Group Vision Progress Report Meeting

Challenge to achieve Carbon Neutrality
- Kawasaki Solutions for the Sustainable Society -

December 9, 2021

Kawasaki Heavy Industries, Ltd.

Yasuhiko Hashimoto,
President and Chief Executive Officer

Kawasaki
Powering your potential

カワる、サキへ。
Changing forward

New Values

A Safe and Secure Remotely-Connected Society

つぎの社会へ、信頼のこたえを

Trustworthy Solutions for the Future

Cross Over

Energy and Environmental Solutions

Near-Future Mobility

Frontier

Challenge to achieve Carbon Neutrality

- Kawasaki Solutions for the Sustainable Society -

1. **Hydrogen Energy: Critical for Achieving Carbon Neutrality**
2. Hydrogen Power Generation: The History
3. Hydrogen-Powered Mobility: Creating New Value
4. Contributing to Carbon Neutrality through CO_2 Separation and Capture
5. Together with various partners

Global Warming Reduction Targets

2018 IPCC* Global Warming of 1.5°C

*IPCC: Intergovernmental Panel on Climate Change

100% reduction in CO_2 emissions by 2050

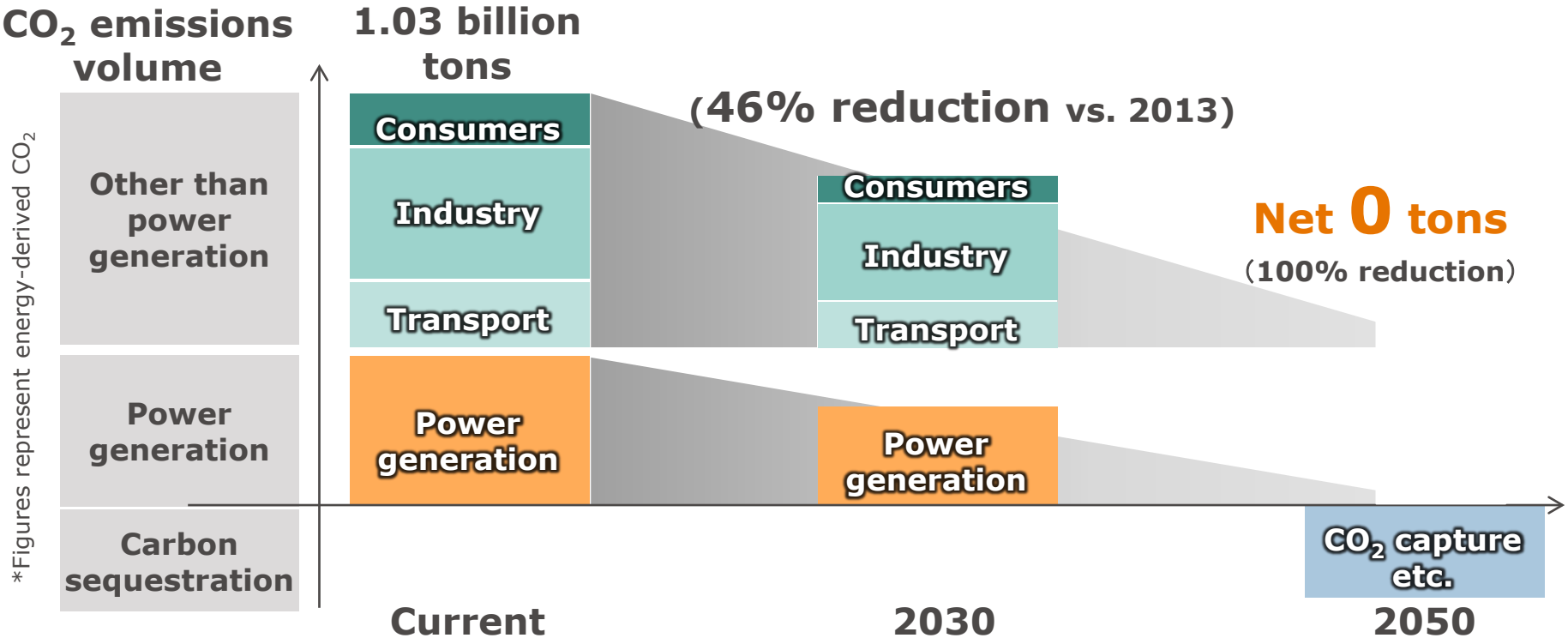
Restricting temperature rise in 2100 to 1.5°C or less

COP26 also firmly maintained the 1.5°C target

(Japan)

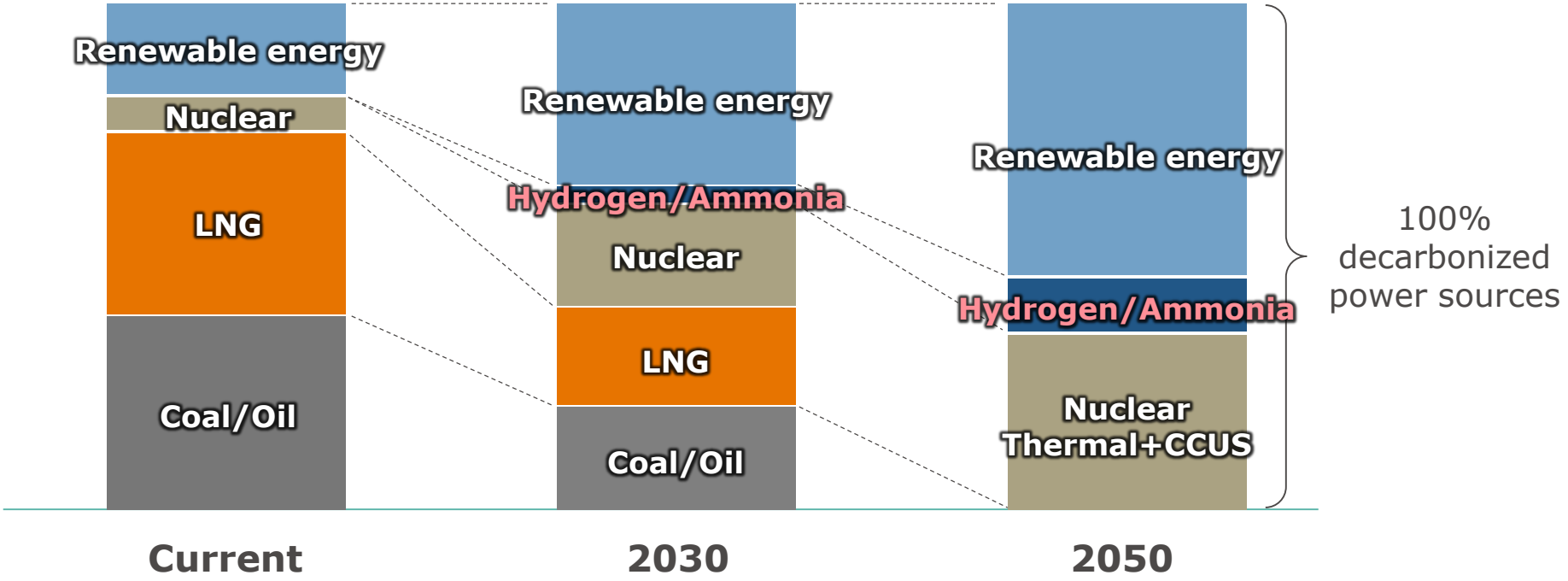
Policy of aiming for net zero CO_2 emissions by 2050

Scenario in which Japan becomes Carbon Neutral in 2050



*Estimated by Kawasaki with reference to the Ministry of Economy, Trade and Industry's "Green Growth Strategy Through Achieving Carbon Neutrality in 2050", June 2021 edition

Electricity Supply Mix oriented toward Achieving Carbon Neutrality

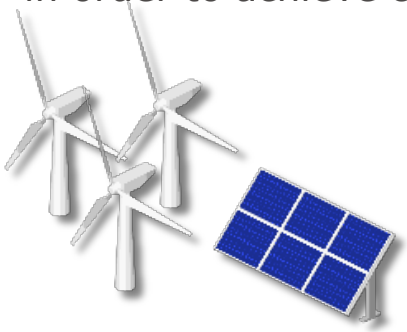


* Estimated by Kawasaki with reference to the Ministry of Economy, Trade and Industry's "Green Growth Strategy Through Achieving Carbon Neutrality in 2050" December 2020 edition as well as "The 6th Strategic Energy Plan" October 2021 edition

Renewable Energy

(Japanese Government policy)

Working to promote electrification and decarbonization of power supply as well as **implement renewable energy to the maximum extent possible** in order to achieve carbon neutrality.



(Challenges)

- Correspondence with fluctuating power supply given natural constraints such as sunlight hours and wind conditions
- Constraints on further implementation due to Japan's small land area, etc.

Use together with other forms of clean energy is critical

Kawasaki will contribute to global carbon neutral as a hydrogen industry leader

Hydrogen Energy Implementation in Japan

20 million
tons/year

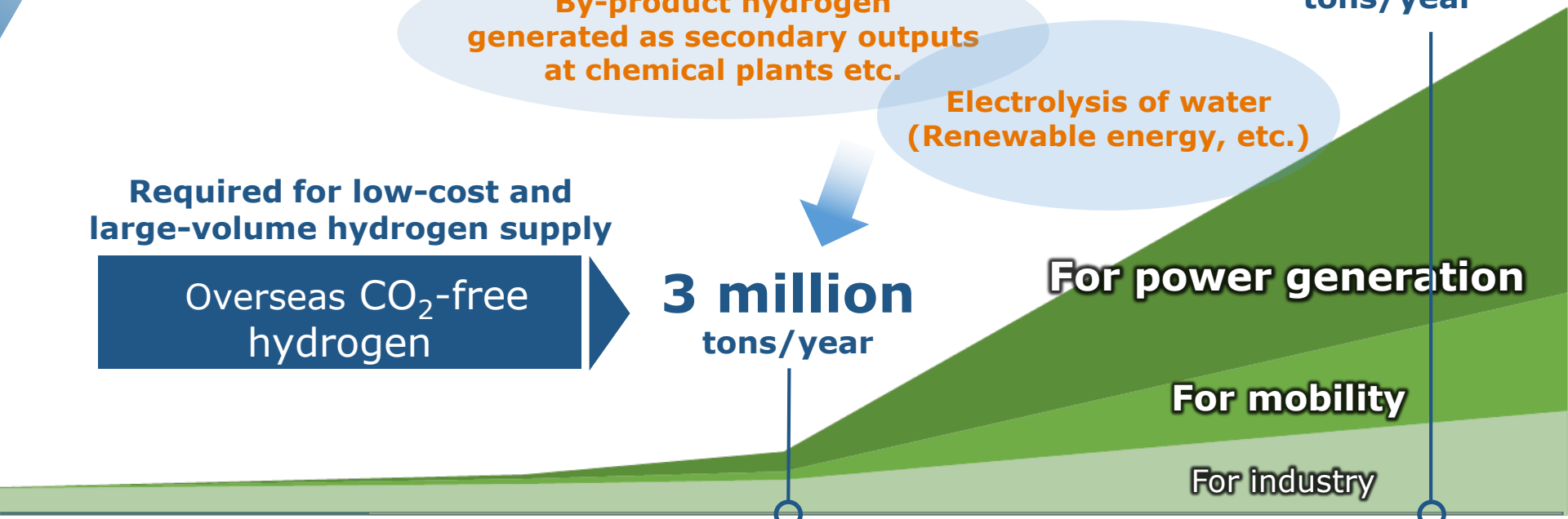
"By-product hydrogen" generated as secondary outputs at chemical plants etc.

Electrolysis of water (Renewable energy, etc.)

