

For
IAPH International Association of Ports and Harbors
Japan Seminar

Toward Carbon Neutrality International Liquefied Hydrogen Supply Chains

July 9, 2024

Shigeru Yamamoto
Hydrogen Strategy Division
Kawasaki Heavy Industries, Ltd.

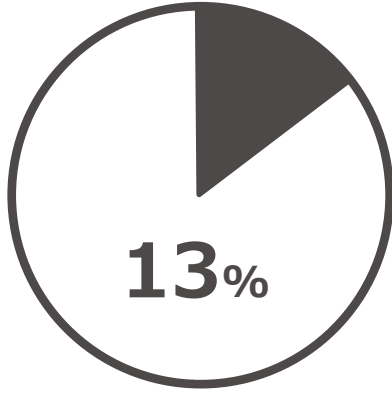


- 1. Why Kawasaki chose hydrogen?**
- 2. International liquefied hydrogen supply chain**
- 3. Recent Activity for Commercialization**

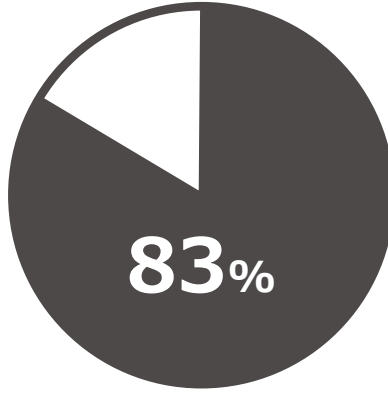
Video

- 1. Why Kawasaki chose hydrogen?**
2. International liquefied hydrogen supply chain
3. Recent Activity for Commercialization

Structural issues related to energy supply and demand in Japan



Low energy self-sufficiency



Domestic primary energy depends on fossil fuels



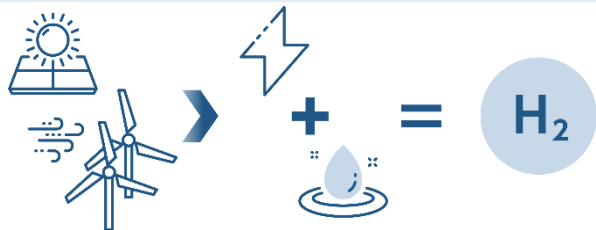
Stabilization of renewable energy power

Social Requirement

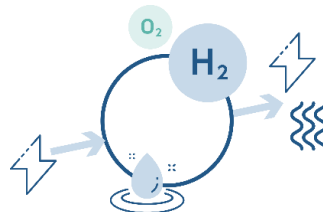
- Securing diverse energy sources
- Energy that does not emit Green House Gas:GHG
- Energy for stabilizing power supply

Characteristics of hydrogen, which is a carbon-neutral energy source

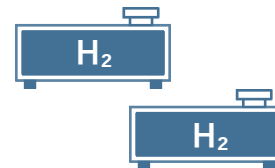
Can be manufactured and transported from renewable energy sources around the world



No CO₂ emissions



Converted into stable energy



(1) Can be imported from renewable energy sources around the world

It can be produced and transported from a variety of primary energy sources, including renewable energy sources from around the world.

There are also high expectations for the improvement of energy security.

(2) Contribute to the reduction of environmental impact

If hydrogen is produced from renewable energy, it can be used as a CO₂-free energy.

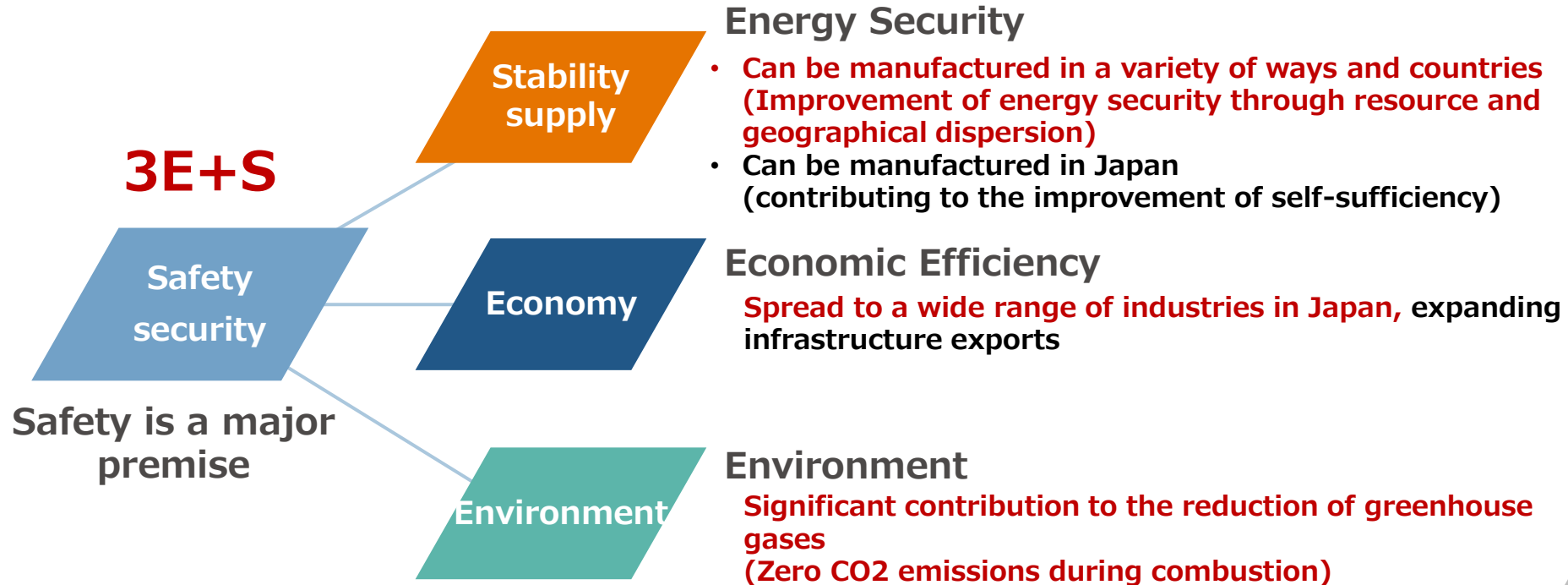
(3) Conversion into stable energy

Secondary energy is difficult to store in large quantities, and if power is stored for a long time, it will cause a large amount of energy loss due to self-discharge

