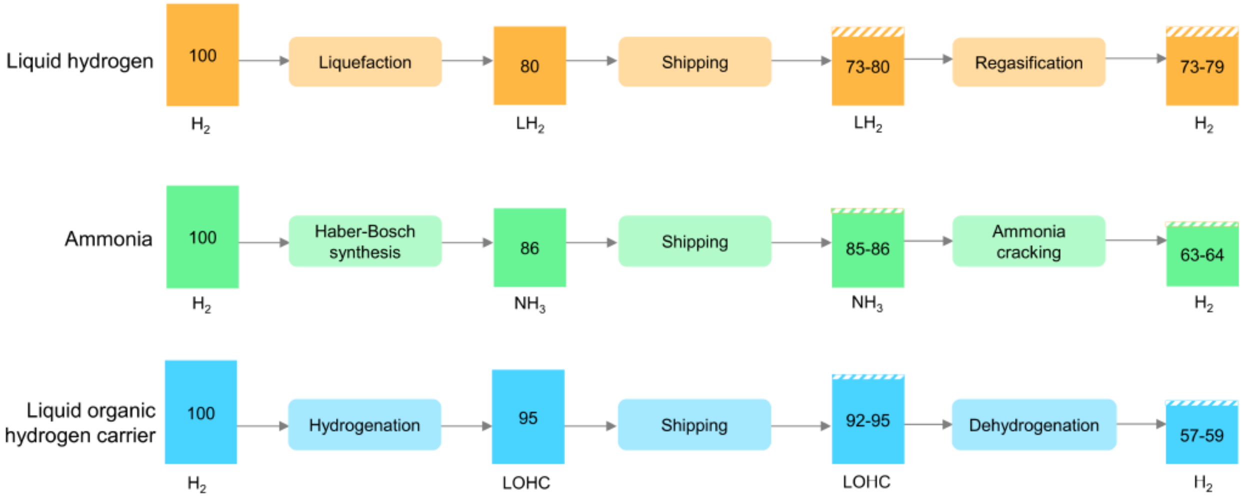
Comparison of energy efficiency of hydrogen carriers

Global Hydrogen Review 2022

Hydrogen infrastructure

The final use will influence the choice of the shipping option, as energy losses vary between the different hydrogen carriers

