Reposting Not Allowed

Kawasaki Heavy Industries Hydrogen Business Initiatives and Future Prospects

Kawasaki Heavy Industries, Ltd.
Hydrogen Strategy Division
Executive Officer
Shigeru Yamamoto

Powering your potential

カワる、サキへ。
Changing forward

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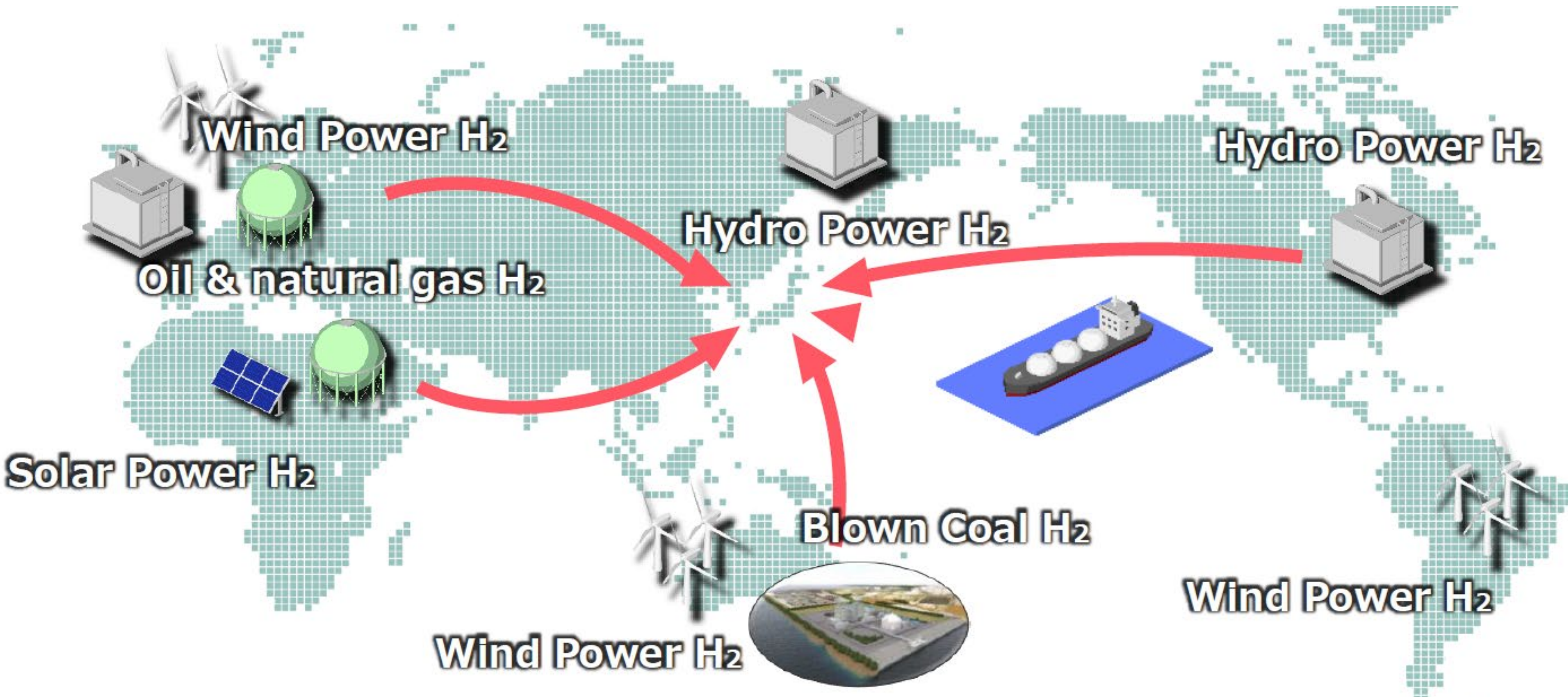
Contribution of hydrogen energy to economic security and domestic industry

Hydrogen can also be produced domestically and also from a wide range of countries and resources.

Guraranteeing Japan's energy security and stable supply to domestic industries



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Movement to implement hydrogen society

Japanese Government	Private Sectors	Kawasaki Heavy Industries, Ltd.

2010

● Start hydrogen supply chain research and development

*Tanegashima Island Space Center (JAXA)
Liquefied Hydrogen Tanks proven for over 40 years

● Cooperation among private companies

- HySTRA
- Hydrogen Council
- Hydrogen Value Chain Promotion Council (JH2A)

2014 **Fifth Strategic Energy Plan**

*At the time, only Japan formulated a comprehensive hydrogen strategy in the world.

2015 **Support from the Japanese and Australian governments**

● Launch pilot demonstration project

2018 **Basic Hydrogen Strategy and Hydrogen Energy Ministerial Meeting**

2020 **Declaration of Carbon Neutrality**

Green Growth Strategy

● First movers

2021 **Sixth Basic Energy Plan**

Establishment of the Green Innovation Fund

● Start commercialization demonstration project

"Large-Scale Hydrogen Supply Chain Development Project "

2022 **Green Economic Transition Bonds and Support System**

*Compensation for value difference compared to the existing fuels
Accelerated discussion on support for efficient base infrastructure development

2023 **Revision of Basic Hydrogen Strategy**

2030 **Start commercial chain operations that benefit the public**

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Japan government: Basic Hydrogen Strategy

- **The world's first Basic Hydrogen Strategy was formulated in 2017 and revised on June 6, 2023.**
- **The Hydrogen Industrial Strategy aims to create a society where our country's hydrogen core technology can be used in domestic and international hydrogen businesses..**

[Key Points of the Basic Hydrogen Strategy Revision]

- Target for introduction of hydrogen: 3 million tons in 2030, **12 million tons in 2040, and** 20 million tons in 2050.
- The target for Japanese companies to install electrolyzers in Japan and overseas is set at 15 GW by 2030.
- **Development of support systems for building supply chains and improving supply infrastructure**
- G7 agreed on carbon intensity, shift to low-carbon hydrogen, etc.

[Key Points of Hydrogen Industrial Strategy]

- **In order to "win both in technology and in business," the government will promote mass production and industrialization at an early stage.**
- **Japan's hydrogen core technology** (fuel cells, electrolyzer, power generation, **transportation**, materials, etc.).

->Support for large-scale investment aimed at decarbonization, stable energy supply, and economic growth.
Supply chain investment plan of 15 trillion yen over 15 years for the public and private sectors

Source: https://www.cas.go.jp/jp/seisaku/saisei_energy/kaigi_dai4/gijisidai.html

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Trend of the global companies: Hydrogen Council

Hydrogen Council

- Comprised of 150 leading companies in the world, including energy, transportation, manufacturing, trading companies, and banks

(market capitalization is more than 1,100 trillion yen)

- Japanese companies: Toyota, Honda, Kawasaki Heavy Industries[Note], Iwatani Corporation, ENEOS, Toyota Tsusho, Mitsubishi Corporation, Mitsui & Co., Marubeni, Sumitomo Corporation, Mitsubishi Heavy Industries, NGK, SMBC, ITOCHU, Nippon Yusen, Tokyo Gas ・・・

- Global Initiative to advocate for a joint vision and long-term goals for a hydrogen-based new energy transition

  =>January 2022: Chairperson of Kawasaki Heavy industires, Ltd., Mr. Yoshinori Kanehana, has been appointed to co-Chair of the Hydrogen Council

- In June 2023, the CEO meeting was held in Japan for the fiest time. (Awaji Island, Hyogo Prefecture)

Note: Japanese companies among the 13 companies established in 2017 are written in green.