Required for low-cost and large-volume hydrogen supply

Overseas CO_2-free hydrogen

3 million
tons/year



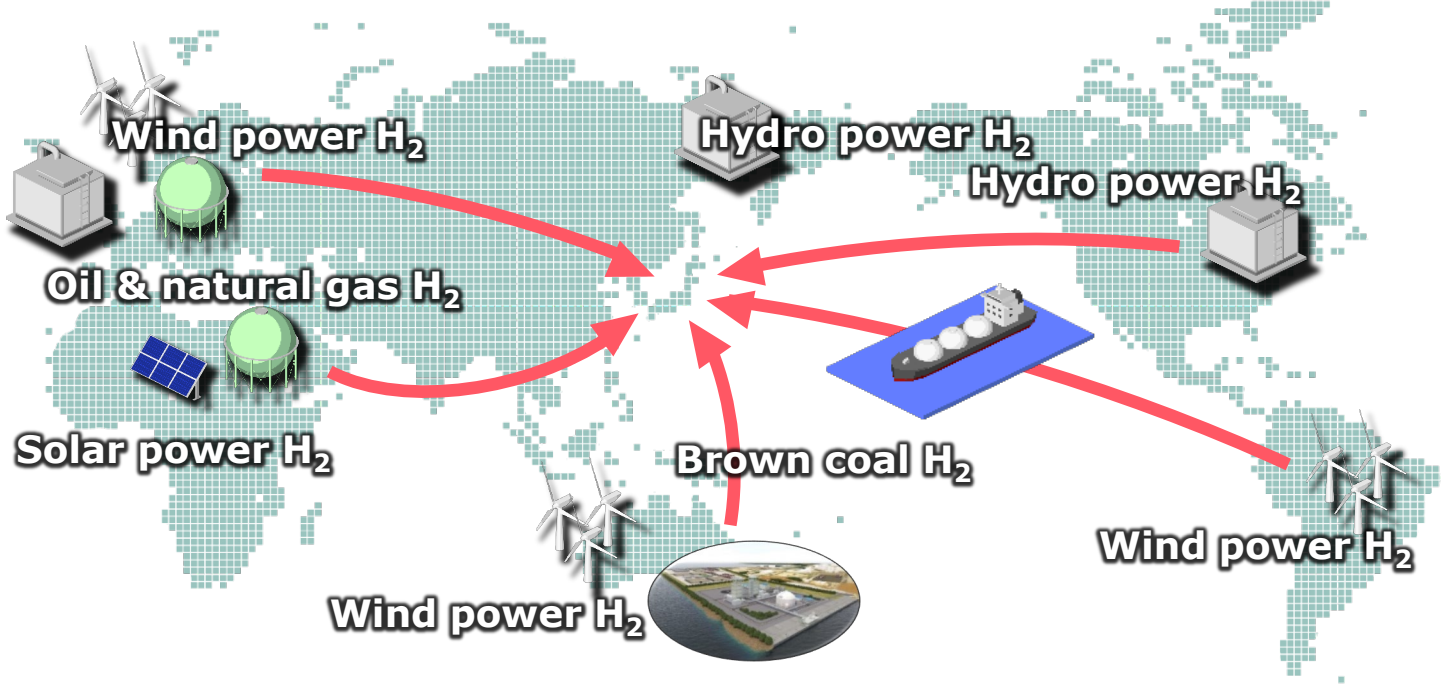
2020 **2030** **2050**

*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

Economic Security

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

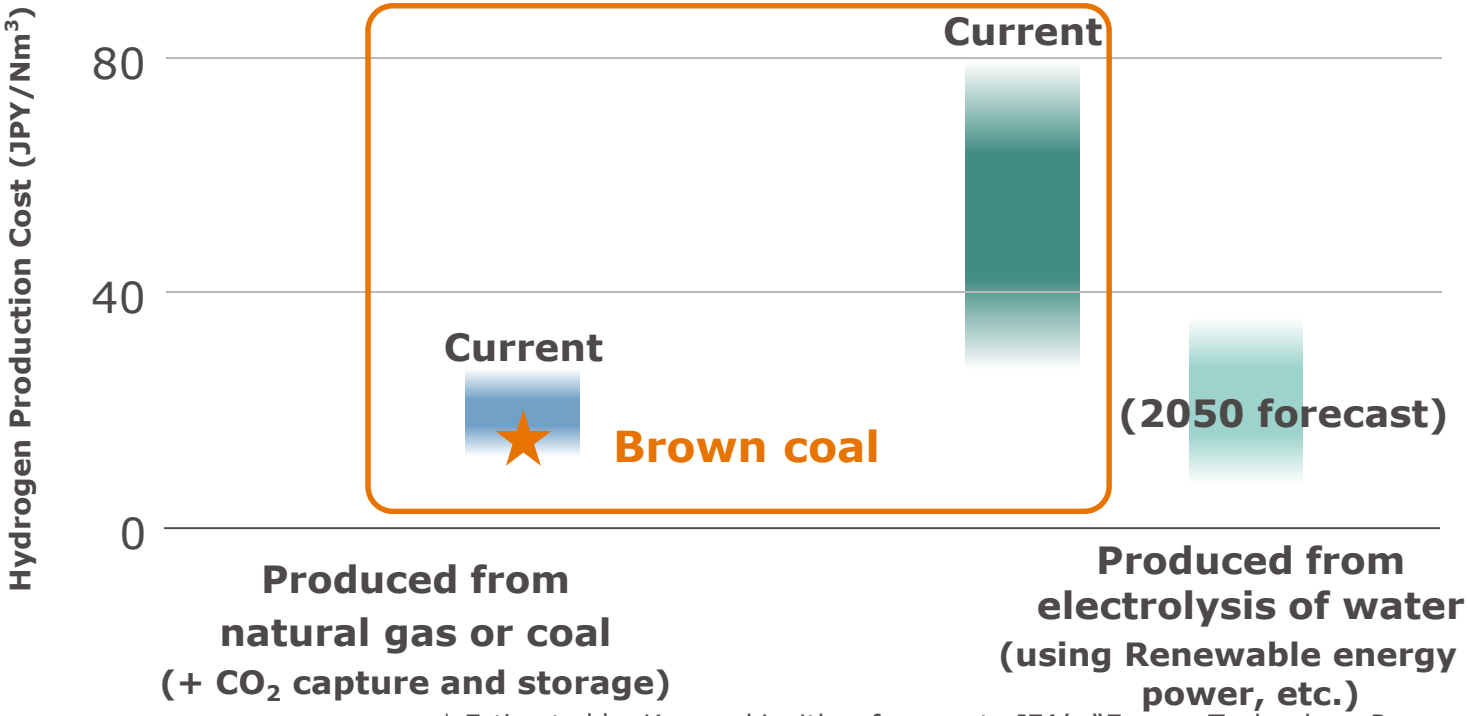
Guaranteeing Japan's energy security



Hydrogen Production Cost

Fossil fuel-derived hydrogen will be used in combination until the spread of hydrogen derived from renewable energy sources.

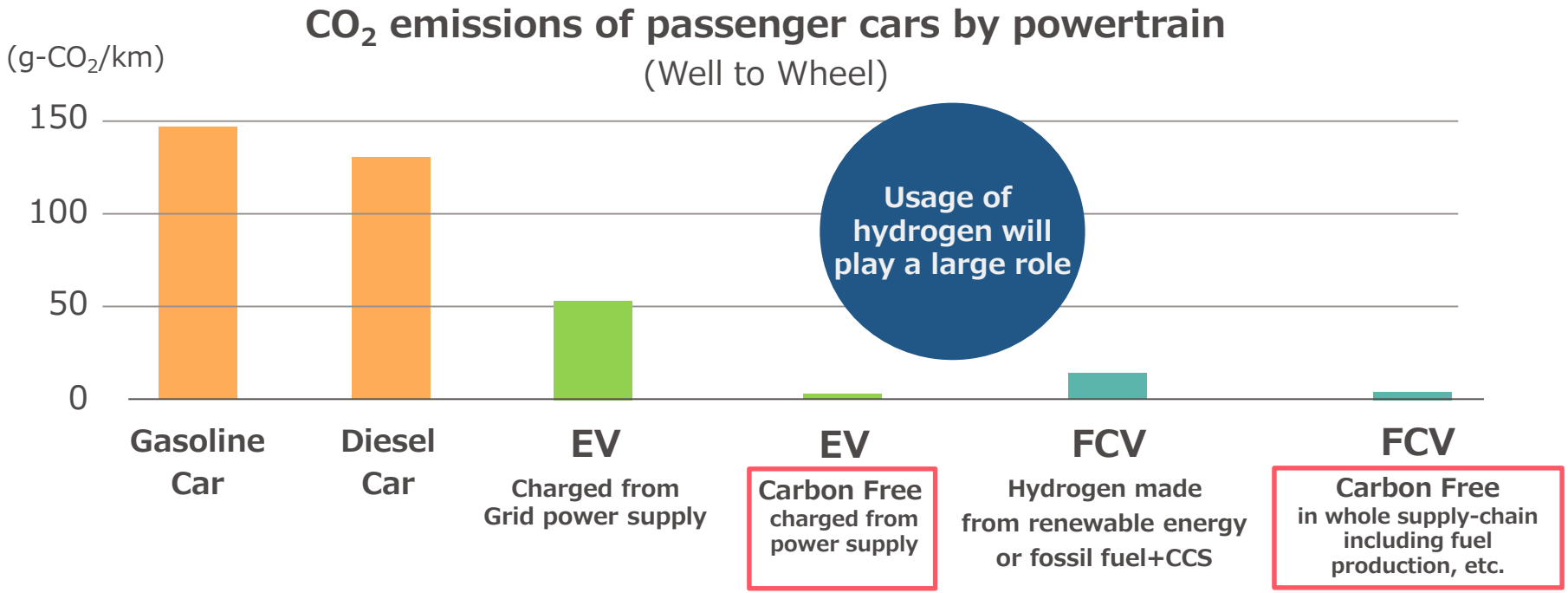
→ Achieve early introduction of inexpensive hydrogen



* Estimated by Kawasaki with reference to IEA's "Energy Technology Perspectives 2020"

Focus on brown coal (unused resources) of fossil fuel to produce hydrogen at low cost and in large volumes

Example of CO_2 Emissions



*Estimated by Kawasaki with reference to Japan Automobile Research Institute "Analysis Report on Comprehensive Efficiency and GHG Emissions", and Mizuho Research & Technologies, Ltd. "Assessment Report on Greenhouse Gas Emissions of Hydrogen Considering the Life Cycle (Summary Version)"

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.

30 Years' Experience in Transportation and Storage of Hydrogen

Liquefied hydrogen tanks
(Tanegashima Space Centre)

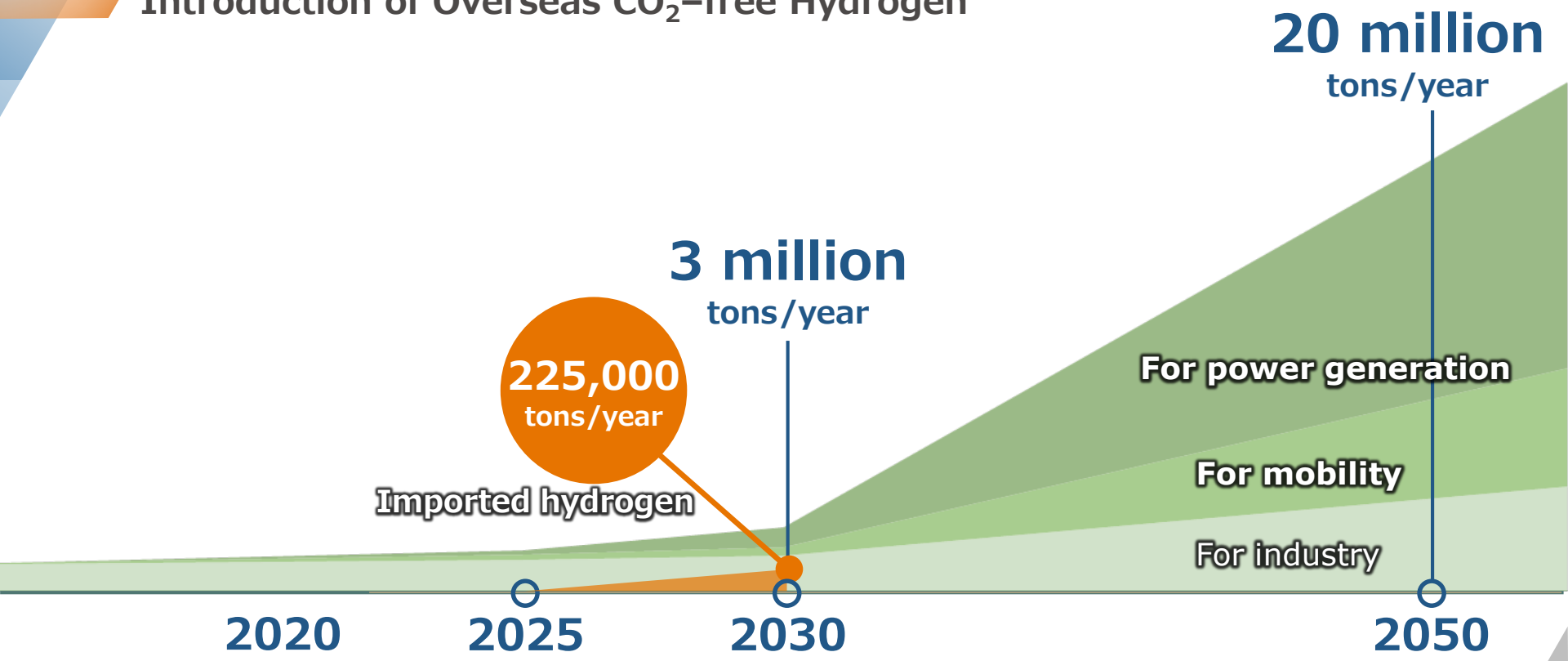
Liquefied hydrogen container

Progress of Technology Demonstration

Approvals by International Institutions related to Liquefied Hydrogen Carriers

The safety requirements proposal related to liquefied hydrogen transport put forward by Japan was formally approved at IMO (International Maritime Organization) of the United Nations in 2016