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

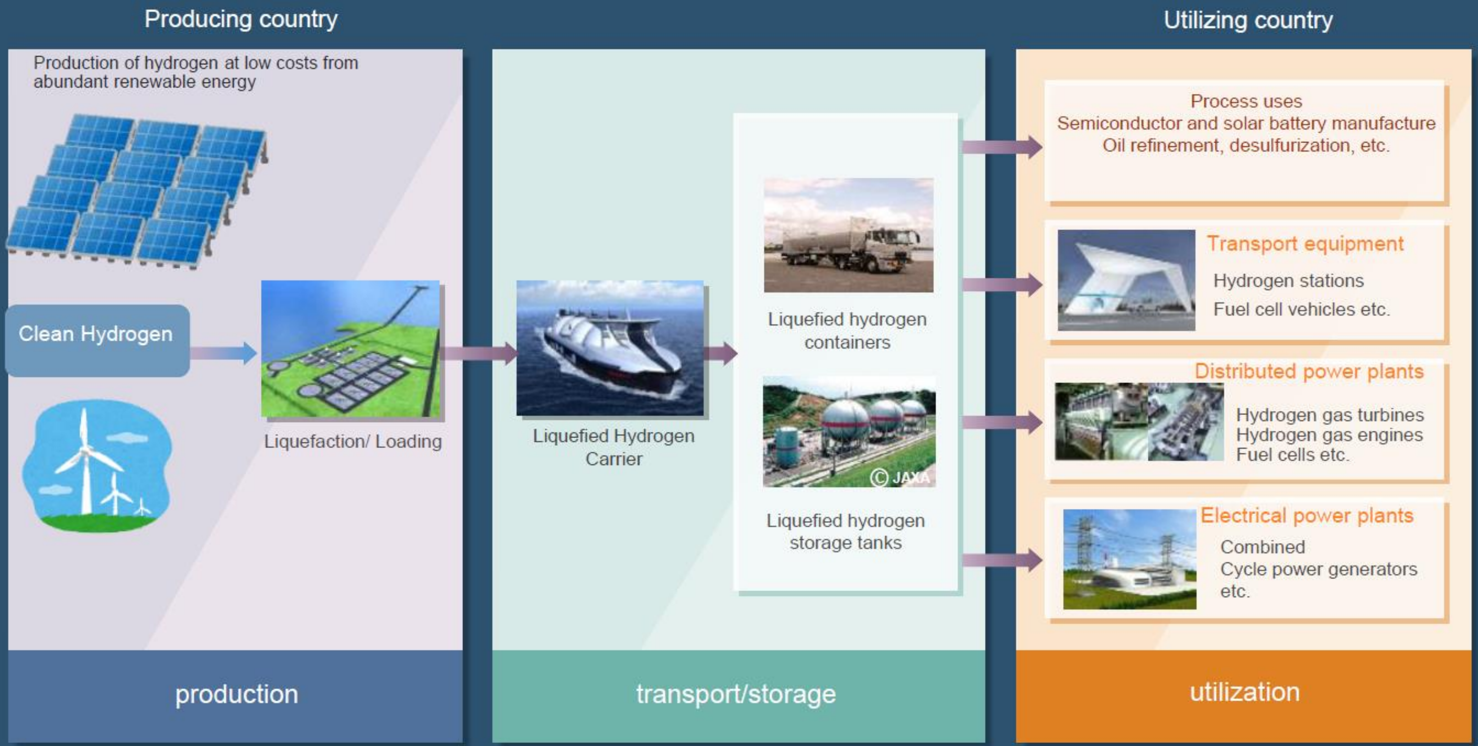


Notes: LH_2 = liquefied hydrogen; NH_3 = ammonia; LOHC = liquid organic hydrogen carrier. Numbers show the remaining energy content of hydrogen along the supply chain relative to a starting value of 100, assuming that all energy needs of the steps would be covered by the hydrogen or hydrogen-derived 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.

Source: IEA Global Hydrogen Review 2022

Vision for Hydrogen Supply Chains

Stable energy supply while reducing CO2 emissions



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Progress of commercial scale equipment development on demonstration

Pilot Demonstration

1,250m3

Proven for 40 years

Spherical tank: 2,500 m ^{3}

Electricity consumption in general households
* equivalent to about 5,000 households

Demonstration towards Commercialization

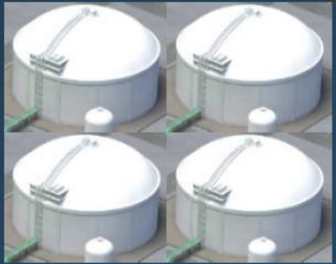
160,000 m ^{3}

advantageous to large scale

Cylindrical tank: 50,000 m ^{3}

Development of commercial-scale equipment is steadily underway at Kawasaki Heavy Industries

Commercial Chain



160,000 m ^{3} x 2 Carriers Cylindrical Tank: 50,000 m ^{3} x 4 (plan)

Household electricity consumption *
Equivalent to about
400,000 houses

*Estimation condition: 50% generation efficiency, use up all tanks in one month

International hydrogen supply chain: completed pilot demonstration

February 2022

World's First International Liquefied Hydrogen Transportation

Liquefied hydrogen carrier ‘SUISO FRONTIER’ attracts high level of interest from both home and abroad

*This project is supported by the "FY 2015 to FY 22 NEDO Target-Set Industrial Technology Development Grants' Demonstration Project for Construction of Unused Lignite-derived Hydrogen Large-Scale Maritime Transport Supply Chain."