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Trend of domestic companies: Japan Hydrogen Association

Abbreviation: JH2A=Japan Hydrogen Association

Purpose	As a cross-industry, open organization, with a bird's-eye view of the entire supply chain, build a hydrogen society at an early stage by introducing social implementation projects		
Main activities	Generate hydrogen demand, reform laws and regulations, develop standards, and finance		
Chairperson	Takeshi, UCHIYAMADA (Toyota Motor Corporation) Tsuyoshi, KUNIBE (Sumitomo Mitsui Financial Group) Myoji, MAKINO (Iwatani Corporation)	**Vice Chairper-son**	Takeshi SAITO (ENEOS) Yasuhiko HASHIMOTO (Kawasaki Heavy Industries) Yotsuyanagi HATA (Toshiba) Tatsuo YASUNAGA (Mitsui & Co., Ltd.)
Board member 13 companies	Iwatani Corporation, INPEX, ENEOS, Obayashi Corporation, Kawasaki Heavy Industries, Kansai Electric Power, Kobe Steel, Chiyoda Corporation, Toshiba Corporation, Toyota Motor Corporation, Panasonic, Sumitomo Mitsui Financial Group, Inc. Mitsui & Co., Ltd. (As of December 2022)		
Number of members	338 companies and organizations (as of December 2022) Total market capitalization: ¥267 trillion		

April 2022 Commemorative photo of incorporation

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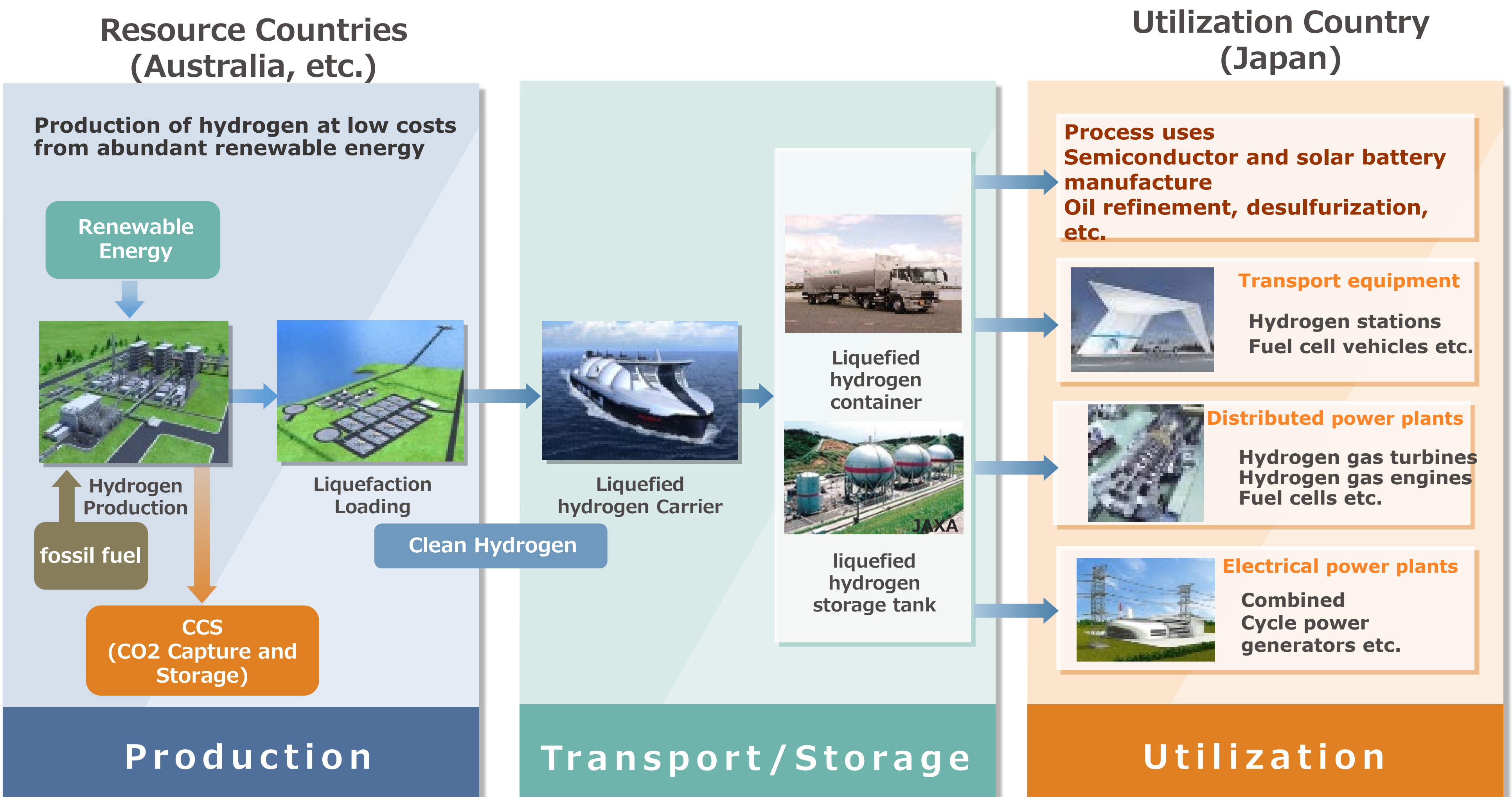
Concept of CO_2 free hydrogen supply chain