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

Hydrogen Cost
(from Technology Demonstration to Commercialization)

Compact liquefied hydrogen carriers (1,250m³)

Approx. JPY 170/Nm³

*CIF cost

Current

JPY 89/Nm³

22 JPY/Nm³ | 30 JPY/Nm³ | 33 JPY/Nm³

0.1 t/day → 5 t/day → 2,500 m³ → 36 t/year

Hydrogen production + CCS | Hydrogen liquefaction | Loading terminal

Australia

Liquefied hydrogen carriers

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

Hydrogen Cost
(from Technology Demonstration to Commercialization)

2050 JPY 20/Nm³

JPY 30/Nm³

Approx. JPY 170/Nm³

*CIF cost

128 times

2030

Compact liquefied hydrogen carriers (1,250m³)

JPY 2.5/Nm³

JPY 89/Nm³

JPY 14.7/Nm³ | JPY 9.4/Nm³ | JPY 3.2/Nm³

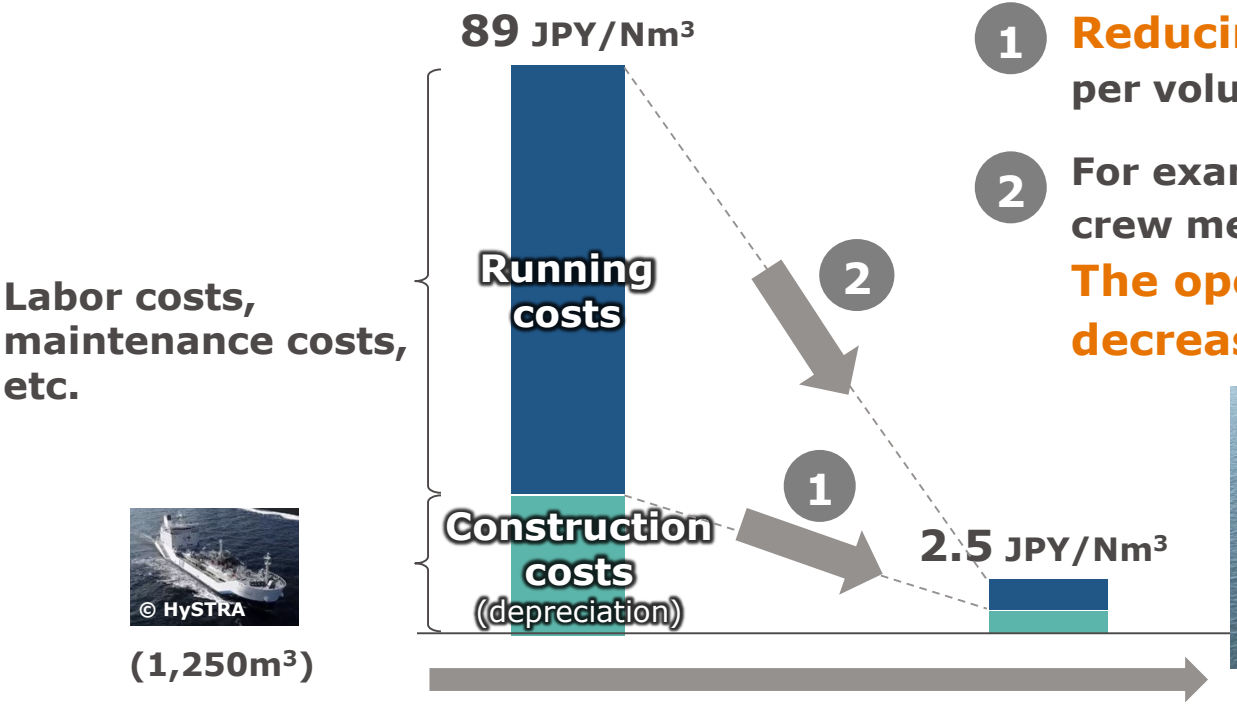
22 JPY/Nm³ | 30 JPY/Nm³ | 33 JPY/Nm³

770 t/day → 1,000 t/day → 200,000m³ → 225,000 t/year

Hydrogen production + CCS | Hydrogen liquefaction | Loading terminal | Australia | Liquefied hydrogen carriers

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

Cost Structure of Liquefied Hydrogen Carriers



1 **Reducing the construction cost per volume unit**

2 **For example, if the number of ship crew members roughly doubled The operating cost would decrease significantly**

By upscaling the ships, the volume transported will increase by 128 times (however, the construction cost will increase by several times)

*This graph is an illustrative image. The proportions in the graph may differ from actual figures.

“Hydrogen Supply Chain Commercialization Demonstration” Selected as a NEDO Green Innovation Fund Project

- **Selection for this Fund is a major step toward hydrogen commercialization**
- **Large-scale demonstration (several tens of thousands of tons per year) by Japan Hydrogen Energy*, ENEOS, and Iwatani Corporation**

Project scale:
Approx. **300** billion yen

Of which, subsidies cover approx. **220** billion yen

Projects included
1. Liquefied hydrogen supply chain commercialization demonstration (FY 2021-2029)
2. Development of large, high-efficiency equipment for hydrogen liquefaction machinery (FY 2021-2030)

*Wholly-owned subsidiary of Kawasaki

★ Kawasaki will supply the large-scale Facilities necessary for the demonstration

Positioning of the Commercialization Demonstration Project

– Current technology –

Approx. JPY 170/Nm³

Fossil Fuel etc → 5 t/day → 2,500 m³ → 36 t/year

Hydrogen production＋CCS

Hydrogen liquefaction

Loading Terminal

Evaluate economic feasibility

Commercialization Project (NEDO GI Fund)

Fossil Fuel etc → ★100 t/day → ★50,000 m³ → ★30,000 t/year

Supplying multiple Similar devices

Commercialization

Fossil Fuel etc → 1,000 t/day → 200,000 m³ → 225,000 t/year

JPY 30/Nm³

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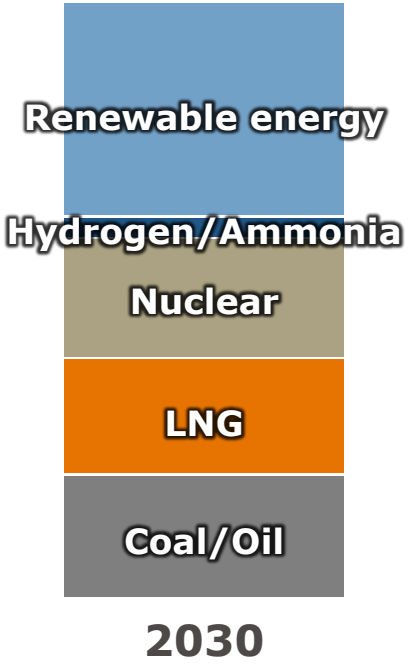
Future Demand for Hydrogen Power Generation

Japanese Government target: Approx. 9 billion kWh of hydrogen power generation in Japan by 2030



Converted to power generation equipment capacity, we anticipate approx. 1,000MW

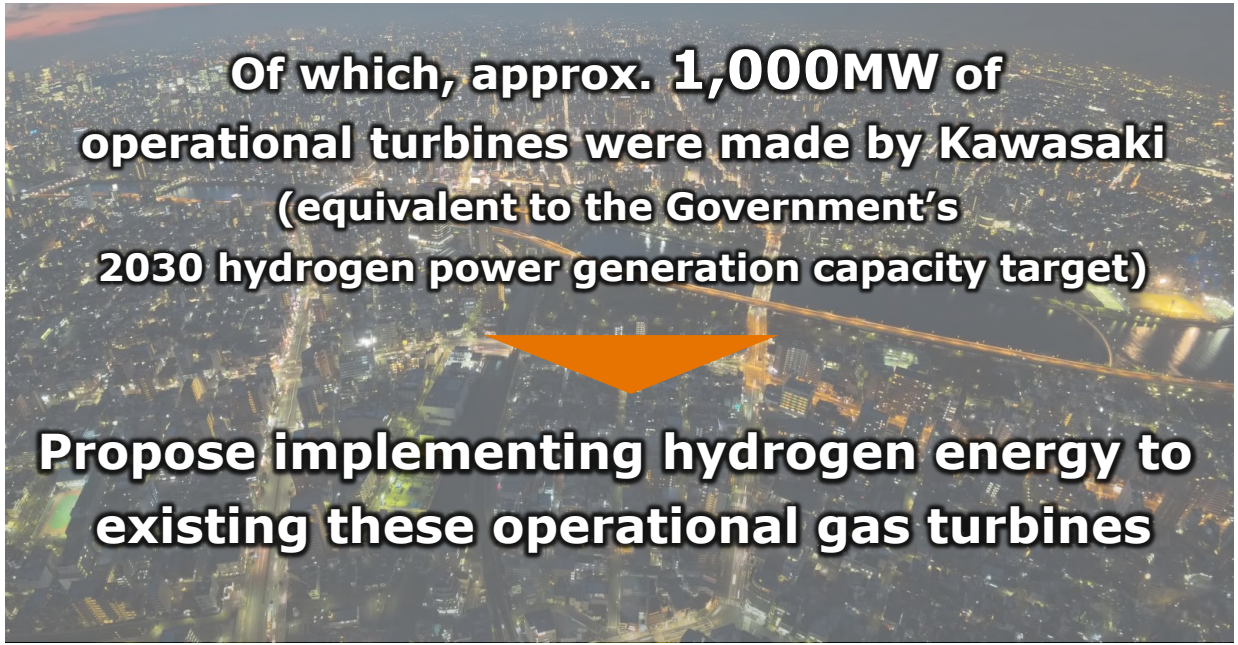
As a pioneer in hydrogen power generation, Kawasaki will lead the charge to reach this target, working to implement this technology quickly

Zero-emission in-house plant with hydrogen power generation as its core

Proposals for the introduction of hydrogen energy into existing power generation facilities