Kawasaki's Cryogenic Technology Enables Large-Scale Transportation

Storage of very large amounts of liquefied hydrogen at -253 ◦ C for extended periods of time

World's first liquefied hydrogen carrier

Japan's largest liquefied hydrogen storage tank

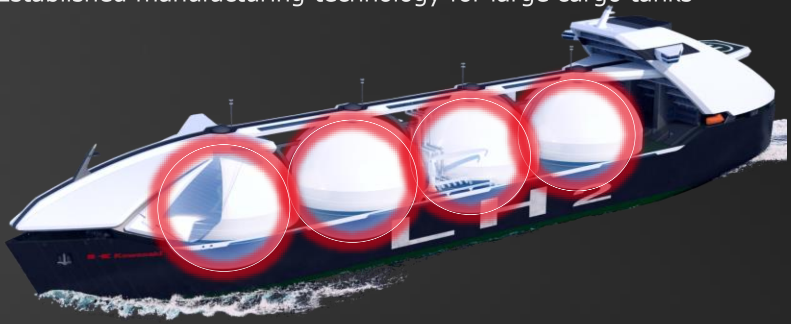
Realized through a giant double-wall low-temperature insulation structure

Development of major commercial-scale equipment
- Cargo tanks for large liquefied hydrogen carriers

Jun. 2023 **Completed technological development** of cargo tank for large liquefied hydrogen carriers by using the test tank desined based on “CC61H type” (grantd by NEDO*)

Completing the technical challenges of increasing size and verifying tank operation technology

- New cargo tank with our company's proprietary technology (Spherical Bilayer Structure, Two-Stage Thermal Insulation)
- Confirmed insulation performance as planned
- Established manufacturing technology for large cargo tanks



Large liquefied hydrogen carriers are planned to be Zero-Emission powered carriers using boiled-off hydrogen as fuel for maritime transportation.

» The government of Japan and our company are leading the revision of the international regulations on transport requirements for liquefied hydrogen to be adopted by the IMO_MSC108 (Maritime Safety Committee) in the spring of 2024

Development of major commercial-scale equipment
- Ternimal Tanks

Large tank for hydrogen terminals

- **Basic design is to be completed in March 2024**
- **Start of approval procedures for the High Pressure Gas Safety Law**

~ March 2024	Completion of pre-screening
~ October 2024	Detail design
October 2024	Application for inspection of specified equipment

Developed a tank that can be enlarged
Our unique structure and cooling system

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Existing business contributes to hydrogen business promotion

Low-temperature technology and production technology through history of large LNG tanks contribute to establish cryogenic technology for the large liquefied hydrogen tanks

Large LNG tank / Liquefied hydrogen tank / Liquefied hydrogen Container

Deliveries of large LNG tanks and liquefied hydrogen storage facilities
(including under construction)

2010 and later
Large LNG tanks:
24unites(including 7 after 2020)
Liquefied hydrogen storage equipment:
20 units (including 9 after 2020)

Large liquefied hydrogen tank

50,000m^3 class (commercialization demonstration project)

Further enlargement with lower costs

200,000m^{3}class (future project)

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Hydrogen Gas Turbine CHP* at Kobe Port Island

*CHP: Combined heat and power

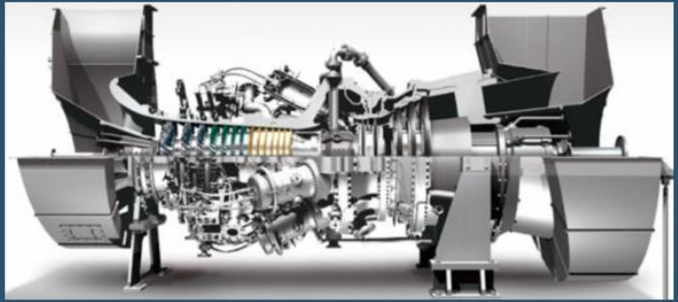
Started power generation by hydrogen combustion in 2018