Stable supply of energy while reducing CO_2 emissions



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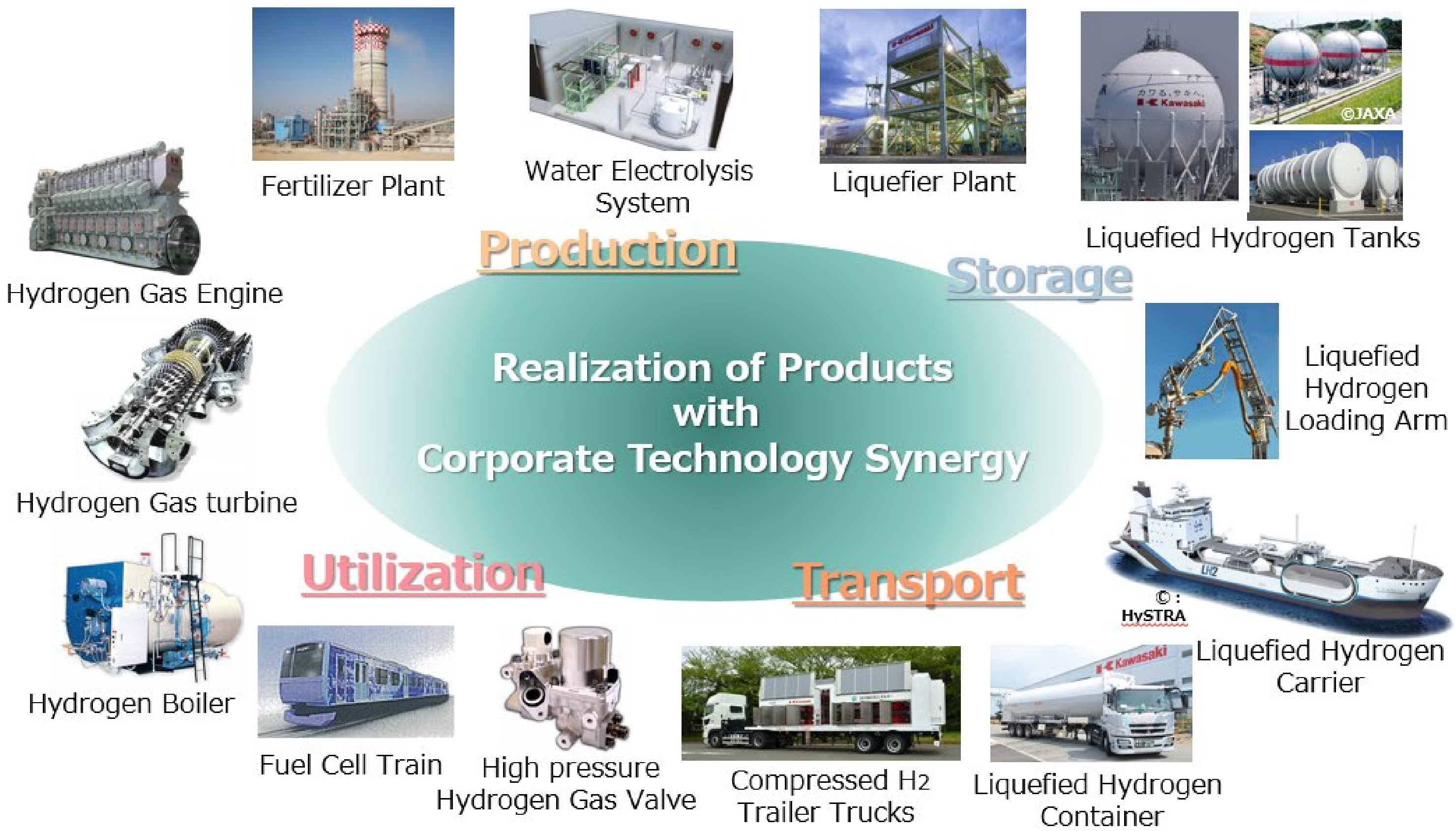
Hydrogen-related products

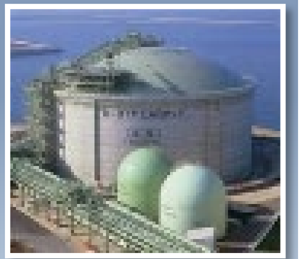
Kawasaki Heavy Industries contributes to decarbonization as **the only company in the world** that has the technology for the entire hydrogen supply chain **to produce, transport, store, and utilize hydrogen**



Liquefied hydrogen: Mass transport of hydrogen

- Liquefaction at cryogenic temperature (-253°C) ⇒ **1/800 volume compared to gas**
- High-performance thermal insulation technology (double-shell vacuum insulation) **enables long-term storage** equivalent to LNG.
- **Nontoxic, odorless, no greenhouse gas**

Kawasaki Heavy Industries know-how and knowledge of cryogenic technology can be utilized!



LNG Technology

Liquefied Hydrogen Tank (Tanegashima Space Center)

Japan's largest liquefied hydrogen tank (Kobe Liquefied Hydrogen Loading Terminal)

World's First 1,250 m ^{3} Liquid Hydrogen Carrier

Large Liquefied Hydrogen Carrier

Liquefied Hydrogen Technology

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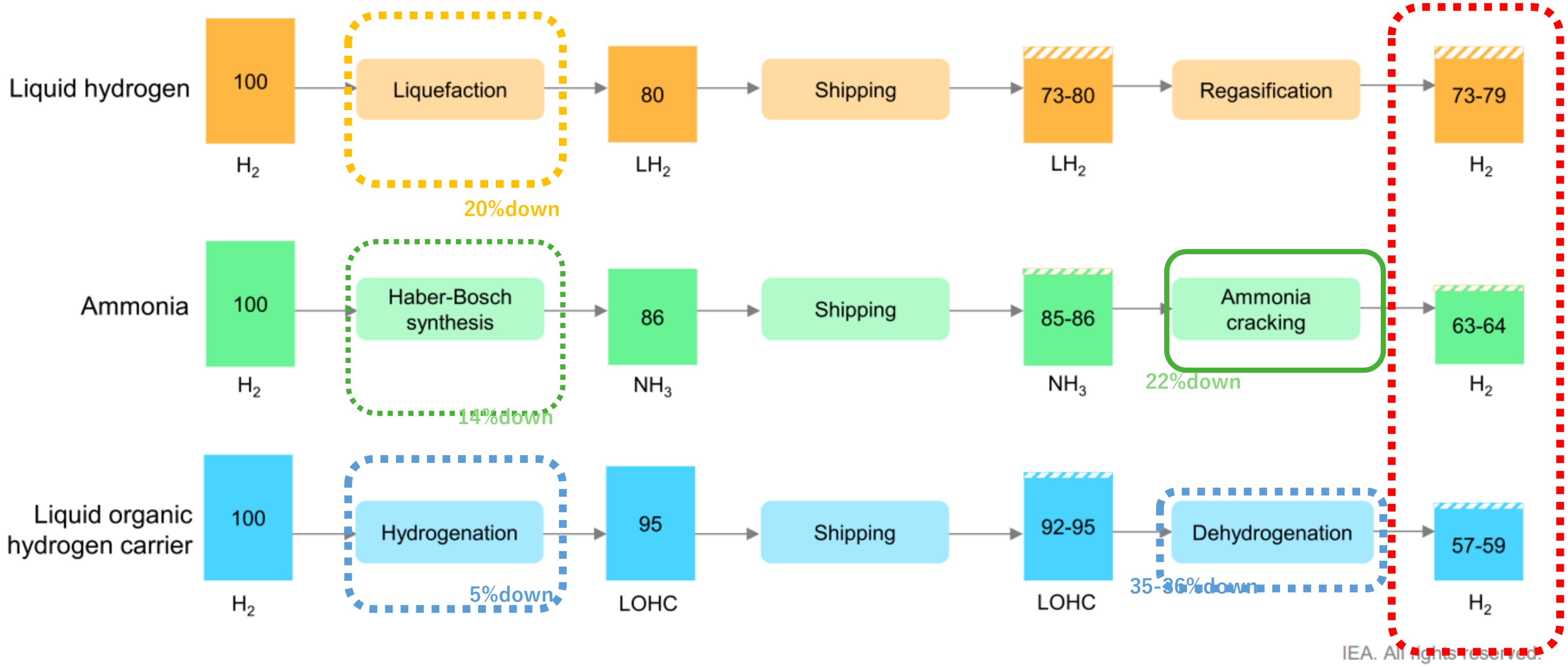
Energy efficiency and cost reduction effects of liquefied hydrogen

Considering energy losses during carrier conversion and transport, **liquefied hydrogen has energy efficiency advantage for end-use,** according to the IEA.

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.