Potential for Implementing Hydrogen Energy to Existing Gas Turbines

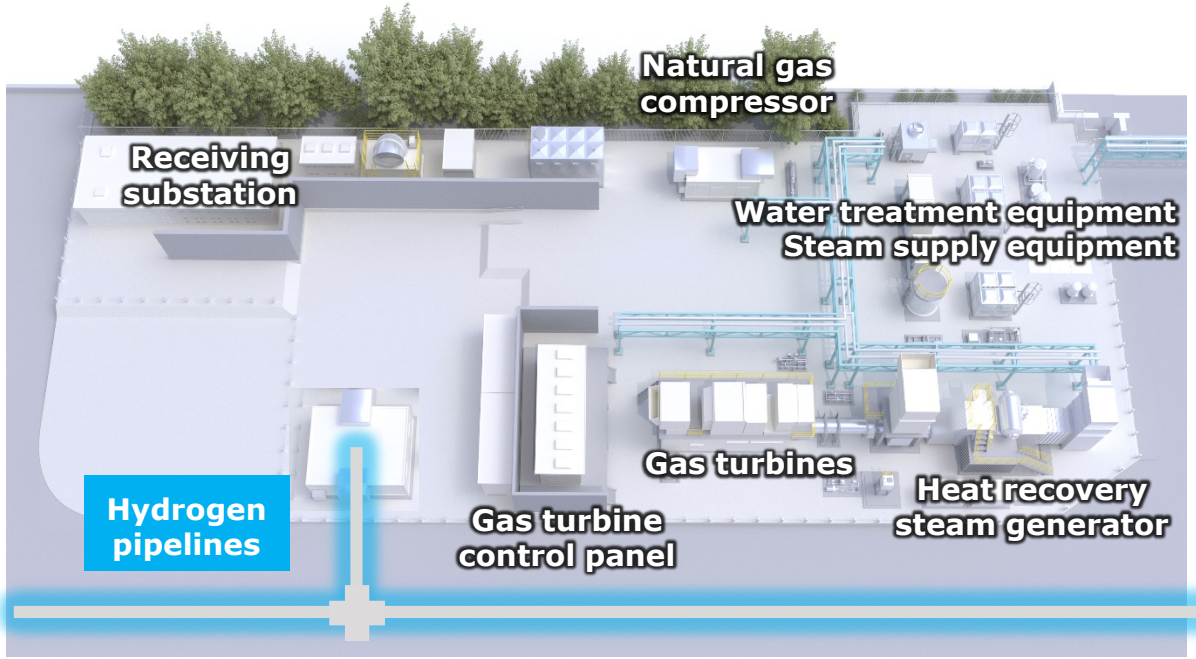
The power generation equipment capacity of existing turbines fired by natural gas is approx. 5,000MW*



*Estimated by Kawasaki with reference to Advanced Cogeneration and Energy Utilization Center's "Prime Mover (new & renewal)" report

Transition to hydrogen energy (Gas turbine power generation)

Transition to hydrogen energy is possible without large changes in infrastructure equipment



Mixed combustion ~30% hydrogen

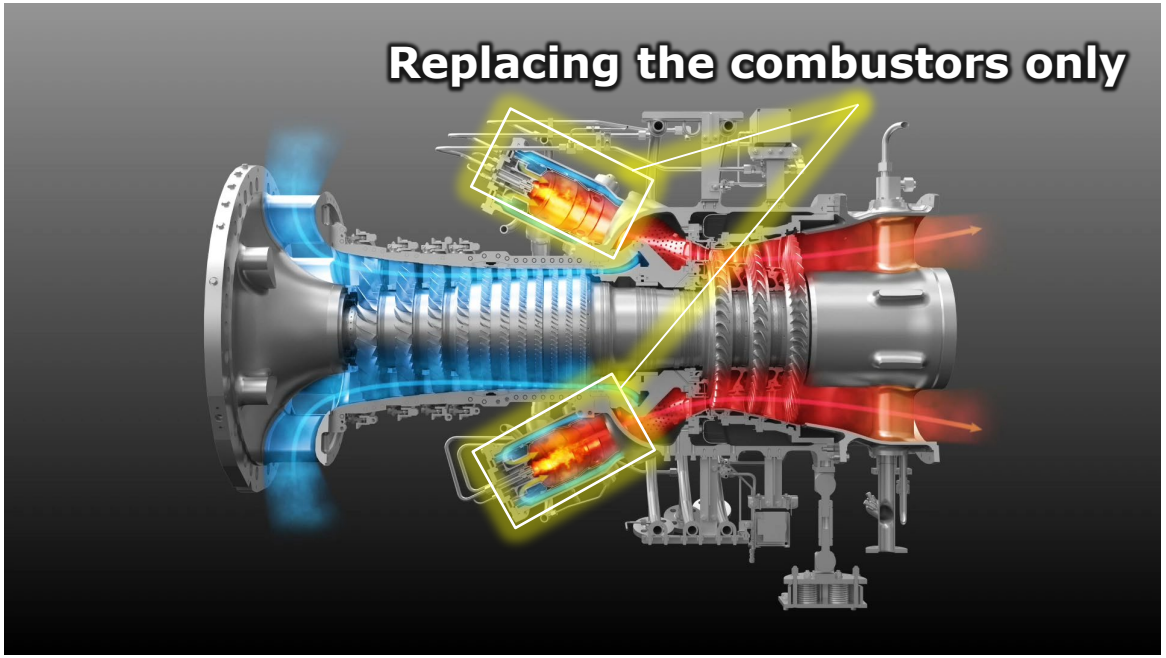
In cases where fuel can be supplied from hydrogen pipelines, **existing facilities can be used without modification**

This will reduce CO_2 emissions by **10%**

Transition to hydrogen energy (Gas turbine power generation)

Hydrogen mixed combustion
30%～100%

Applicable to partial modification
of the gas turbine itself*



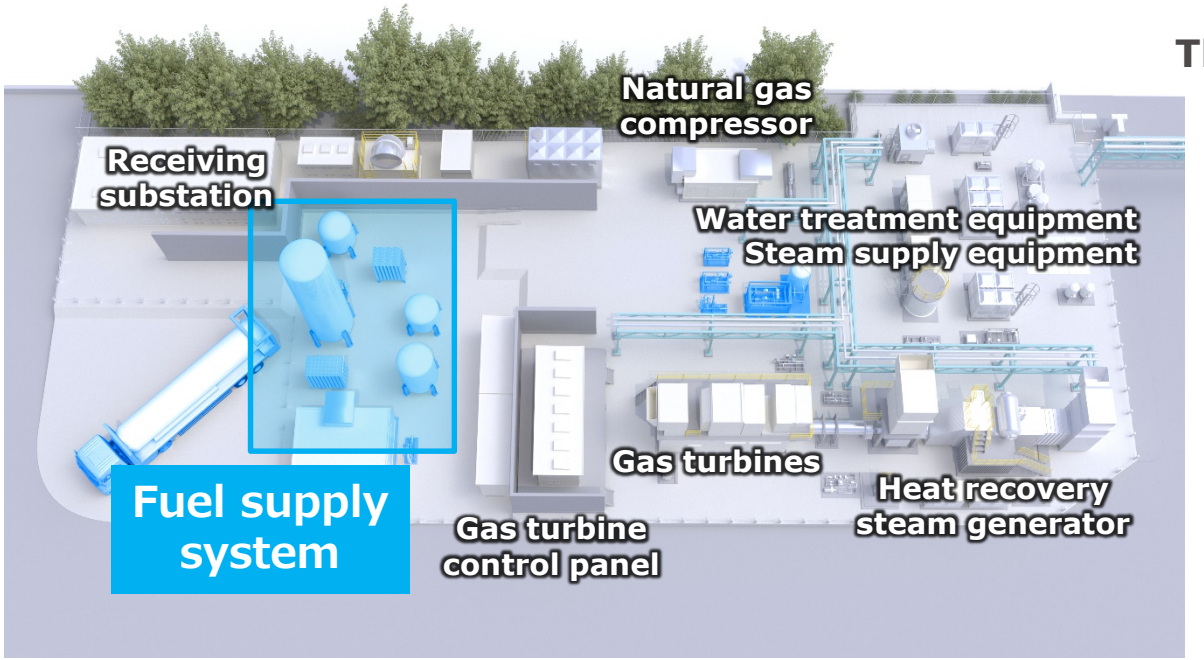
The modification cost is approx. 10% of the total cost of the power plant.

Carbon free electricity
by hydrogen combustion

*Space for explosion-proofing is a prerequisite.

Transition to hydrogen energy (Gas turbine power generation)

In the case where no pipeline is available and the company installs its own independent hydrogen supply



The modification cost is approx. 10% (combustors) of the total cost of the power plant.

+

Approx. 25%

*Examples of our calculations.
Depends on site conditions.

Moving from "Demonstration" to "Commercialization" Hydrogen Power Generation

In April 2018, Kawasaki achieved the world's first heat and electricity supplied in an urban area using 100% hydrogen

(Smart Community Technology Development Project Utilizing Hydrogen Cogeneration Systems)

Heat and power generated by the Hydrogen CGS is supplied to four nearby public facilities

*CGS: Co-Generation System (general name for a system supplying both power and heat)

Moving from “Demonstration” to “Commercialization”
Hydrogen Power Generation

Power generation output:
34,000 kW
Mixed combustion
(20%-50% hydrogen)

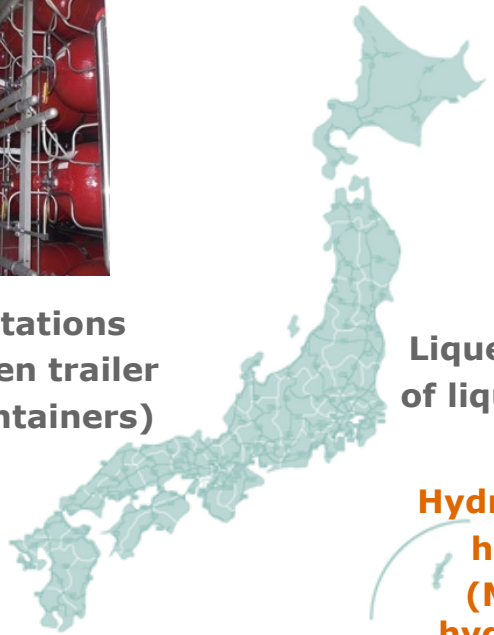
Hydrogen power generation plant for Seibu Oil Co., Ltd.* (started operations in August 2021)

*This project uses by-product hydrogen generated through the refining of petroleum products

Hydrogen Distribution

Contributing to expanding the use of hydrogen by addressing a wide range of transportation requirements in Japan

Transport to off-site hydrogen stations (Japan's first compressed hydrogen trailer featuring a composite storage containers)



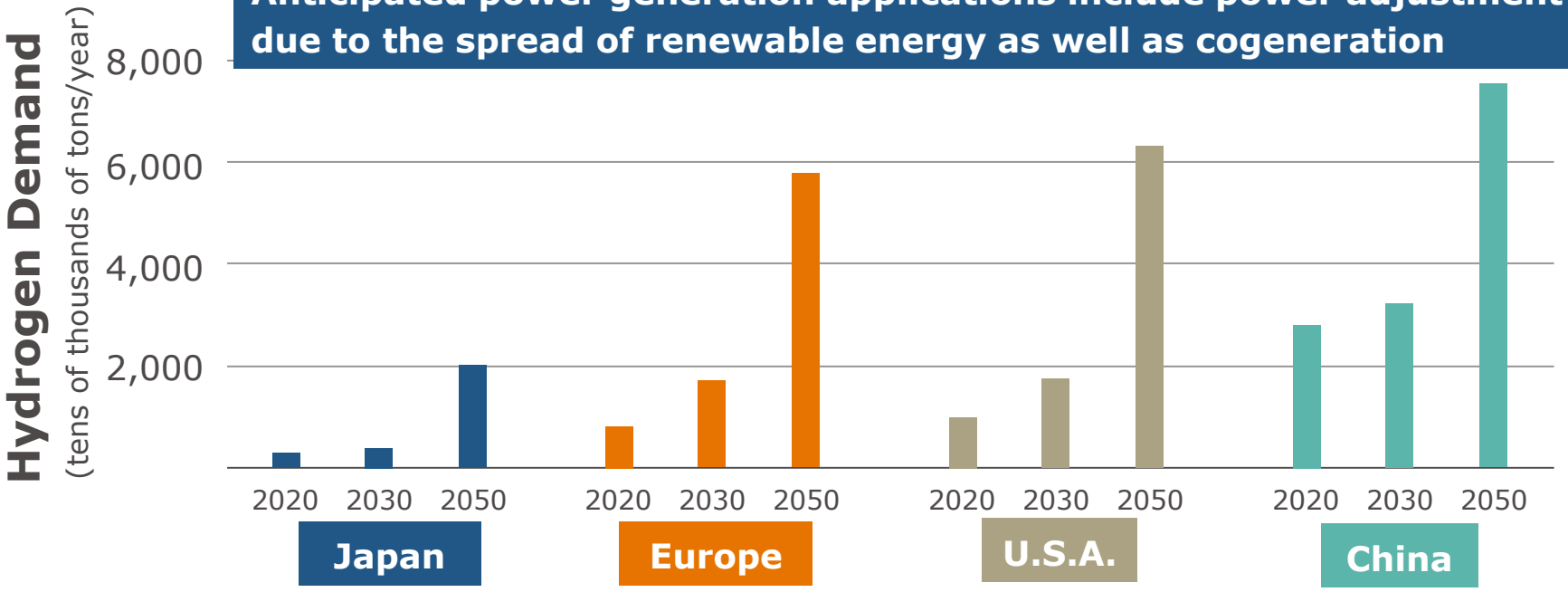
Liquefied hydrogen container for land transport of liquefied hydrogen to high-volume consumers such as power stations

Hydrogen distribution in Japan is shifting from high-pressure gas to liquefied hydrogen. (Many transportation bases for "liquefied hydrogen" are being built overseas as well.)