Supported by NEDO

NEDO : New Energy and Industrial Technology Development Organization

The world's first industrial scale 100% Hydrogen-To-Power Demonstration with RWE

- Agreed to develop a joint hydrogen power generation demonstration project with **RWE**, a major power company in the US & Europe
- The project is scheduled to start operation in 2025

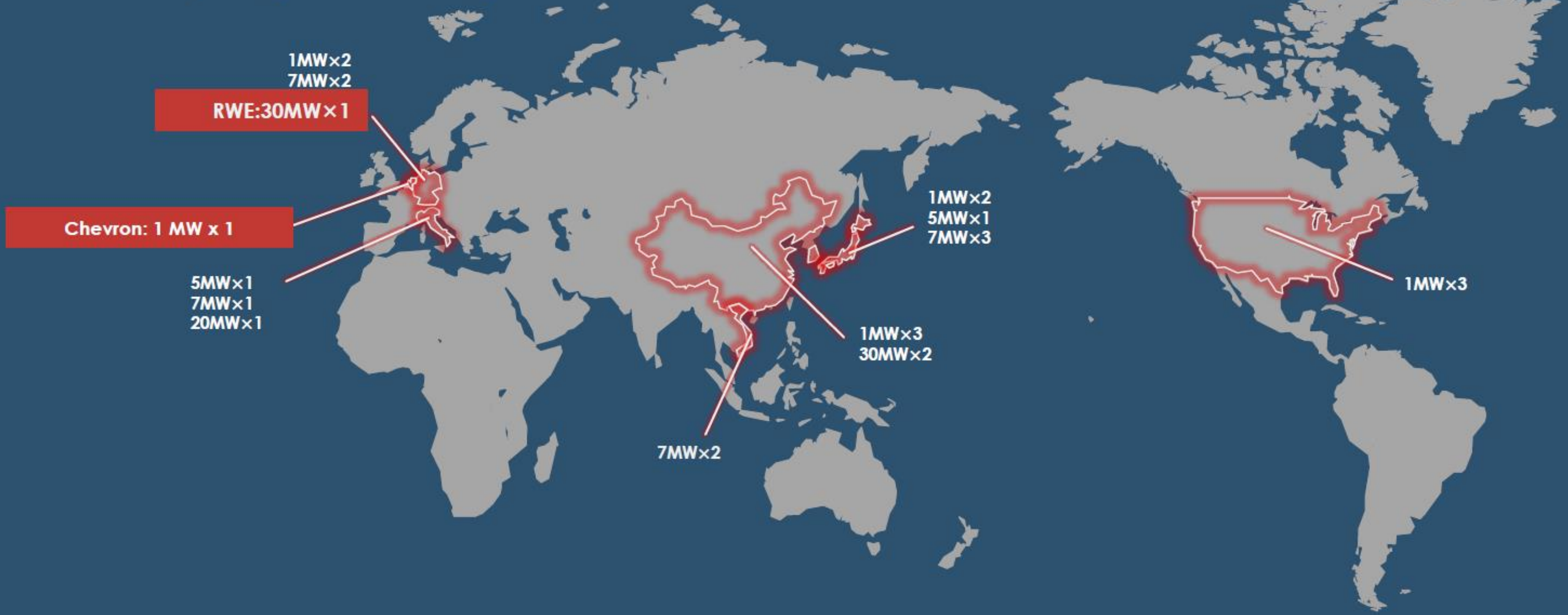


30MW-class gas turbine

Planned location:
Lingen, Lower Saxony, Germany

High attention to Kawasaki hydrogen gas turbine

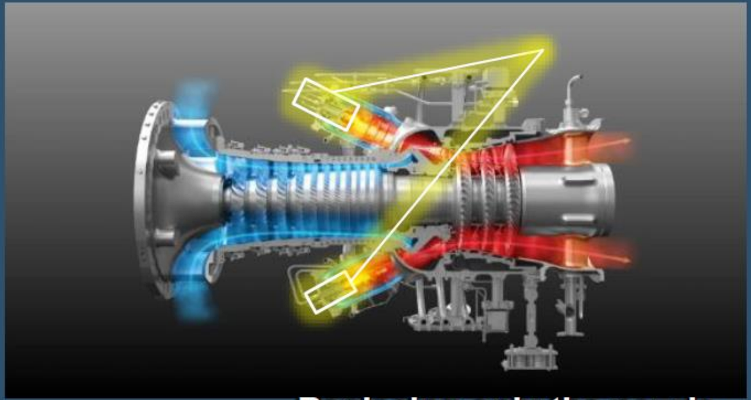
- Dozens of hydrogen power inquiries coming to our company from around the world
- Received an order from Chevron (Belgium) to remodel an existing natural gas turbine for hydrogen co-firing.



Kawasaki Hydrogen GT

- Hydrogen transition achieved while reducing CAPEX
- The refurbishment cost is approx.10% of the total cost of gas turbine power plant

- Existing Kawasaki Gas Turbine can be hydrogen-compatible only by replacing the nozzle
- A smooth decarbonization solution for existing gas turbine users in operation as well as new users



Replacing only the nozzle

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Expanding hydrogen fuel to Marine and Aviation

- Know-how to burn hydrogen safely and cleanly developed through hydrogen power generation
- Pursuing Kawasaki's combustion technology further, leading the world in mobility internal combustion engine

Development of Hydrogen-Fueled Vessel Propulsion System *1

Complete lineup for various applications by around 2026

Hydrogen Aircraft Core Technology Development Project*2

Promote development in anticipation of full-scale launch after 2035

Joint Research on Hydrogen Engines

Domestic two- and four-wheel manufacturers collaborate to develop hydrogen engine

*1 NEDO Green Innovation Fund Project "Development of a Hydrogen Fuel Ship Propulsion System" (about 21.9 billion yen in subsidies) (Yanmar Power Technologies to be Adopted in Consortium with Japan Engine Corporation)

*2 NEDO Green Innovation Fund Project "Core Technology Development for Hydrogen Aircraft" (grant: about 18 billion yen)