Resource: IEA Global Hydrogen Review 2022

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Liquefied hydrogen:
Cost reduction measures

- Liquefied hydrogen: **The larger the transport volume, the greater the cost reduction effect.**
- **Benefit from liquefied hydrogen imports in a large-scale**

MT(Middle Term): 2030
LT (Long Term): 2050 years

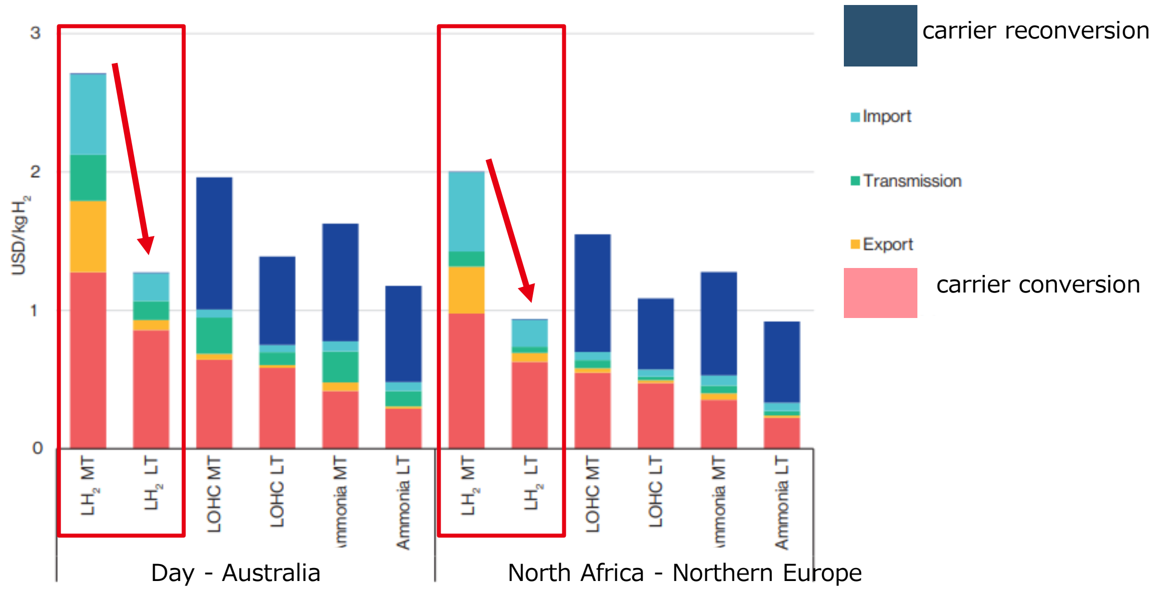

Figure 8. Projected cost of delivering liquid hydrogen, LOHCs and ammonia from resource countries to demand countries in the medium and long term

Further improvements in efficiency and scaling up can reduce transport costs by 25-50% and more in the long term.

Notes: MT = medium term. LT = long term. LH_2 = liquid hydrogen. Assumes distribution of 100 t/day in a pipeline to an end-use site 50 km from the receiving terminal. Storage costs are included in the cost of import and export terminals.
Low fuel costs, efficiency improvements and CAPEX reductions will bring down the cost of hydrogen-derived products. Carbon feedstock costs are also critical for hydrocarbon products.

Source. IEA analysis based on IAE (2016).

IEA 2020. All rights reserved

Source: https://www.cceguide.org/wp-content/uploads/2020/08/07-IEA-Cross-cutting.pdf

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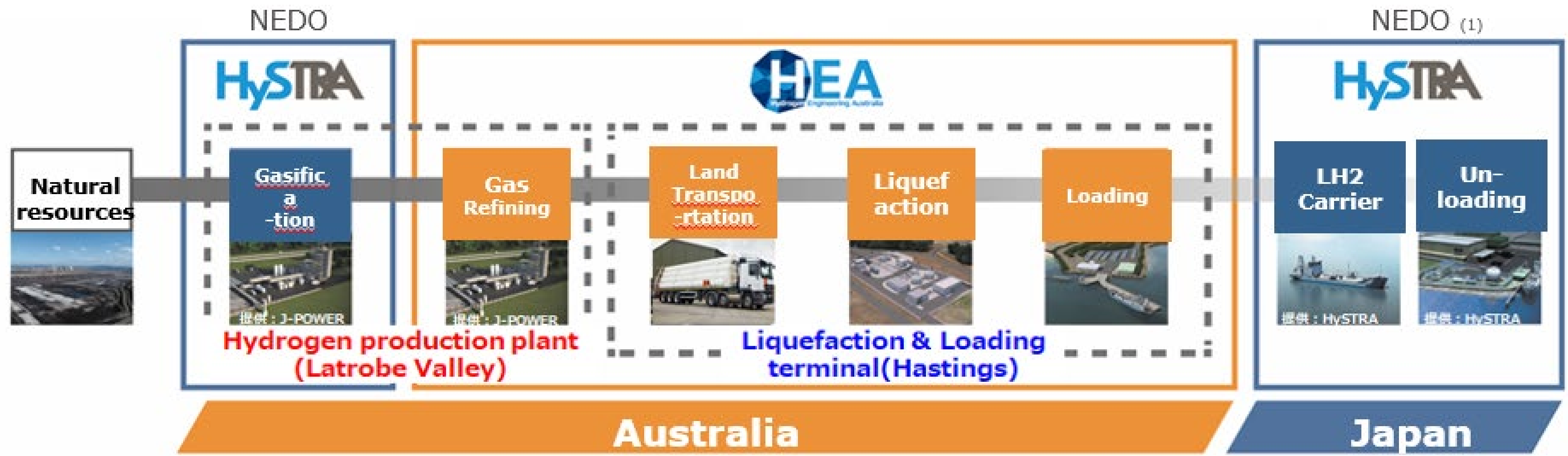
Japan-Australia Pilot Project ※1

- 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

【 CO_2-free Hydrogen Energy Supply-chainTechnology Research Association】

Iwatani Industry, Kawasaki Heavy Industries, Shell Japan, Power Development, Marubeni, ENEOS, KLINE
(As of March 2023)

HEA Hydrogen Engineering Australia

Supported by Australia and Victoria government

【Hydrogen Engineering Australia】

HEA handles contact and coordination
Kawasaki Heavy Industries, Power Development, J-Power Group, Iwatani Industries, 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"

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Focus on unused brown coal

What is brown coal?

- Large quantities of young coal, widely distributed worldwide
- High water content of 50~60%
- It is difficult to transport because it tends to spontaneously ignite when it dries, therefore, it is used only for local power generation.

- There are not overseas transactions, but only mining rights.

Unused resources = 'low cost' and 'easy to acquire interests.'

- Among many hydrogen production methods, hydrogen production from brown coal is one of the most economical method.

Brown coal mining site

There is a lignite layer up to the horizon, and one layer up to 250 meters deep from the ground.
In addition, there is a brown coal layer beneath it (equivalent to 240 years of Japan's total electricity generation, when all of it is converted to hydrogen).