Global Expansion of Hydrogen Power Generation

Global usage of hydrogen will expand rapidly after 2030

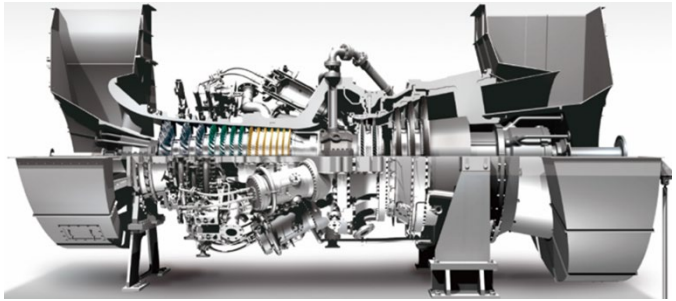
Anticipated power generation applications include power adjustment due to the spread of renewable energy as well as cogeneration



*Estimated by Kawasaki with reference to each country's hydrogen roadmap

Hydrogen Power Generation Demonstration Projects in Europe

Agreed to work on consideration of a joint hydrogen power generation demonstration project with major German energy company RWE Generation SE



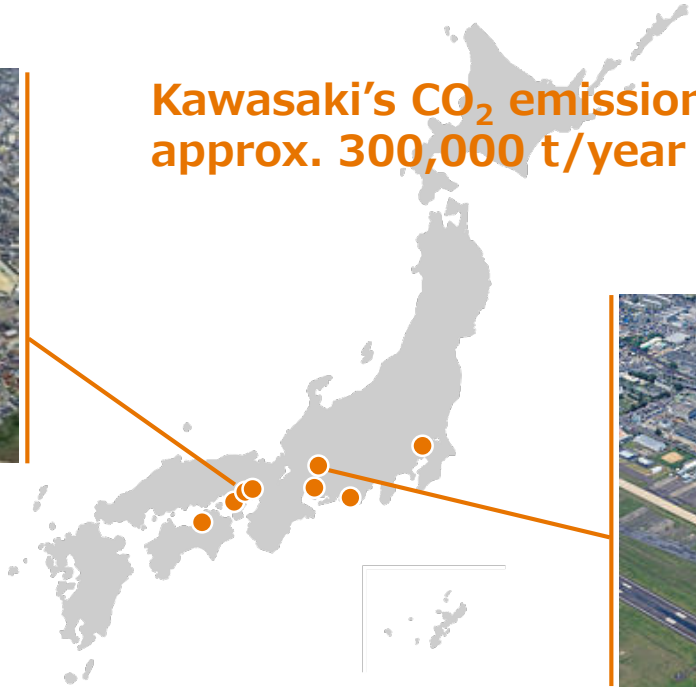
30MW-class gas turbine

Planned location:
Lingen, Lower Saxony, Germany

Kawasaki Group Carbon Neutral Initiatives

Akashi Plant

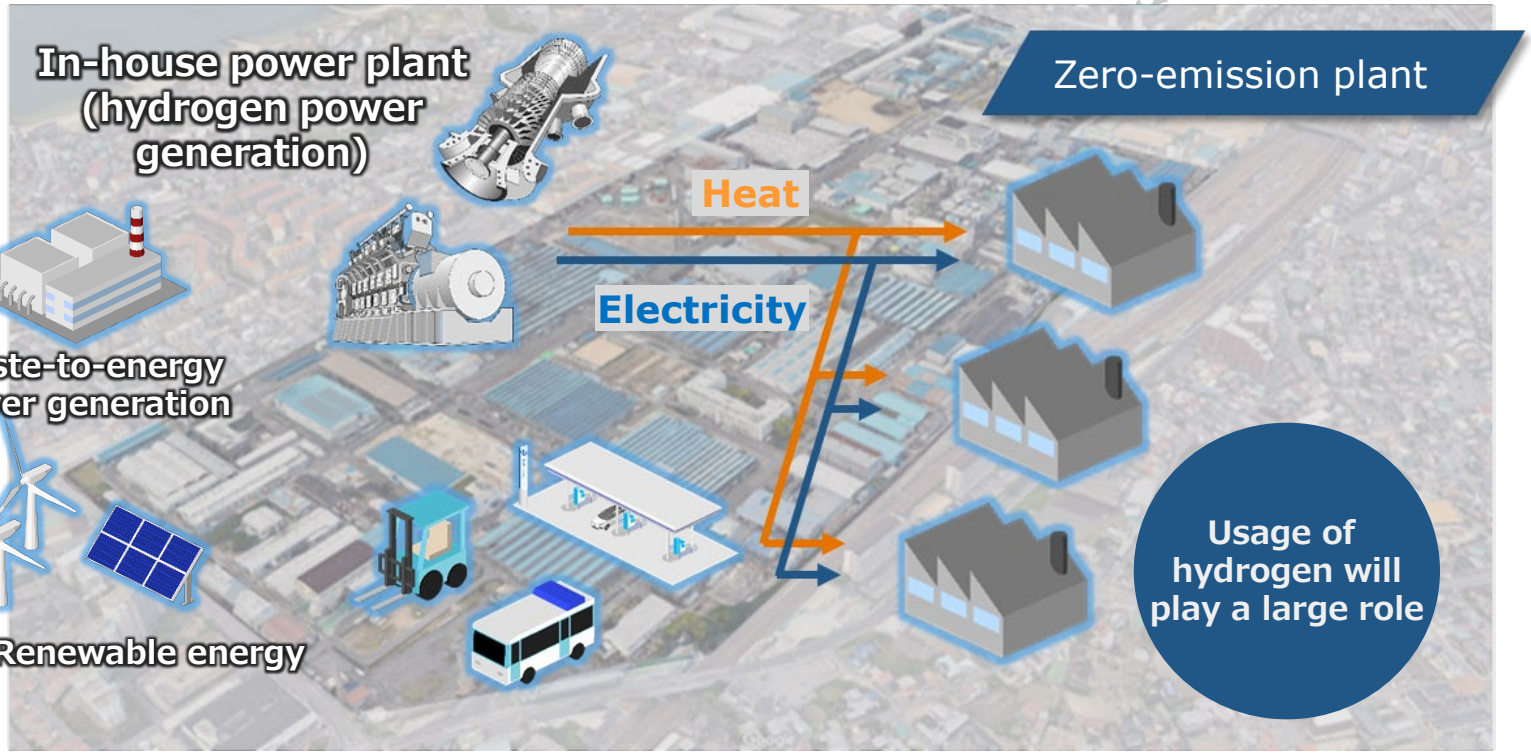
Kawasaki's CO_2 emissions volume approx. 300,000 t/year



Gifu Plant

Kawasaki Group Carbon Neutral Initiatives

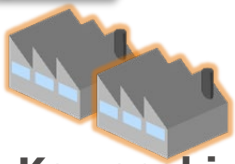
Reducing CO_2 emissions from our plants



Usage of Overseas CO_2-free Hydrogen

100MW of power generation capacity is equivalent to **10%**
of the Government's 2030 hydrogen power generation capacity target

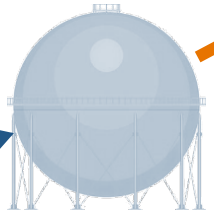
Hydrogen power generation projects (Kawasaki)



Kawasaki plants etc

Hydrogen transportation from Australia to Japan (in 2030)

225,000 t/year



45,000 t/year

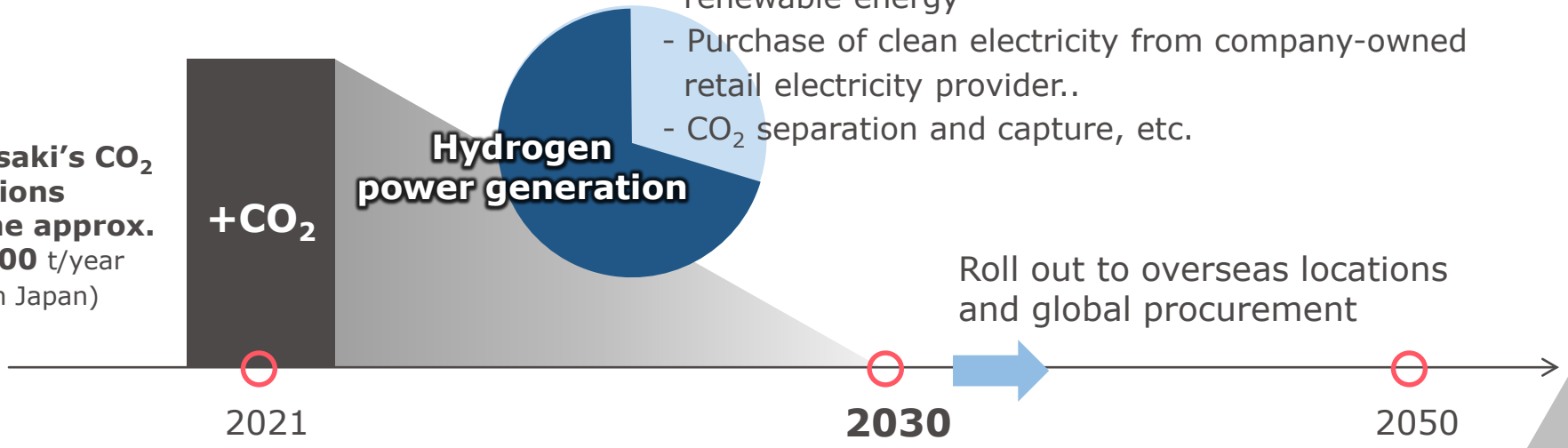
Japan

Zero Emission Plant: Reducing CO_2 Emissions from our Business Activities

Our target is to achieve standalone carbon neutrality in 2030 through independent initiatives centered on hydrogen power generation

- Introducing energy-saving technologies and renewable energy
- Purchase of clean electricity from company-owned retail electricity provider..
- CO_2 separation and capture, etc.