→ Hydrogen is easy to store and convert and can be stored in large quantities and stored for a long time.

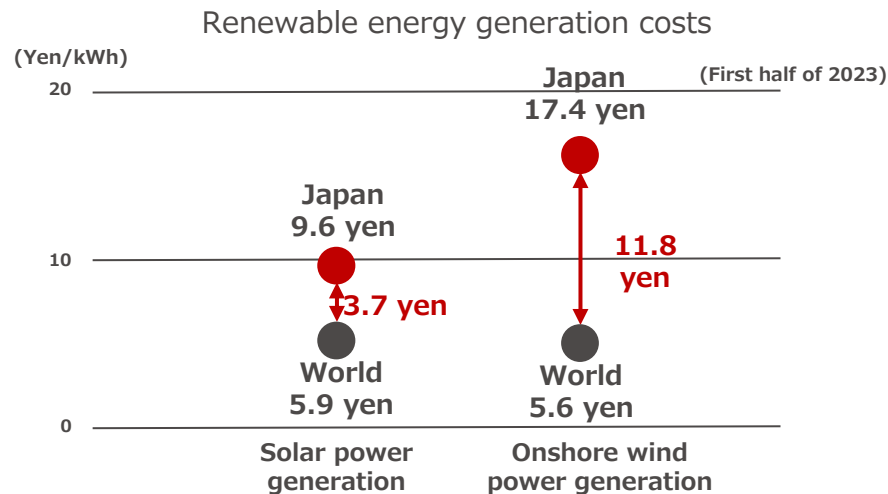
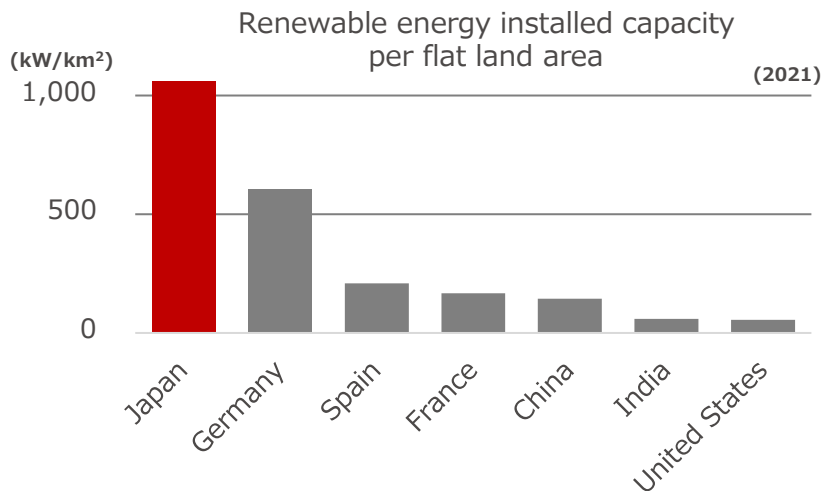
It also contributes to the stability of the power supply and demand system.

Expectations for "Hydrogen" energy in Japan's



Necessity for an international hydrogen supply chain

Japan's renewable energy installation density is the highest level among major countries, and its renewable energy generation costs are still higher than any other countries.