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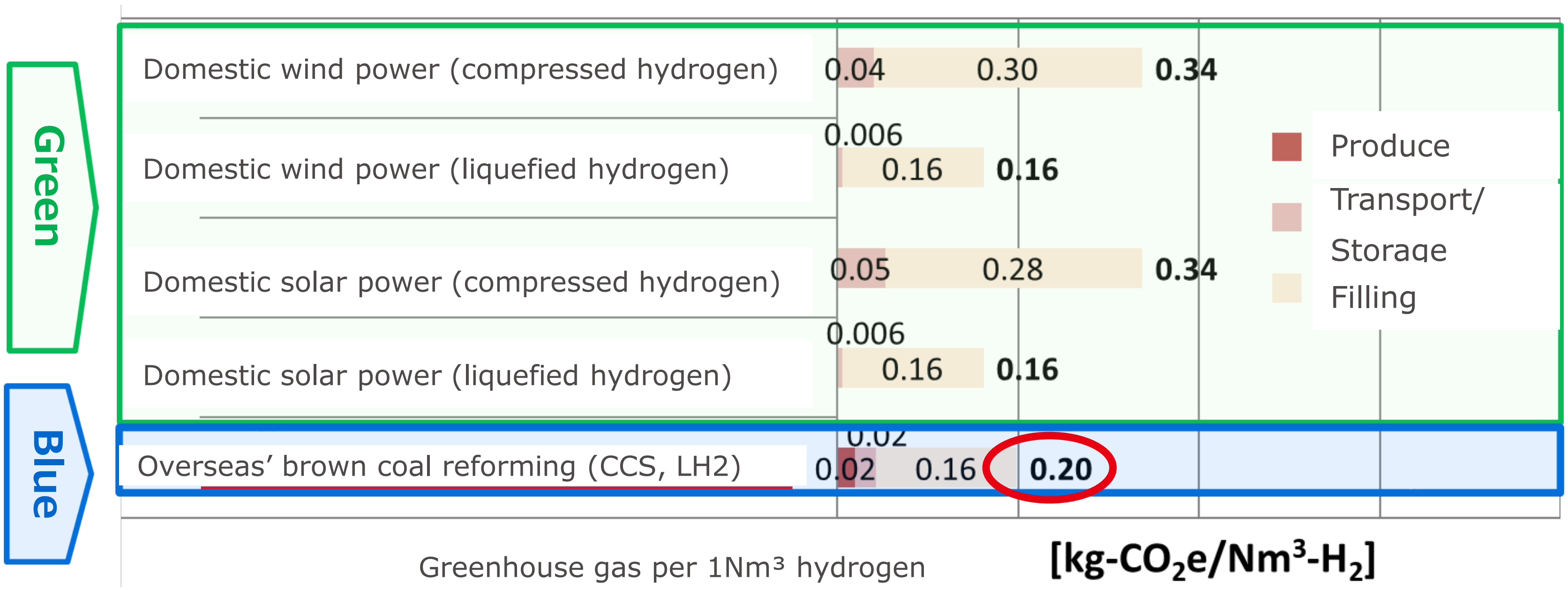
Efforts to reduce CO2 emissions during hydrogen production

- Combined with carbon capture and storage (CCS), CO2 emissions of **hydrogen from brown coal is as low as hydrogen from domestic renewable energy** for filling a FCV with hydrogen.
- **Blue hydrogen, which can be supplied in large quantities stably and increased production, is particularly important during the energy transition period.**



Source*, a document of Mizuho Information & Research Institute Co., Ltd.

***Assessment Report on Greenhouse Gas Emissions of Hydrogen Considering Life Cycle (Summary Version) (December 2016)**

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Liquefied hydrogen carrier “Suiso Frontier”

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

*1 knot =1 nautical mile/hour =1.852 km/hour

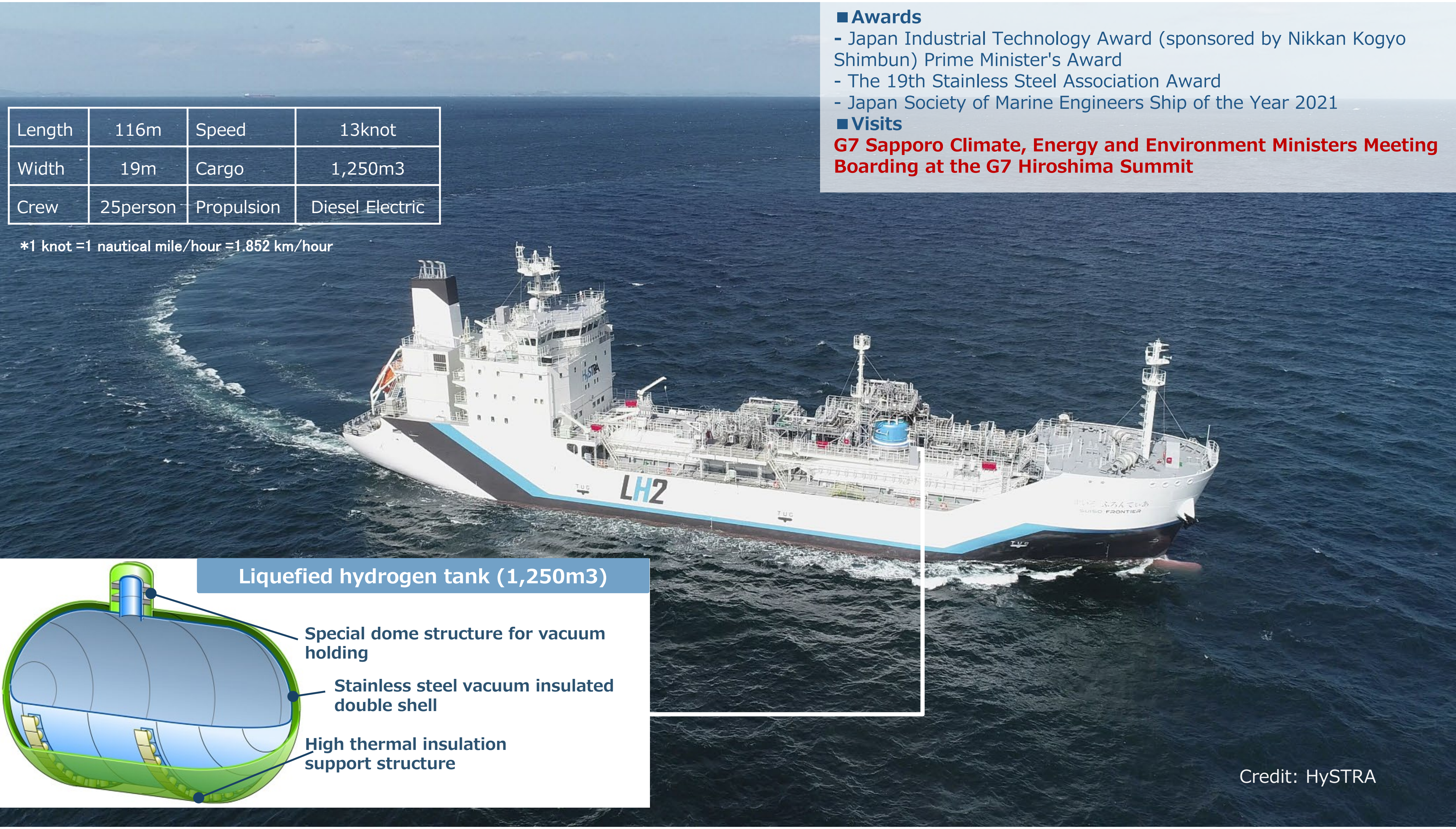
■ **Awards**

- Japan Industrial Technology Award (sponsored by Nikkan Kogyo Shimbun) Prime Minister's Award
- The 19th Stainless Steel Association Award
- Japan Society of Marine Engineers Ship of the Year 2021

■ **Visits**

G7 Sapporo Climate, Energy and Environment Ministers Meeting

Boarding at the G7 Hiroshima Summit



Credit: HySTRA

Liquefied hydrogen tank (1,250m3)

Special dome structure for vacuum holding

Stainless steel vacuum insulated double shell

High thermal insulation support structure

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Building the world's first international supply chain using liquefied hydrogen

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

First voyage from Japan to Australia 2021/12/24

"Suiso Frontier" Australia arrival ceremony 2022/1/21

Japan-Australia Pilot Project Completed (2022/4/9)

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

Prime Minister Kishida attended the meeting.