Further Development of Hydrogen-Related Products / Businesses

Liquefied Hydrogen Supply Chain

Energy Solution & Marine Engineering Company

Hydrogen Valves

Precision Machinery & Robot Company

Fuel Cell Vehicles

Rolling Stock Company

HQ Hydrogen Strategy Division

Hydrogen Power Generation

Hydrogen Vehicles

Motorcycle & Engine Company

Hydrogen Aircraft Engines

Aerospace Systems Company

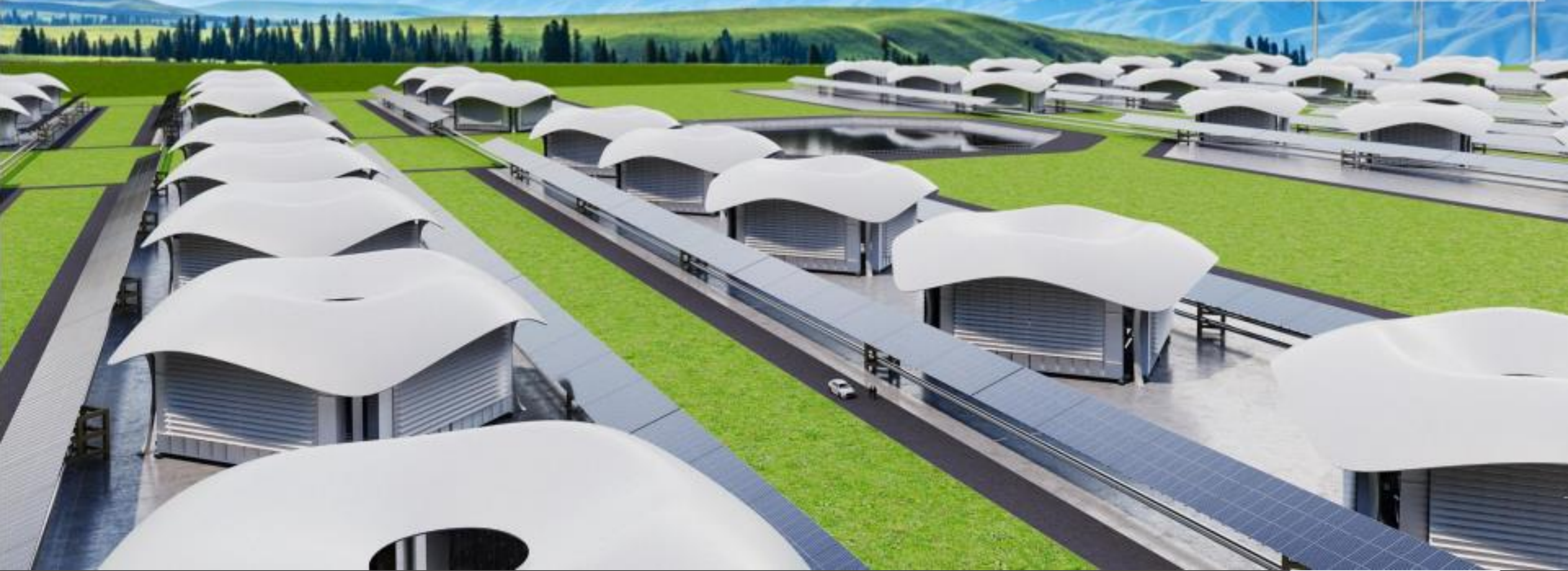
Our DAC business

Large-Scale DAC ready around 2025

KHI promotes
CO_2 capture business from the atmosphere through large-scale DAC facilities (Approx. 500,000 - 1million t - CO_2 / year)