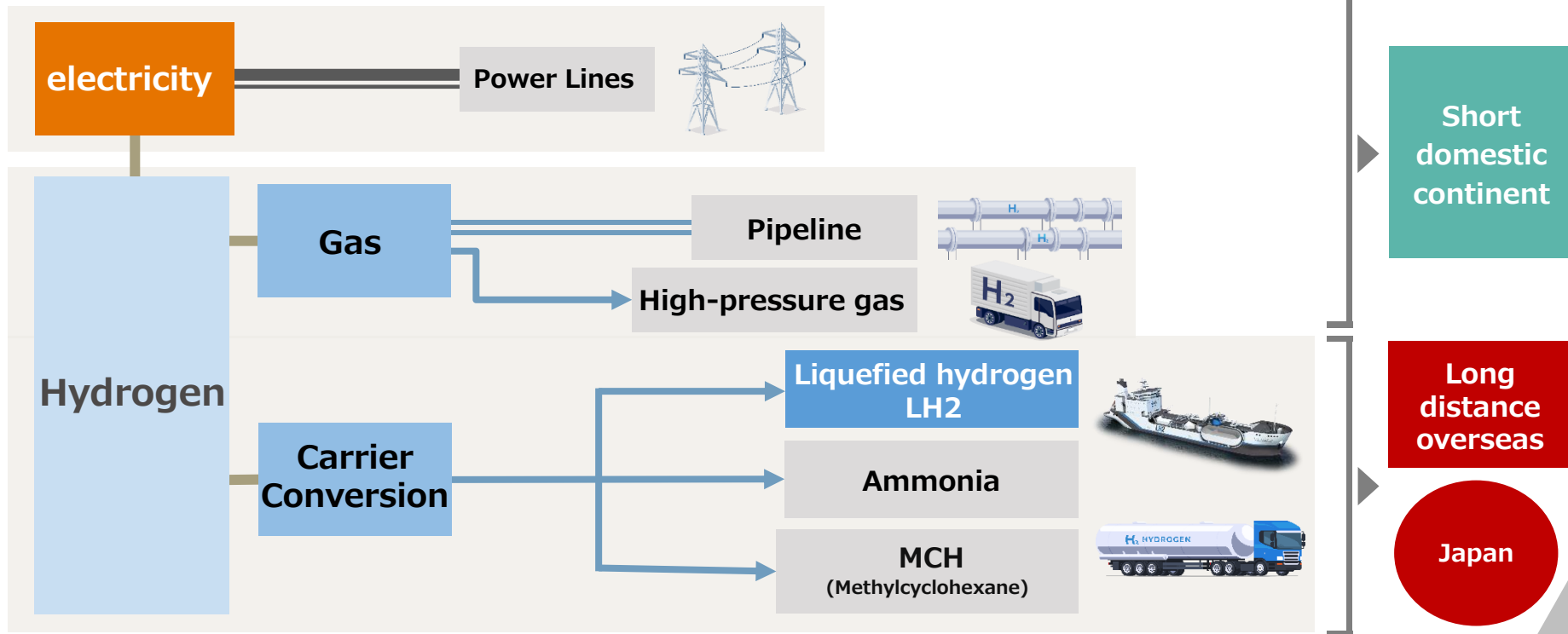


- It is important to bring green hydrogen to Japan from overseas where renewable energy costs are lower than Japan.
- Conversion to liquefied hydrogen, ammonia, and MCH (methylcyclohexane) enables mass transportation.

Compiled by our company the Ministry of Economy, Trade and Industry Agency for Natural Resources and Energy in October 2023 with reference to "Current Status of Renewable Energy in Japan and Overseas and Proposed Issues of the Procurement Price Calculation Committee for the Current Fiscal Year."

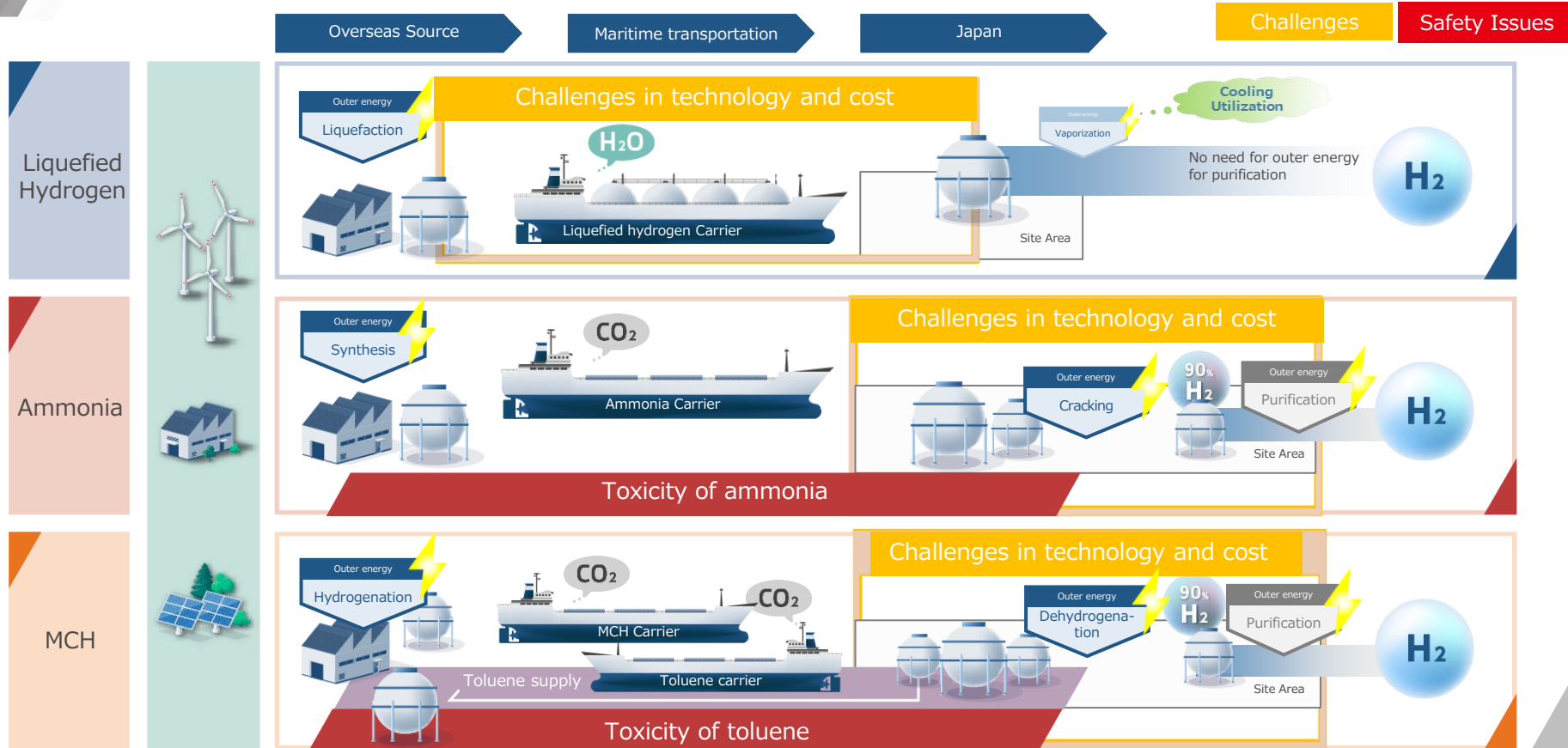
How to transport hydrogen energy

There are many ways to transport hydrogen energy.