Supported by NEDO's "Demonstration Project for Construction of a Large-Scale Maritime Transport Supply Chain for Hydrogen Derived from Unutilized Brown Coal"

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Liquefied hydrogen carrier unveiled at G7 summit

- The world's first liquefied hydrogen carrier, "Suiso Frontier" was unveiled at the G7 meeting. **There was also much attention from ministers around the world.**

(April 2023 G7 Climate, Energy and Environment Ministers Meeting in Sapporo & May 19 G7 in Hiroshima Itsukaichi Port)

- The joint statement included the following passage:

  *"**Strengthen efforts to develop rule-based and transparent global supply chains in a variety of ways, including liquefied hydrogen and liquid organic hydrogen carriers, and to promote organic cooperation between suppliers and consumers to reduce costs.** We will disseminate relevant regulations, safety codes and standards and create an environment to promote the safe use of hydrogen in order to promote the hydrogen utilization and accelerate the reduction of emissions."*

G7 Climate, Energy and Environment Ministers Meeting in Sapporo
Visitors: U.S. Secretary of Energy Granholm, European Commissioner for Energy Simson,
British Minister for Energy Security and Net Zero Shapps

G7 Hiroshima Summit
Visitor: Prime Minister Pham Minh Chin of Vietnam

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Green Innovation Fund Project
Large-scale demonstration of liquefied hydrogen supply chain

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

Began a commercialization demonstration project which implements technology for enlargement.

Green Innovation Fund

Participants

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

*A wholly-owned subsidiary of Kawasaki to administer the project

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.

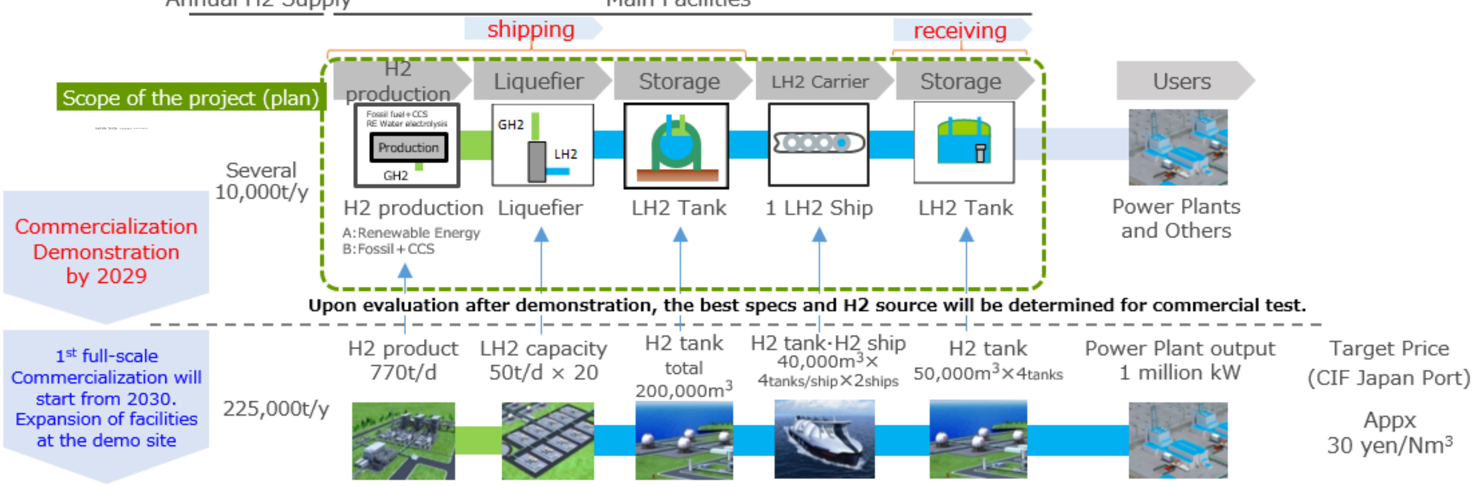
1US$=110¥

Japan-Australia pilot demonstration carrier

Approx. 130 times

commercial LH2 carrier

Overview



Source: NEDOHP https://www.nedo.go.jp/content/100936315.pdf

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Shipping and receiving locations for commercialization demonstration

- **Building a supply chain which connects the Port of Hastings in Australia with the Kawasaki coastal area in Kanagawa Prefecture.**
- In March 2023, the Australian Green Innovation Fund project developed a commercialization demonstration and **concluded a memorandum of cooperation to agree to develop an international liquefied hydrogen supply chain between Japan and Australia.**

(Witnesses)
Minister of Economy, Trade and Industry Yasutoshi Nishimura,
President of NEDO Hiroaki Ishizuka
McAllister, Assistant Minister for Climate Change and Energy, Australia;
H.E. Mr. Hayhurst, Ambassador of Australia to Japan,
(Signed) Paras Minister of Finance Government of Victoria, Australia

Source: https://www.khi.co.jp/pressrelease/news_230308-2.pdf

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Contribution to the reduction of CO2 emissions during the transport of liquefied hydrogen by sea

Liquefied hydrogen can be used as propulsion fuel for liquefied hydrogen carriers by reusing hydrogen from boil-off gas (BOG) during transportation, and contributing to CO2 zero emissions during maritime transportation.

Marine propulsion

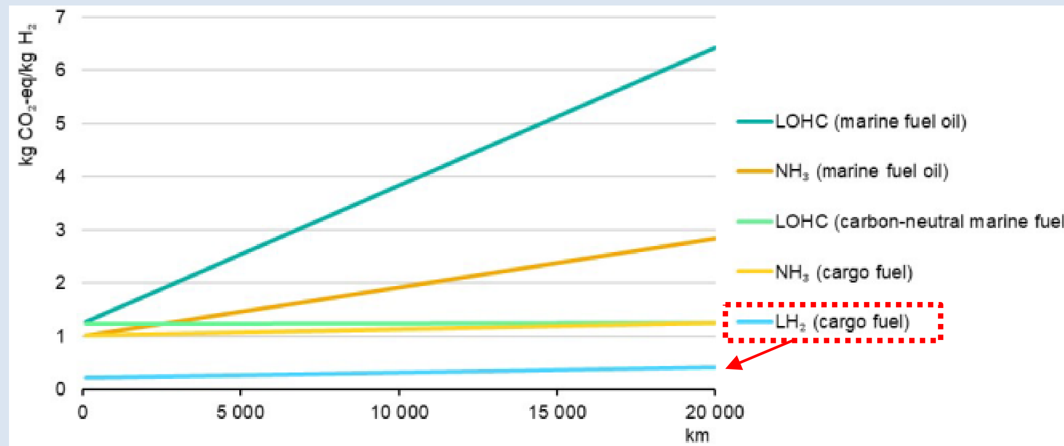
Hydrogen propulsion system using BOG

Boiler Turbine to Gas Engine

BOG: B oil O ff G as Gas vaporized by external heat input

[Comparison of CO2 Emissions during Maritime Transport in IEA Report]

Illustrative analysis on emissions of hydrogen transport by tanker including conversion and reconversion of hydrogen



IEA. CC BY 4.0

Note: LH_2 = liquefied hydrogen; NH_3 = ammonia; LOHC = liquid organic hydrogen carrier. Cargo fuel refers to using the shipped cargo as fuel in the case of LH_2 and ammonia. Carbon-neutral marine fuel represents a shipping fuel with zero direct greenhouse gas emissions. For the use of marine fuel oil, the direct emissions are included, but not any upstream and midstream emissions related to oil production and refining. Emissions include conditioning, i.e. the conversion of hydrogen into other carriers at the export port and the reconversion back into hydrogen at the import port, but emissions from hydrogen production are not included. The illustrative analysis is based on an emission intensity of hydrogen production of 1 kg CO_2-eq/kg H_2, an emission intensity of electricity of 20 g CO_2-eq/kWh at the export port and of 200 g CO_2-eq/kWh at the import port.