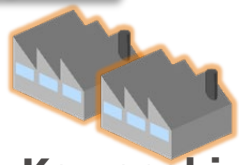
Kawasaki's CO_2 emissions volume approx. 300,000 t/year (sites in Japan)



Usage of Overseas CO_2-free Hydrogen

If all of the 225,000 tons/year were used for power generation,

Hydrogen power generation projects (Kawasaki)



Kawasaki plants etc

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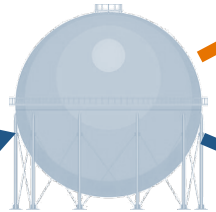
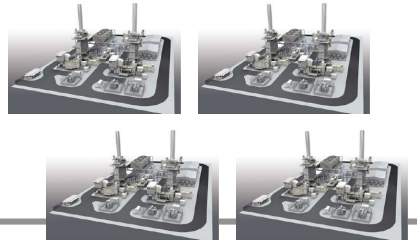


45,000 t/year

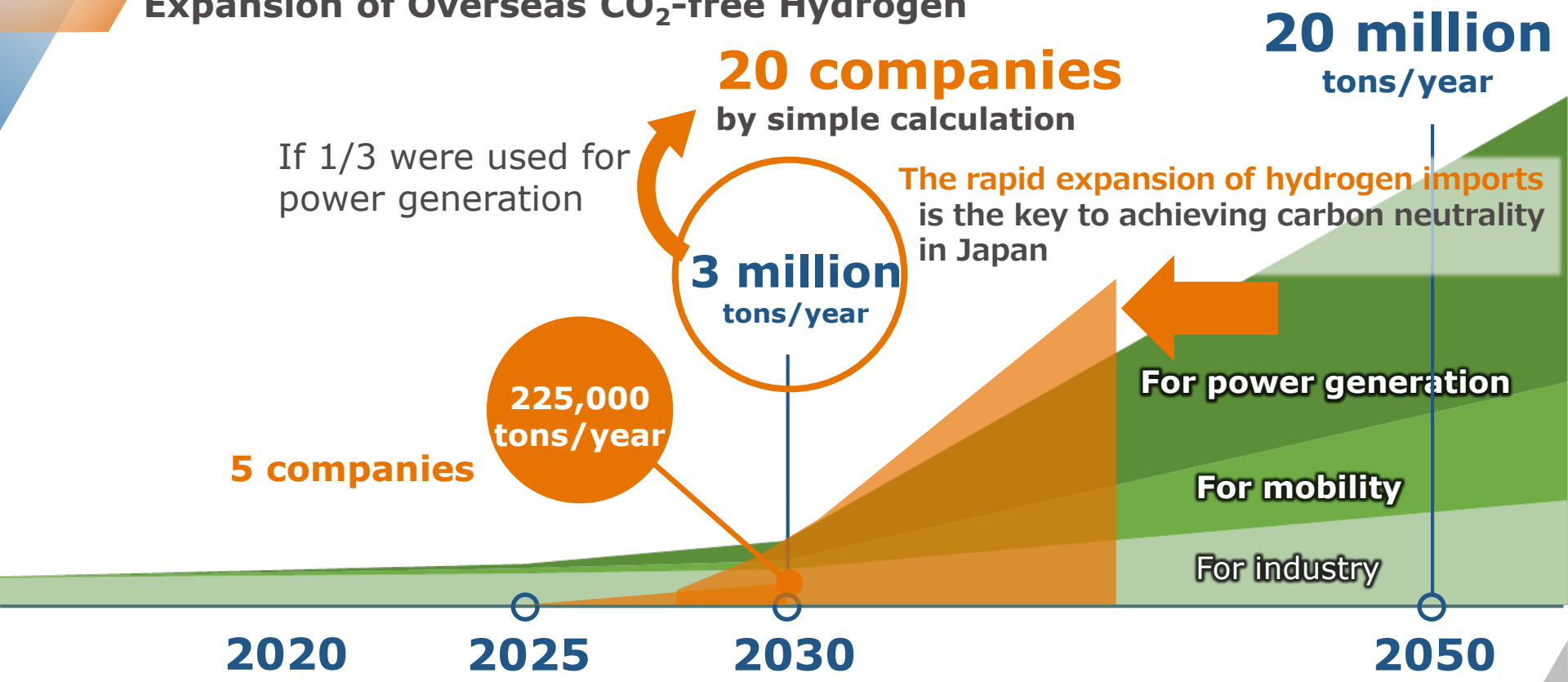
180,000 t/year

Japan

We can provide this solution to 5 companies



Expansion of Overseas CO_2-free Hydrogen



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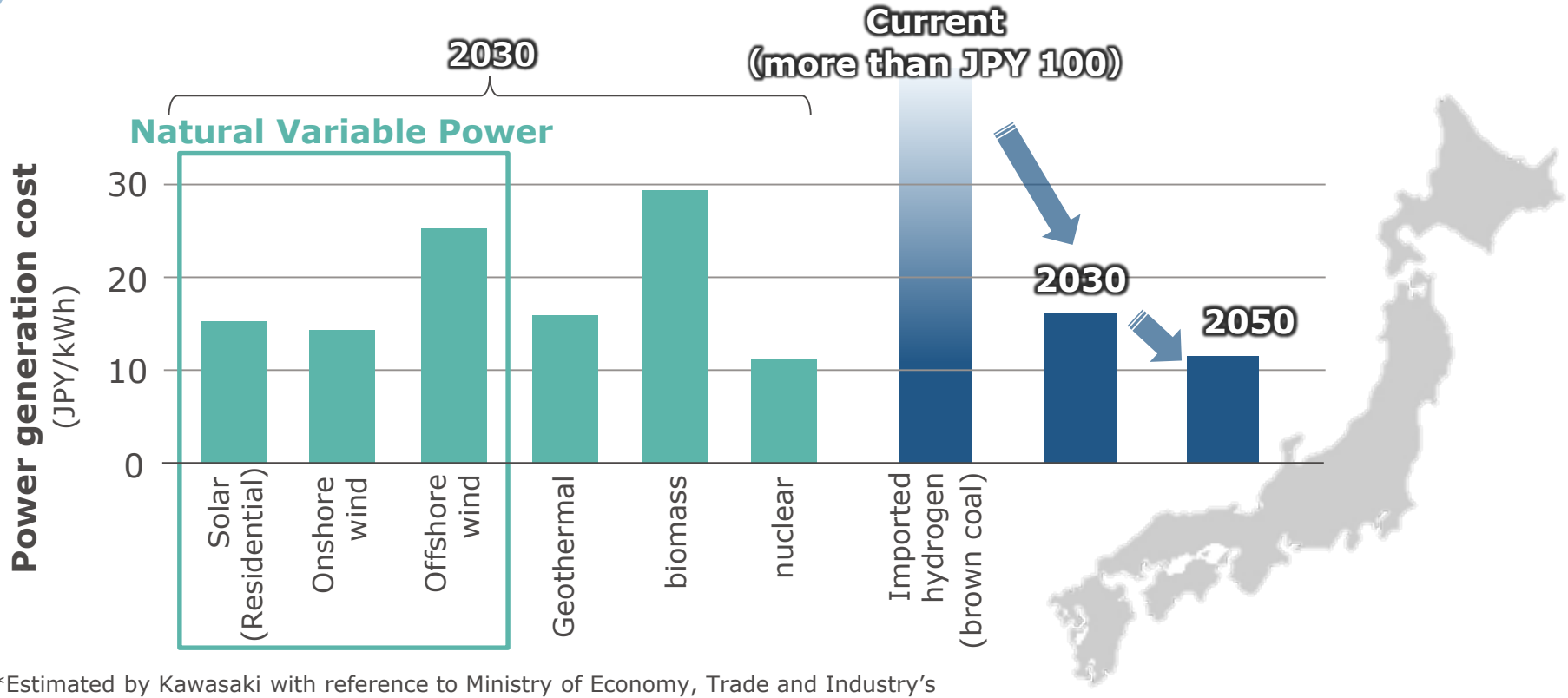
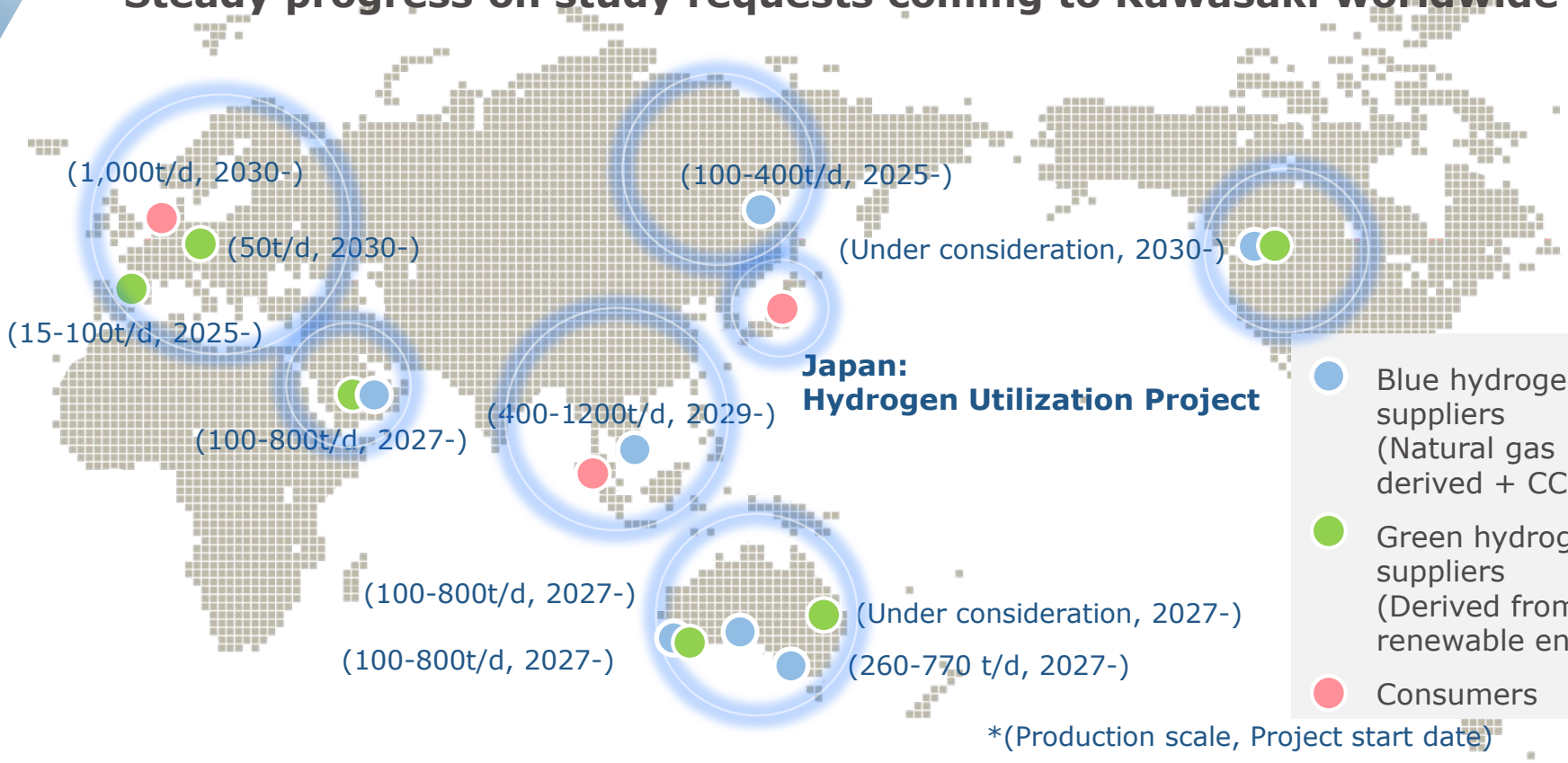
Domestic power generation costs of carbon-free power sources