Note: High-pressure gas is defined by the High Pressure Gas Safety Act as "a pressure of 1 MPa (megapascal, about 10 atmospheres) or more at a normal temperature, and is actually 1 MPa or more."

Why Kawasaki Heavy Industries chooses liquefied hydrogen



Technological Development of Liquefied Hydrogen

LNG : -162°C

-162°C LNG carriers and their track record of increasing size

The first domestically produced LNG carrier



A history of reducing costs through mass transportation
LNG carriers: 45 vessels
LNG tanks: 58 units



Liquefied hydrogen : -253°C

1978

Liquefied Hydrogen Rocket Engine Combustion Test Facility (Akita, Noshiro) delivered liquefied hydrogen tanks

1981

1987

540m³ at JAXA Tanegashima Space Center
Construction of liquefied hydrogen storage tanks

2010

Kawasaki announced in its Business Vision 2020 that it aims to use hydrogen as an energy source

2020

Completed the world's first liquefied hydrogen carrier ship " Suiso Flontier "

2022

Completion of transportation between Japan and Australia



Taking on the challenge of cost reduction with a large liquefied hydrogen carrier

1. Why Kawasaki chose hydrogen?
- 2. International liquefied hydrogen supply chain**
3. Recent Activity for Commercialization

Video

On February 25, 2022,

Demonstration of the HESC Pilot project

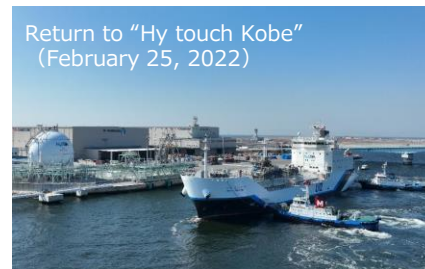
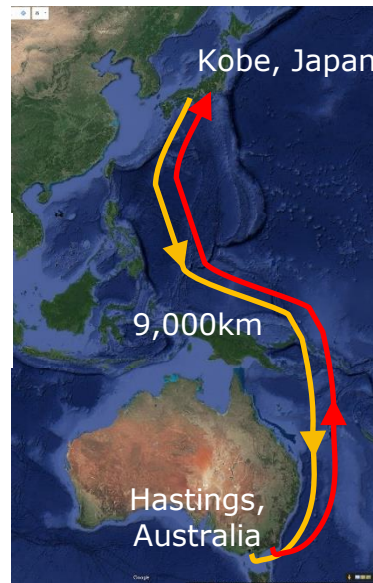
■ Demonstration I

- Loading and unloading tests at LH₂ terminal
- Full load trial voyage in Japan



■ Demonstration II

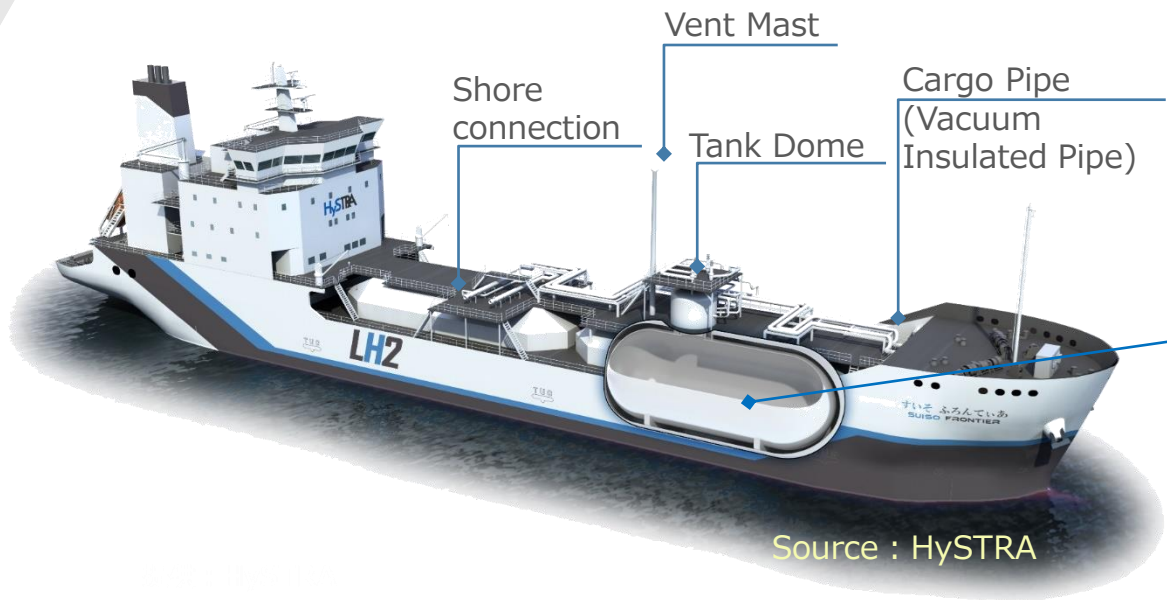
Verification of long-distance transportation technology