Respond to contacts from energy companies

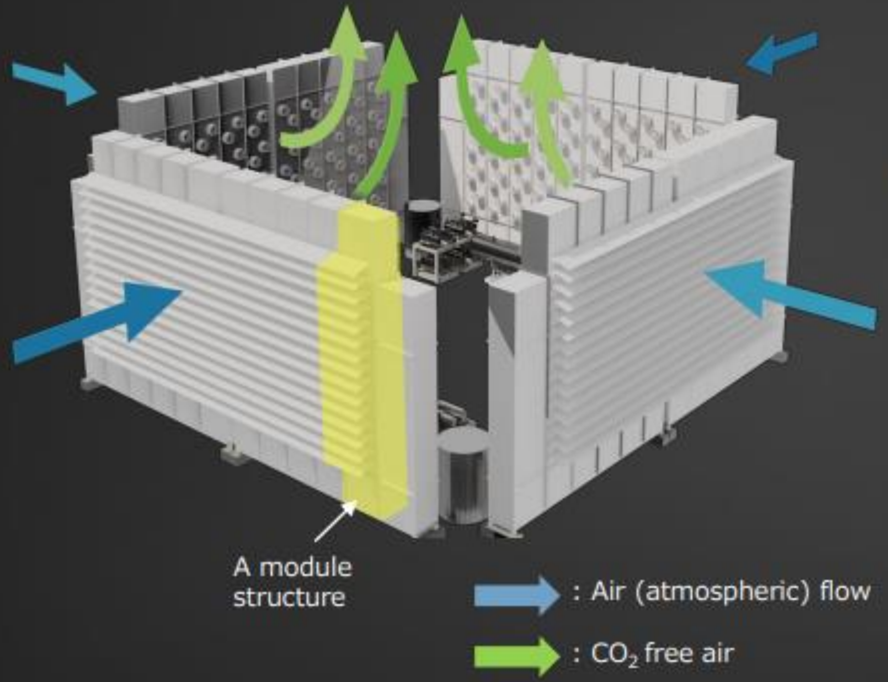
DAC image of 1 million t - CO_2 / year

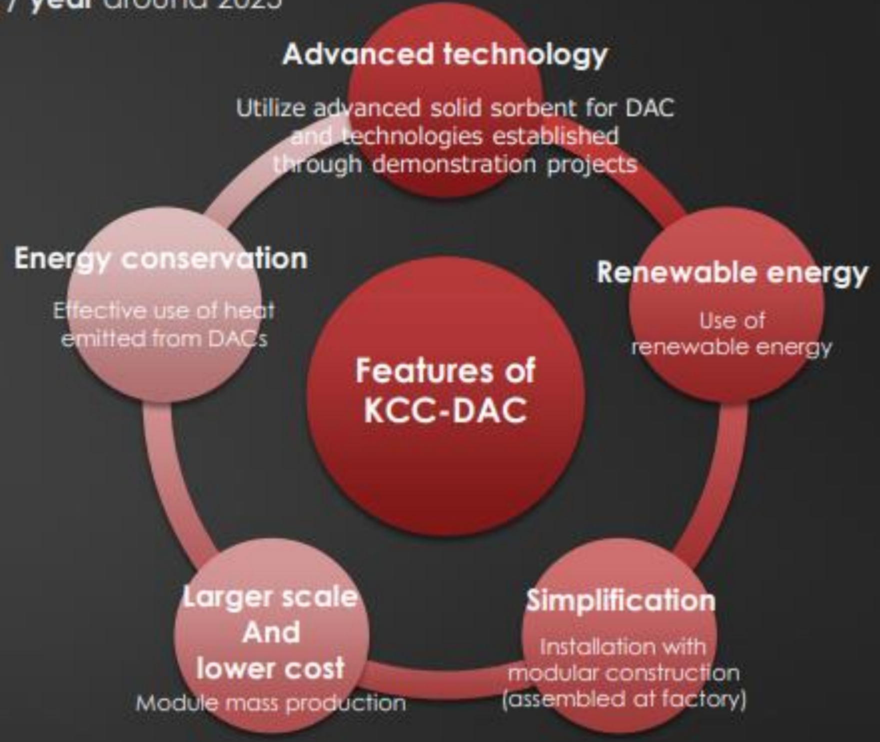


※ KCC : Kawasaki CO2 Capture

Toward large-Scale DAC ready

- Demonstration of facilities **of Approx. 20,000 t - CO_2 / year** around 2025



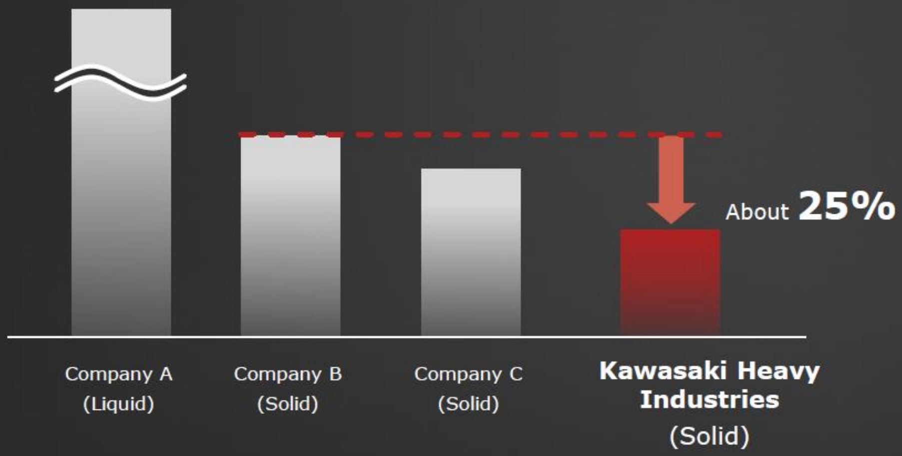


Our unique CO_2 capture technology

Because CO_2 can be desorbed from solid sorbent at low temperatures,

Achieving DAC through energy conservation by using renewable energy and unused waste heat

Thermal energy required for capturing CO_2



Individual solid sorbent

In-house developed solid sorbent to save energy

We will contribute to the early realisation of global carbon neutrality by expanding the decarbonisation solutions, including our group's hydrogen business

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