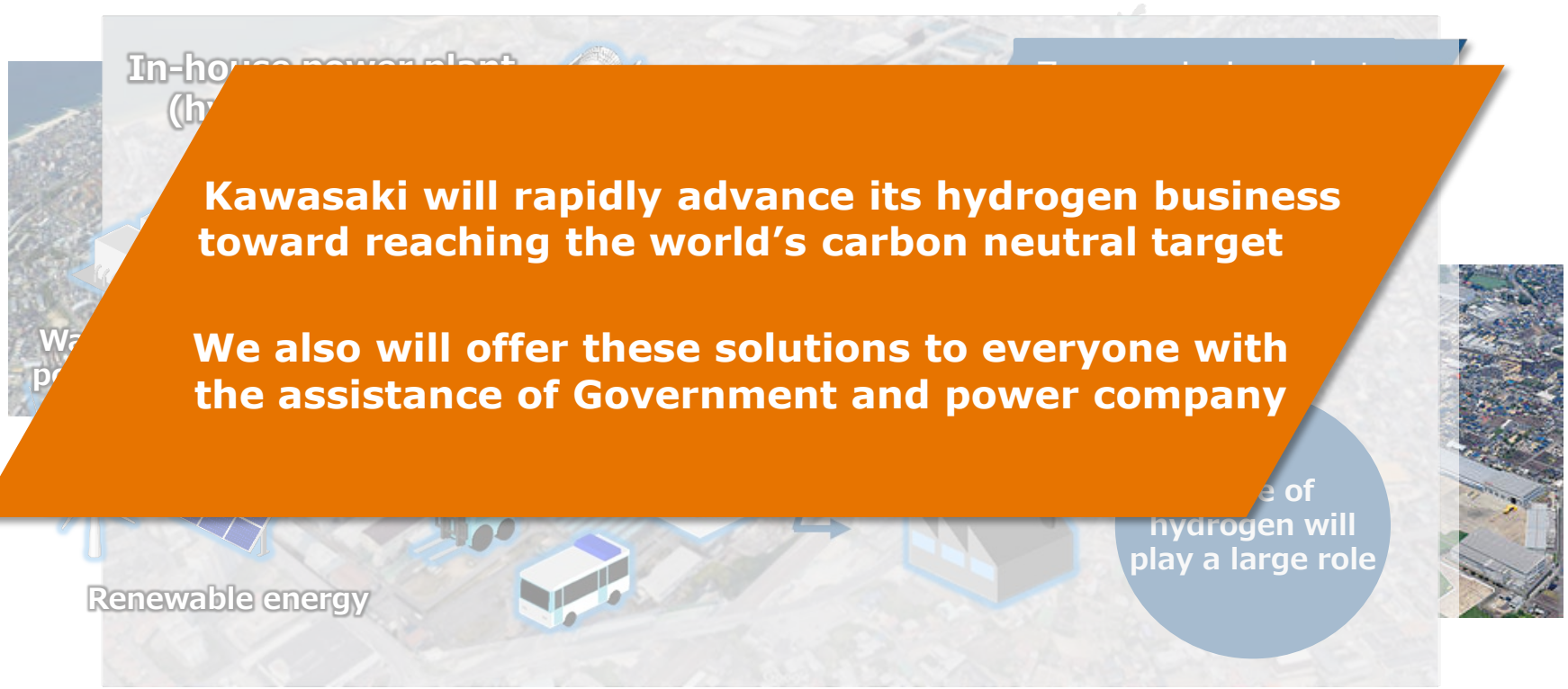
*Estimated by Kawasaki with reference to Ministry of Economy, Trade and Industry's "Power Generation Cost Verification Working Group, Advisory Committee on Natural Resources and Energy (7th meeting)," July 2021 edition

Hydrogen Businesses:
Steady progress on study requests coming to Kawasaki worldwide



*(Production scale, Project start date)

Kawasaki Group Carbon Neutral Initiatives



Kawasaki will rapidly advance its hydrogen business toward reaching the world's carbon neutral target

We also will offer these solutions to everyone with the assistance of Government and power company

Challenge to achieve Carbon Neutrality

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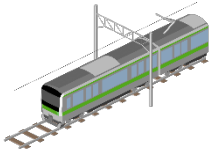
The Potential of Hydrogen Engines in the Mobility Field

Zero emissions for mobility will require various options to increase in accordance with applications and cruising distances, etc.

Cars · Motorcycles

Large automobiles
(Buses, trucks)



Trains
(Non-electric sectors)

Ships

Aircraft

Pursuit of the potential of hydrogen engines

Fuel Cell Vehicle

Battery Electric Vehicle

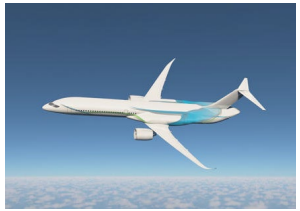
Application of Hydrogen Fuel to "Marine and Aircraft Fields"

"Knowhow to burn hydrogen safely and cleanly" cultivated in hydrogen power generation

Developing KAWASAKI combustion technology further to lead the world in internal combustion engines for mobility too

Development of hydrogen-fueled ship propulsion systems*1

We will complete a lineup compatible with various applications by around 2026



Development of core technology for hydrogen aircraft*2

We will promote development looking ahead to full-scale input of hydrogen-powered aircraft from 2035

The related markets we are targeting by 2050 will be

several trillion JPY in scale

*1 NEDO Green Innovation Fund "Development of hydrogen-powered ship promotion systems" (subsidy: about 21.9 billion JPY)
(Adoption in the consortium with Yanmar Power Technology and Japan Engine Corporation)
*2 NEDO Green Innovation Fund "Technology development aimed at hydrogen-powered aircraft" (subsidy: about 18 billion JPY)

Challenging Towards Hydrogen Engines

The system is almost the same as gasoline engines

Aiming for carbon neutrality while leveraging the industries that have been cultivated in Japan and around the world

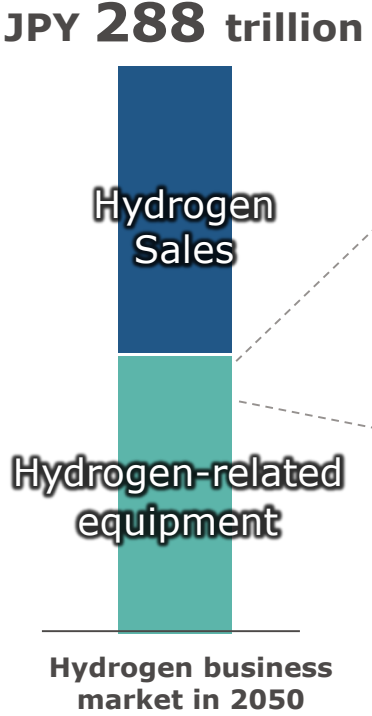
Provided hydrogen for Toyota hydrogen engine Corolla

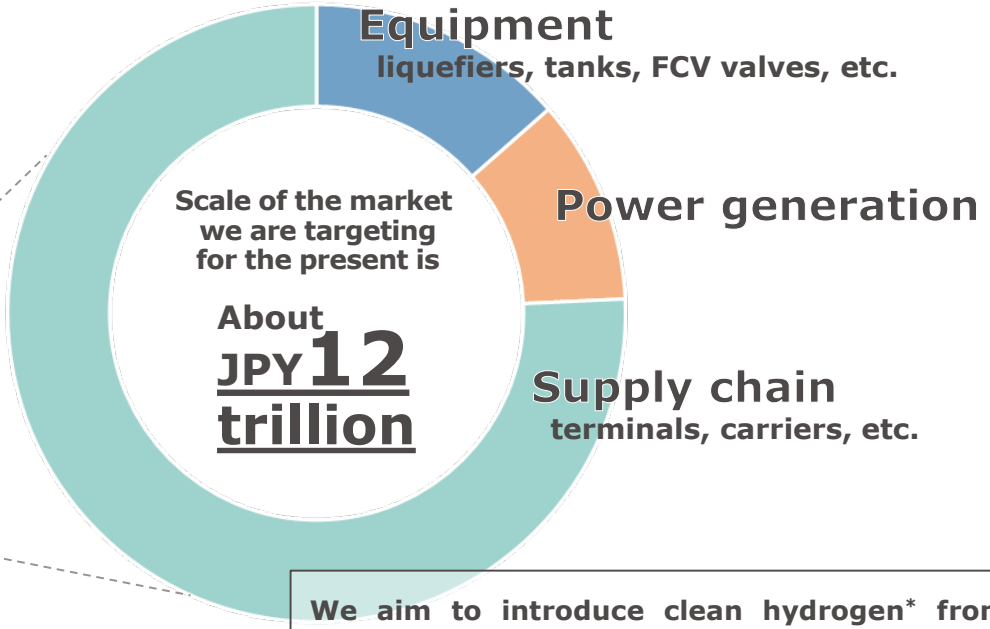
Cooperation of "Transportation (supply side)" and "Utilization (demand side)"

Started consideration of joint research with Yamaha Motors on hydrogen engines with a view to installing on motorcycles, etc.

Hydrogen Business Plans

Hydrogen market in 2050





We aim to introduce clean hydrogen* from overseas for about half of the Japanese government's target of 20 million tons/year by 2050, and establish multiple supply chains

e.g.: **80** liquefied hydrogen carriers, **10** receiving terminals

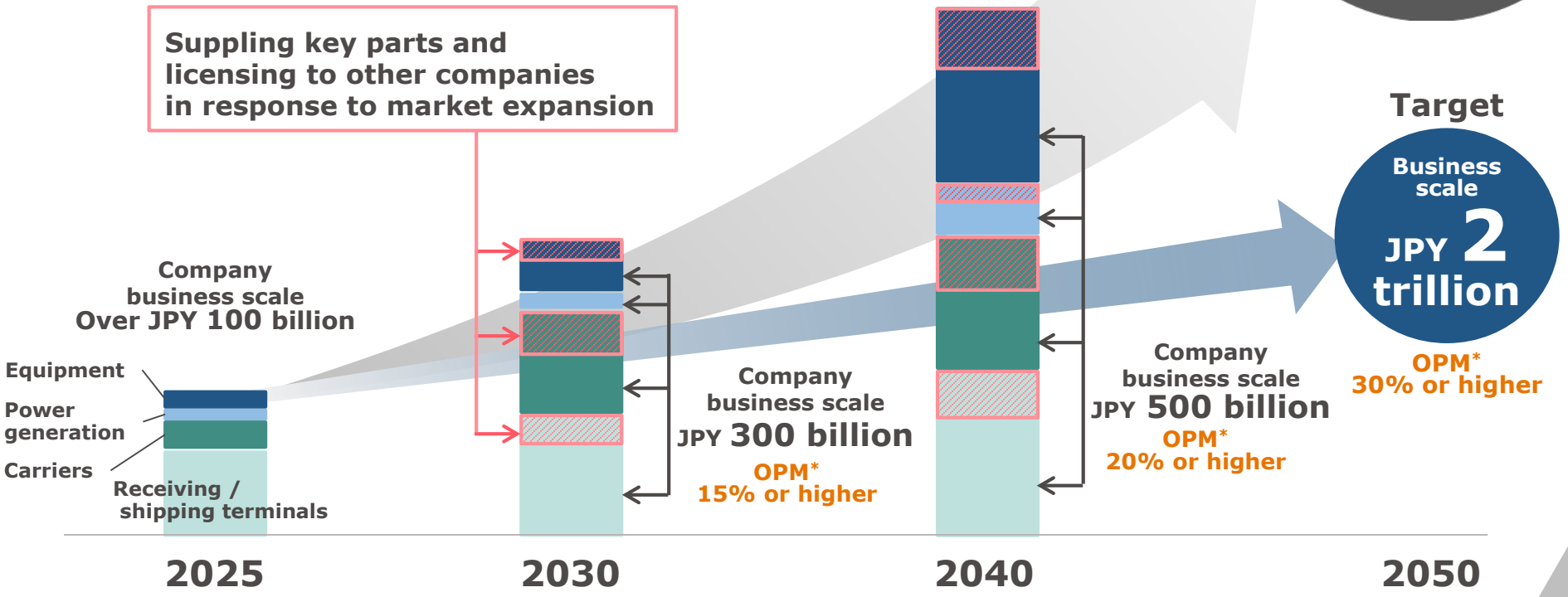
* Fossil fuel + CCUS / renewable sources-derived
** Calculated by the company with reference to the Hydrogen Council's "Hydrogen Roadmap"

Hydrogen Business Plans

Together with various partners

Suppling key parts and licensing to other companies in response to market expansion

Market scale
JPY 12 trillion



*Operating profit margin

Timeline

2020 — Technology Demonstration — **2025** — Commercialization Demonstration — **2030** — **2050**

Launched 5t/day Class
To increase the capacity of liquefiers

To introduce 50t/day class
*Up to 25t/day can be practically used with the existing technology

To introduce 100t~/day class
10 units

To introduce 200t~/day class
10 units × 10 sites

Installed a 2,500㎥ on-shore storage tank in Hytouch Kobe
To increase the capacity of storage tanks

To construct the first 50,000㎥ storage tank

To install 4th 50,000㎥ storage tank

To install 200,000㎥ storage tanks
10 sites

Launched a 1,250㎥ small liquefied hydrogen carrier
To increase the capacity of the carriers