Source : HySTRA

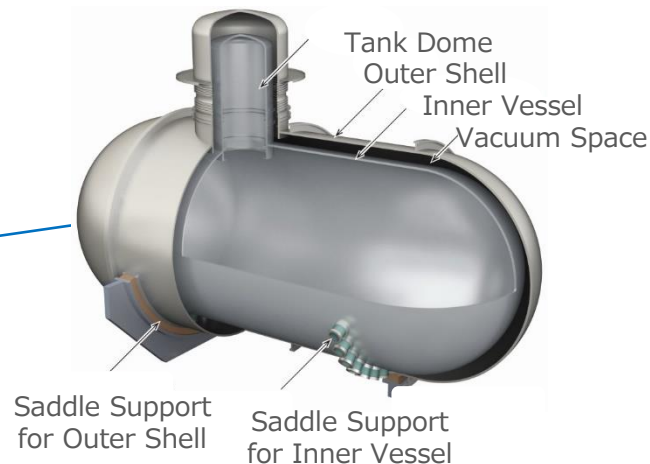
This presentation is based on results obtained from a project subsidized by the New Energy and Industrial Technology Development Organization (NEDO).

The world's first LH2 carrier "Suiso Frontier"



Source : HySTRA

Cargo Containment System (1,250m³)



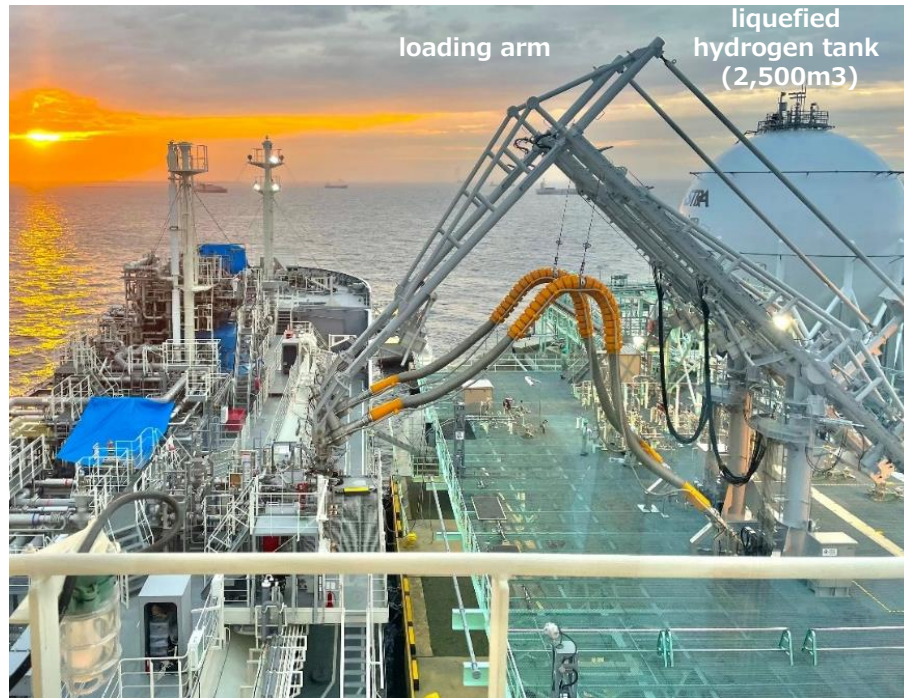
Vacuum Insulated Double Shell Structure

■ Length o.a.	116.0 m	■ Propulsion	Oil fired diesel electric
■ Breadth	19.0 m	■ Service speed	abt. 13 knots
■ Class/Flag	NK/Japan	■ Complement	25 persons

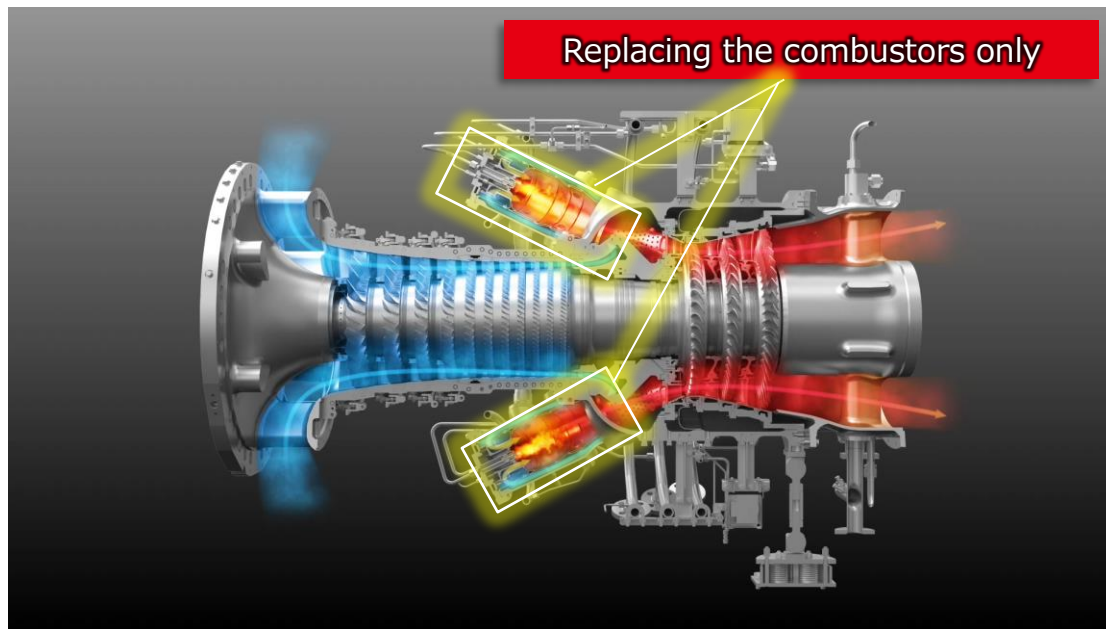
This presentation is based on results obtained from a project subsidized by the New Energy and Industrial Technology Development Organization (NEDO).