Source: Towards hydrogen definitions based on their emissions intensity by IEA

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Development of hydrogen projects for commercialization

2021

Pilot Demonstration

Hydrogen CIF cost
Approx. 170 yen/Nm ³

1,250m3

Proven for 40 years
Spherical tank: 2,500 m ³

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

~2030

Commercialization Demonstration

160,000 m ³

advantageous for scale-up
Cylindrical tank: 50,000 m ³

Determine the feasibility of commercialization, including economic efficiency, by setting the size of equipment to commercial scale
(One step away from commercialization)

From 2031

Commercialization

Hydrogen CIFcost
Approx. 30 yen/Nm ³
*cost of shipboard delivery

160,000 m ³ x 2 carriers

Cylindrical tank: 50,000 m ³ x 4 (plan)

Profitable business which economically independent from installation to operation
*Equivalent to approx. 400,000 households' power consumption

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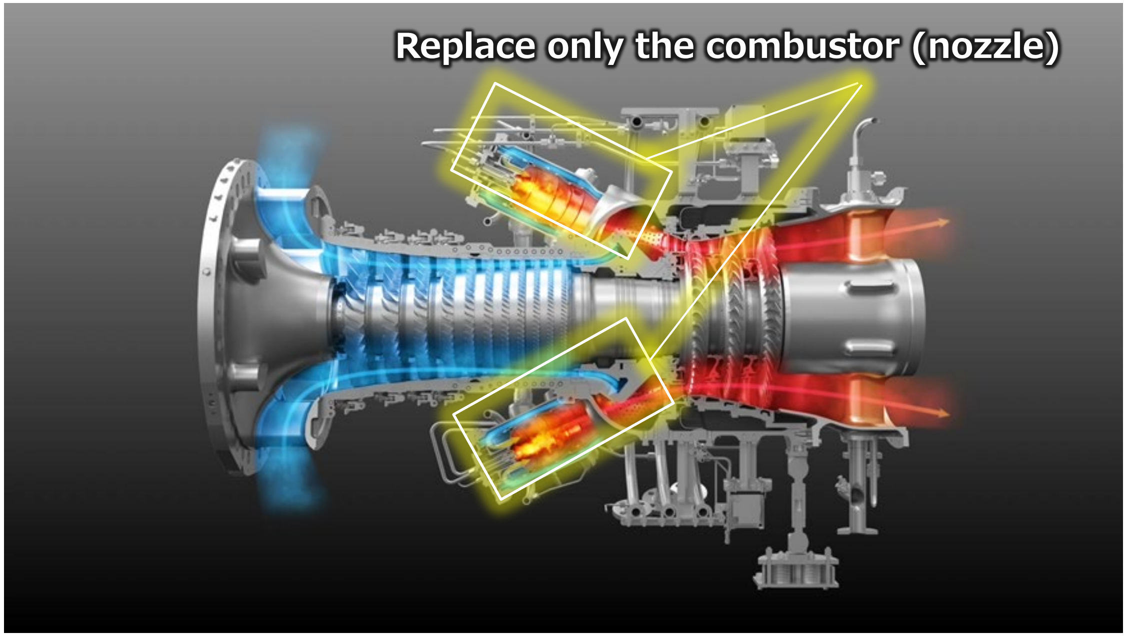
Transition of gas turbine power generation to hydrogen energy

- The combined heat and power supply by 100% hydrogen combustion in gas turbines in city area
  =>First time in the world!
- The gas turbine can be partially refurbished (combustor), and the combustor can operate hydrogen and natural gas in a freely mixed ratio.

Hydrogen Mixed Burning 0%~100% (Exclusive Burning)



The cost of refurbishment is the overall cost of the gas turbine Approx. 10%

Exclusive hydrogen firing

Carbon-free electricity

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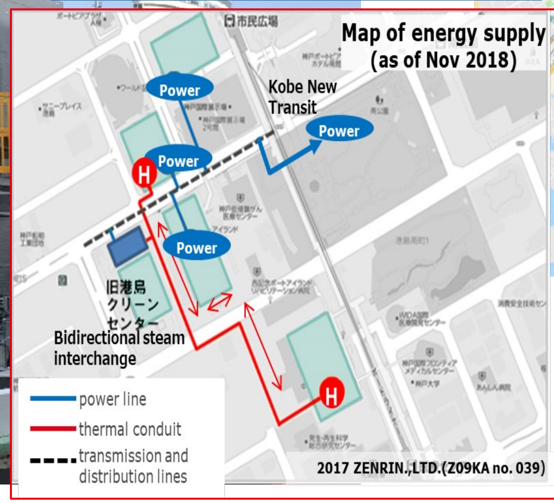
World's first hydrogen power generation in city area

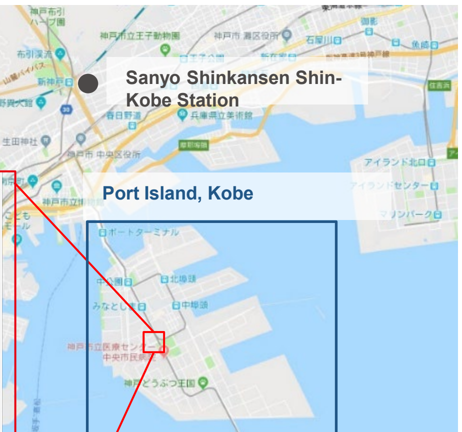
April 2018: Achieved the world's first combined heat and power supply in city area with 100% hydrogen

(Conducted in Kobe City, Kansai Electric Power, Kawasaki Heavy Industries, Obayashi Corp., Iwatani Corp., Osaka University and Kansai University)

2021: Received the Japan Combustion Society Technical Award

Supply heat and power generated by hydrogen to nearby four public facilities





©google Maps

NEDO Grants for Fiscal 2015 – 2022
Smart Community Technology Development Project Utilizing Hydrogen CGS and Others