Hydrogen Energy Supply Chain (The HESC Pilot Project)

Liquefied Hydrogen Receiving Terminal “Hy touch Kobe”



Use of hydrogen energy in gas turbine power generation



Hydrogen mixed combustion
30%~100%

Partial modification only

The modification cost is
approx. **10%**
of the total price of the gas
turbine engine

Achieving
Carbon-free Electricity
through hydrogen-only
combustion

(Space for explosion-proofing is a prerequisite.).

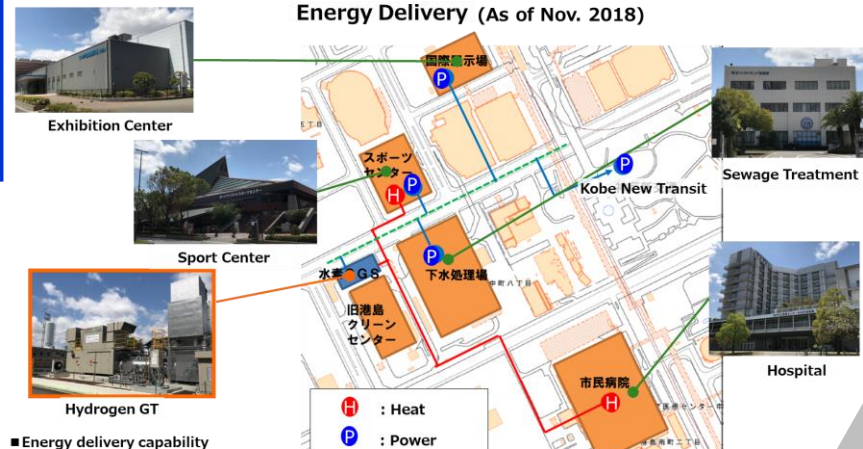
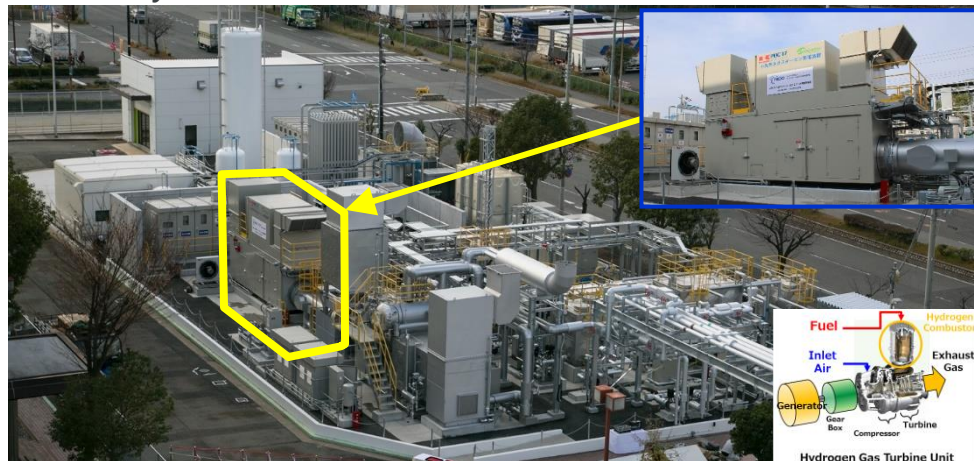
Hydrogen Co-generation Demonstration Project

- Co-generation system (CGS) with 1 MW class hydrogen gas turbine has been installed in city area (Kobe Port Island)
- Demonstrating power and heat derived from hydrogen to community

[Organization] Kawasaki Heavy Industries, Obayashi Corporation, Kobe City, Kansai Electric Power, Iwatani Sangyo, Kenes, Osaka University



Maps (2 sheets) Source: Geospatial Information Authority of Japan website (<https://maps.gsi.go.jp>)



■ Energy delivery capability
 Electric Power : Approx. 1,100 kW
 Heat : Approx. 2,800 kW

■ Heat and power supply at the urban area using a hydrogen fueled gas turbine has been achieved in April 2018 (World first!).

Contents

1. Why Kawasaki chose hydrogen?
2. International liquefied hydrogen supply chain
- 3. Recent Activity for Commercialization**

Development of hydrogen products for Commercial Chains

2021

Pilot Demonstration



1,250m³



2,500m³



Demonstrating the feasibility of hydrogen production and long-distance maritime transportation
(Approximately 1/100 scale of commercial level)

~2030

Commercialization
Demonstration



160,000m³



50,000m³



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

2031~

Commercial
Chains



160,000m³×2



50,000m³×4 (Plan)



From equipment installation to operation
Financially independent.

“Collaboration with hydrogen partners” progressing in both hydrogen supply and demand creation

- Social implementation cannot be achieved by a single company.
- It is important to "cooperate with hydrogen partners" to create a society where many hydrogen related parties can use hydrogen.

Hydrogen Council

Participating companies : 150
(Founding 13 members in 2017)



Japan Hydrogen
Association(JH2A)
Member : 413 • (Nov.2023)
(Founding 87 members in 2020)



CO2-free Hydrogen Energy
Supply-chain
Technology Research
Association
Member:3
(Founding 3 members in 2020)



Hydrogen
Small mobility &
Engine technology

Hydrogen Small mobility &
Engine technology (HySE)
Member 6
(Founding 3 members in 2023)

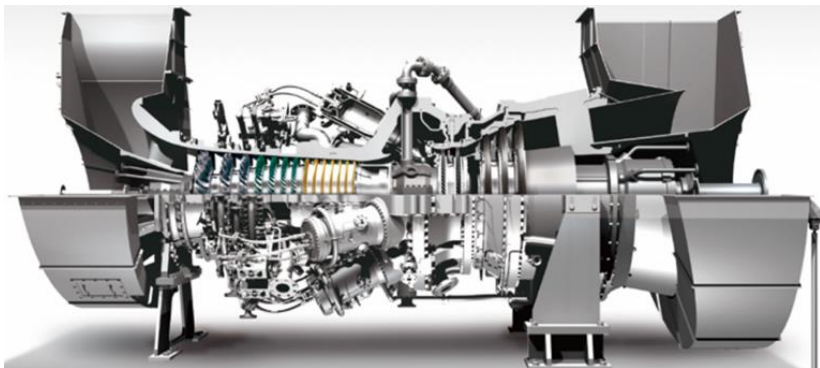
<Partners in major hydrogen-related project>

METI, MLIT, MOE, Kyoto Univ., Osaka Univ., Kobe Univ., Kobe municipal, NEDO, IWATANI, Shell Japan, J-POWER, MARUBENI, ENEOS, KAWASAKI KISEN, OBAYASHI, The KANSAI ERETRIC POWER, JAPAN ENGINEYANMAR POWER TECHNOLOGY, TOYOTA, YAMAHA, INPEX etc.

Demonstration Project in Europe

One of the World's First 100% Hydrogen to Power Demonstrations on Industrial Scale Launches in LINGEN, GERMANY

Power output: 30MW class
(Hydrogen ~ 100%)



RWE

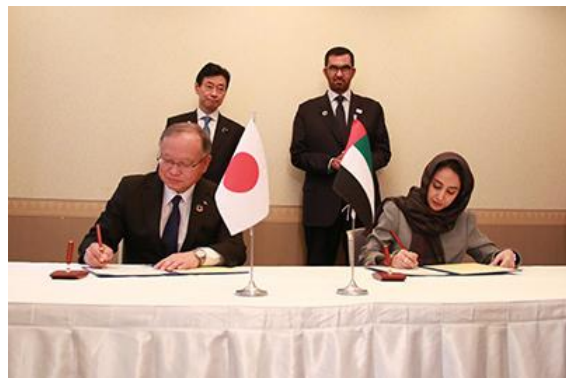
Kawasaki



https://global.kawasaki.com/news_211209-2e.pdf

Collaboration with countries with high hydrogen production

Signed a strategic collaboration agreement with UAE energy company (ADNOC) to build a liquefied hydrogen supply chain



April, 2023

Saudi Energy Minister Prince Abdulaziz bin Salman and Investment Minister Khalid Al Falih visit the ship



July, 2023

Japan-Australia Economic Conference Madeleine King, Minister for Resources, Australian Federal Government, and Tim Pallas, Minister for Finance, Victorian Government.



Oct, 2023

Toyota used hydrogen produced from Australian lignite being transported to Japan



Photo by Toyota Motor Corporation

Ministerial Approval Granted to Form Research Body "HySE" for Development of Hydrogen Small Mobility Engines to Help Build Decarbonized Society



May 2023

HySE-X1
Retracing the Tracks of
the 2024 Dakar Rally



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

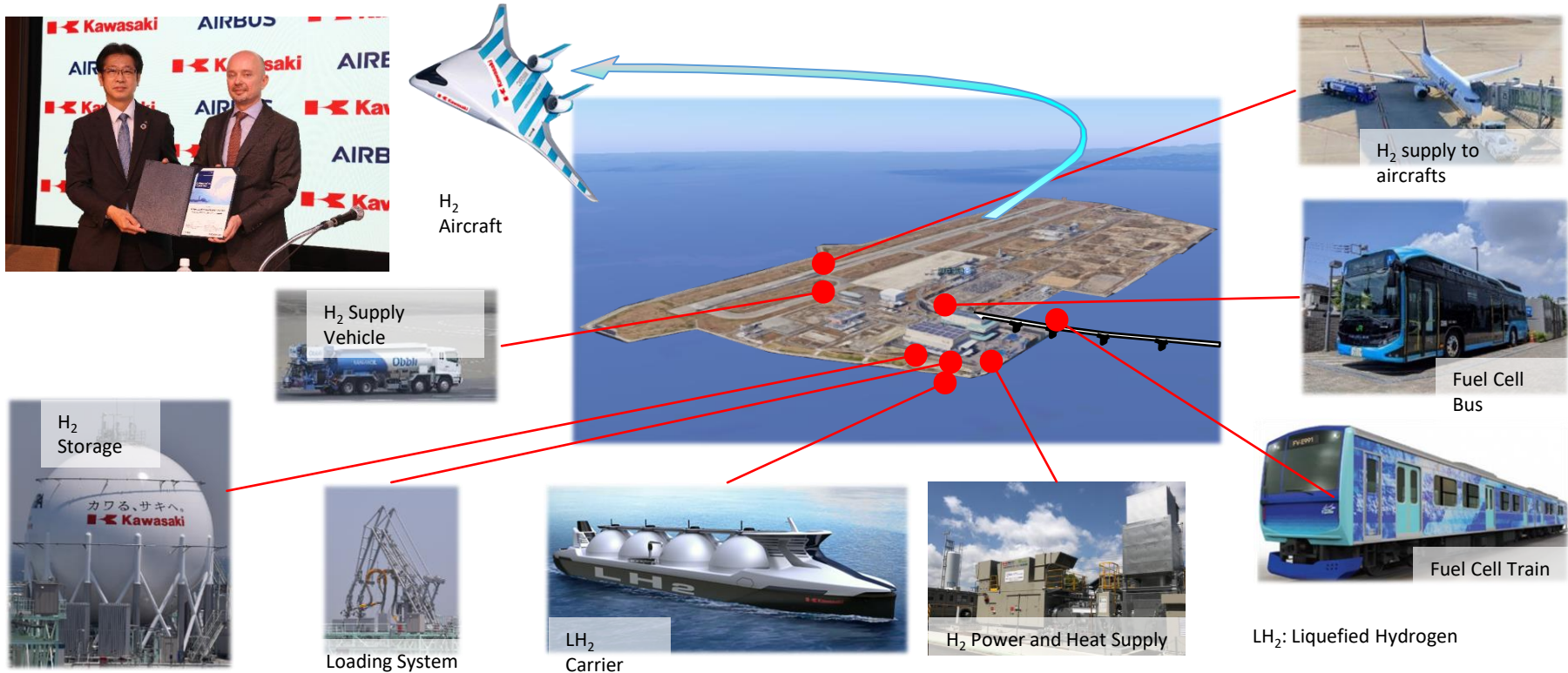
Domestic two- and four-wheel manufacturers collaborate to develop hydrogen engine