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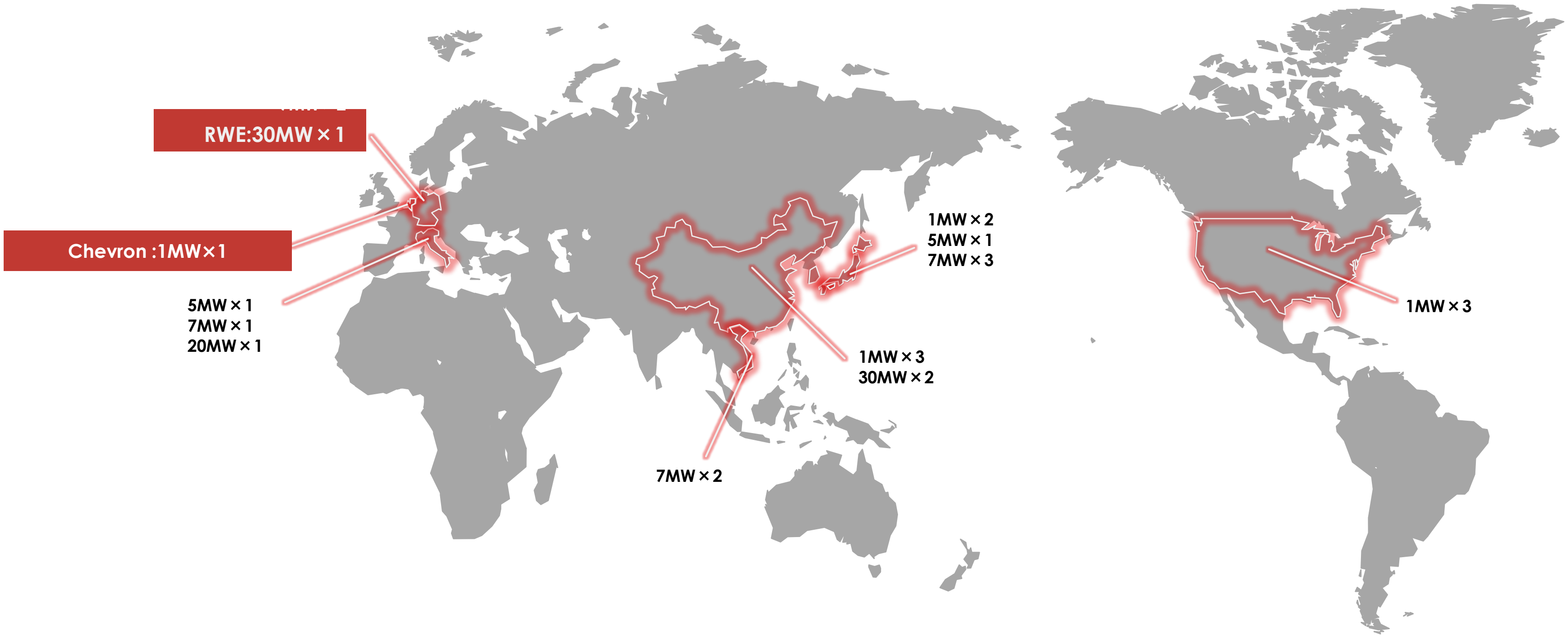
Much attention on our gas turbines

- German power company RWE plans to start operation, 100% hydrogen power generating demonstration, in 2025.
- Received order for hydrogen gas turbine from Chevron Phillips Chemical International N.V. From (Belgium)
- Dozens of hydrogen power generation inquiries to Kawasaki from around the world



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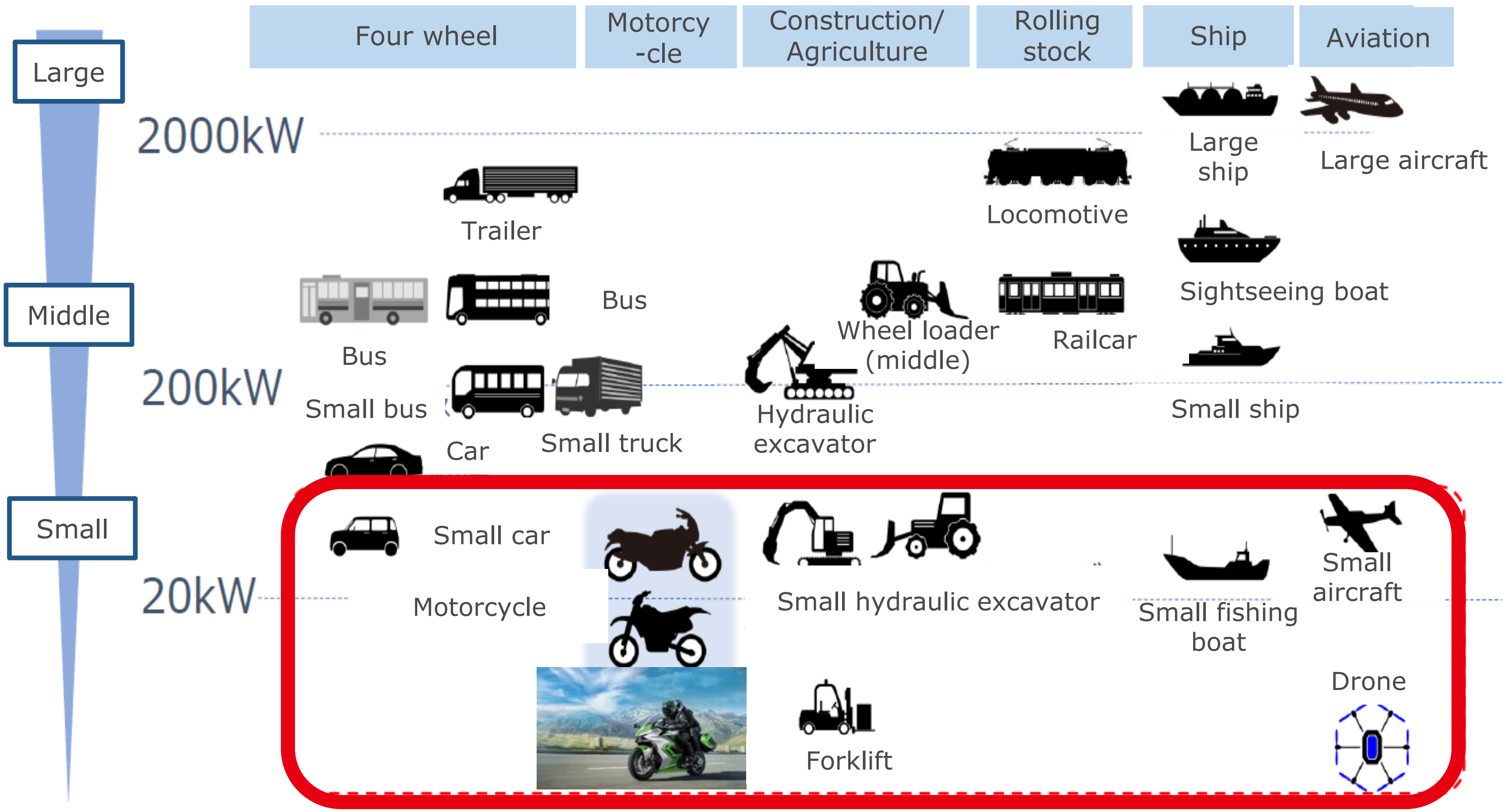
Hydrogen mobility engines

- **<u>Zero-emission mobility offers options based on purpose, range, etc.</u>**
- Established a technical research association for basic research on hydrogen engines



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Development of hydrogen fuel in the marine and aviation sectors

Know-how to burn hydrogen safely and cleanly

Further pursuing Kawasaki's combustion technology, leading the world in mobility internal combustion engines

Related markets worth trillion Yen by 2050

Development of hydrogen fuel ship propulsion system *1

Complete a compatible lineup by around 2026

Core technology development for hydrogen aircraft *2

Promote development looking toward future hydrogen aircraft after around 2035.

*1. NEDO Green Innovation Fund Project "Development of Hydrogen Fuel Ship Propulsion System" (about 21.9 billion yen in subsidies) (Yanmar Power Technology adopted in consortium with Japan Engine Corporation)

*2. NEDO Green Innovation Fund Project "Core Technology Development for Hydrogen Aircraft" (approximately 18 billion yen in subsidies)

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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.

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