*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)

Carbon Neutral Airport

Airbus, Kawasaki Heavy Industries partner to study use of hydrogen in the airport



Kawasaki's Efforts in Hydrogen-Related Businesses and Cooperation with Other Companies



Liquefied hydrogen supply chain



Energy Solution
& Marine Company



GI Fund
Business

Marine hydrogen
engine



NEDO
subsidized busi

Hydrogen power
generation



Yanmar Power Technology,
Japan Engine Corporation



Obayashi
Corporation



Hydrogen valve

Precision Machinery & Robotics Company



Automobile Manufacturers



FCV vehicle

Kawasaki Rolling Stock



JR East



Hydrogen engine two-wheel/four-wheel

Kawasaki Motors



Four Japanese motorcycle companies,
Toyota and DENSO



hydrogen aircraft

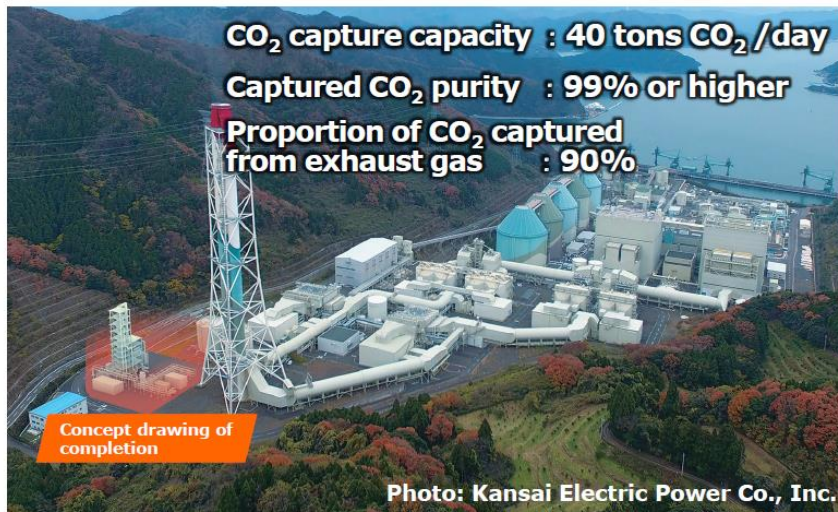
GI Fund
Business

Aerospace Systems Company



Airbus (Airport Infrastructure)

Kawasaki CO₂ Capture (KCC)



Pilot demonstration at KEPCO's
Maizuru Power Plant
Starting from FY 2022

* NEDO "Applied research on coal combustion waste gas and advanced carbon dioxide solid absorption materials"
Joint implementation with Research Institute of Innovative Technology for the Earth (RITE)
Cooperation: Kansai Electric Power Co., Inc.



Demonstration test at
Dry Fork Power Station in Wyoming, USA
Facility operation will start during FY 2023

* Ministry of the Environment "Environmentally friendly CCUS demonstration base / supply chain construction project"
Joint implementation with Japan Coal Frontier Organization (JCOAL)

Large-Scale DAC ready around 2025

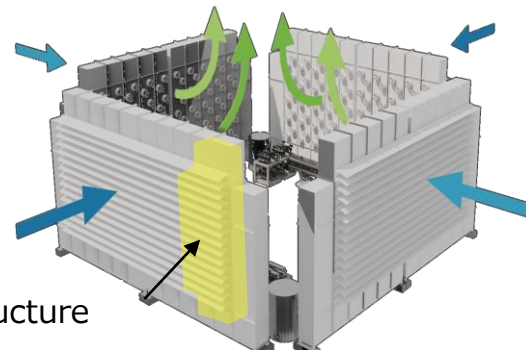
KHI promotes **CO₂ capture business from the atmosphere**

through large-scale DAC facilities (Approx. 500,000 - 1million t - CO₂ / year)

Respond to contacts from energy companies

DAC image of 1 million t - CO₂ / year

➡ : Air (atmospheric) flow
➡ : CO₂ free air



A module structure

Advanced technology

Utilize advanced solid sorbent for DAC and technologies established through demonstration projects

Energy conservation

Effective use of heat emitted from DACs

Renewable energy

Use of renewable energy

Features of KCC-DAC

Larger scale And lower cost

Module mass production

Simplification

Installation with modular construction (assembled at factory)