To build the first large liquefied hydrogen carrier with 40,000㎥ x 4 tanks

To build second large liquefied hydrogen carrier

To commence operation of 80 large liquefied hydrogen carriers

Succeeded to generation by 100% hydrogen-fueled gas turbine with dry low NOx combustion technology

Launched small hydrogen combustion once-thorough boiler

To launch marine hydrogen-fueled engine

To start power sales business using 100MW class hydrogen power generation

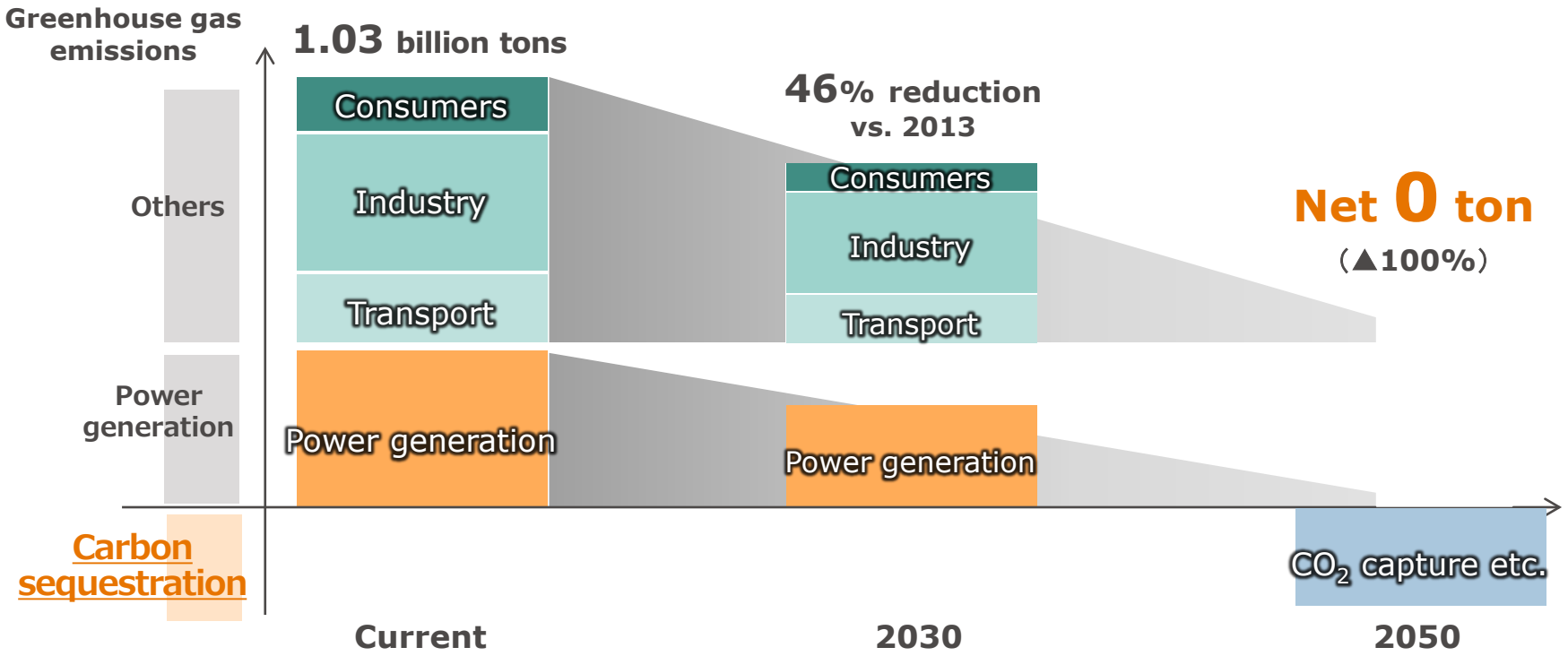
To establish hydrogen aircraft technology

Challenge to achieve Carbon Neutrality

- Kawasaki Solutions for the Sustainable Society -

1. Hydrogen Energy: Critical for Achieving Carbon Neutrality
2. Hydrogen Power Generation: The History
3. Hydrogen-Powered Mobility: Creating New Value
4. Contributing to Carbon Neutrality through CO_2 Separation and Capture
5. Together with various partners

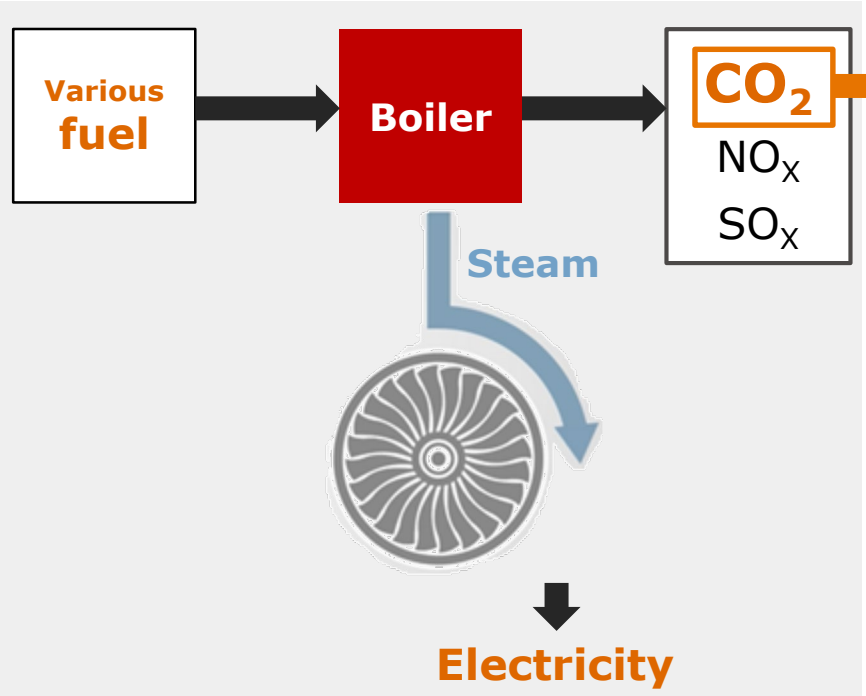
Scenario in which Japan becomes Carbon Neutral in 2050



*Created by Kawasaki based on the Ministry of Economy, Trade and Industry's "Green Growth Strategy Through Achieving Carbon Neutral in 2050", December 2020 edition

What Is the "CCUS" Carbon Sequestration Method?

CC: Carbon dioxide Capture

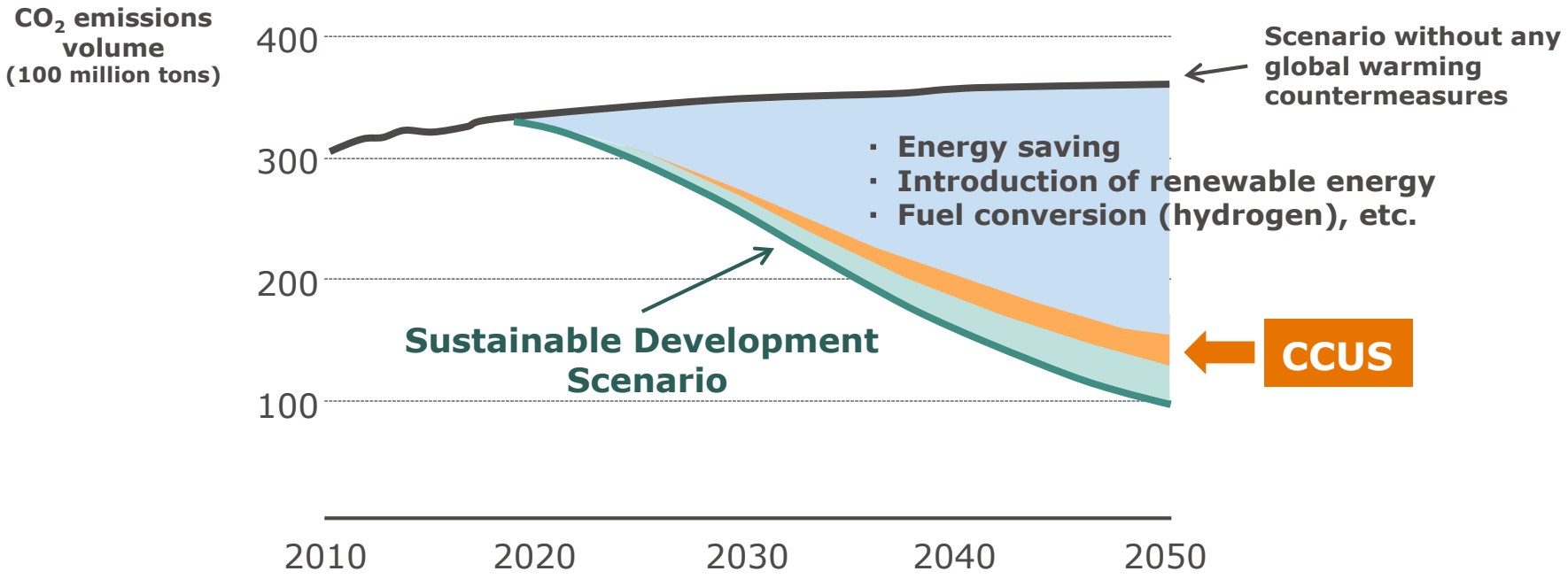


Technology that separates and captures CO_2 in exhaust gas from thermal power plants, etc., for

Storage and Utilization

Role of CCUS : Carbon dioxide Capture, Utilization and Storage

CCUS will contribute to a 9% Reduction of about of CO_2 emissions by 2050



* International Energy Agency (IEA) "Sustainable Development Scenario"

Future Prospects of CCUS : Carbon dioxide Capture , Utilization and Storage

CC : Carbon dioxide Capture

Global CO_2 separation and capture market scale (forecast):

about JPY **6 trillion** / year in 2030

U : Utilization

Utilize **CO_2 as resource** for materials, synthetic fuel, etc.

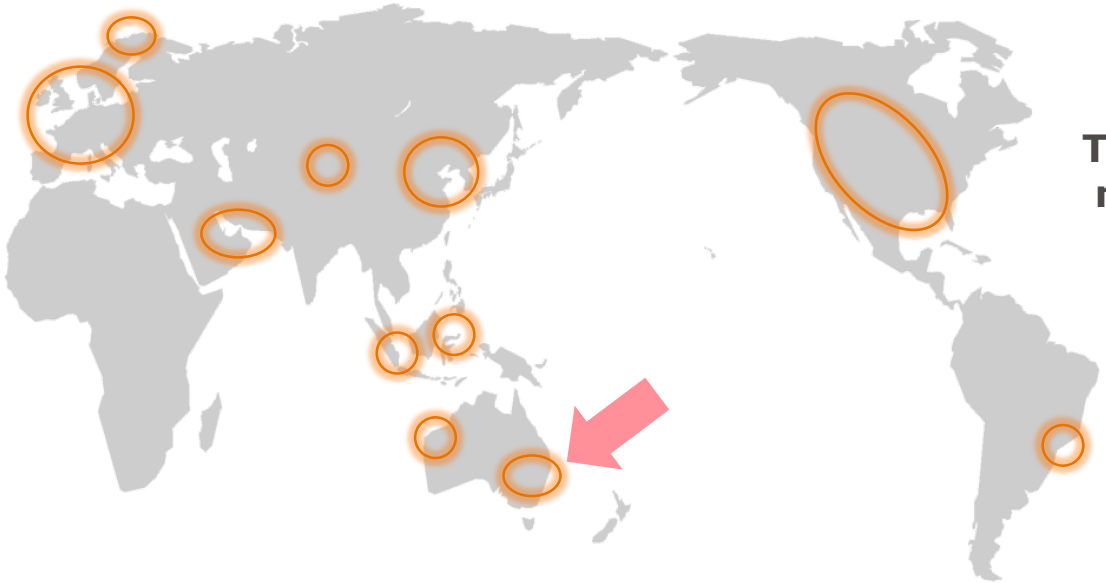
(while increasing productivity and lower costs are issues)

*Created by Kawasaki based on the Ministry of Economy, Trade and Industry's "Green Growth Strategy Through Achieving Carbon Neutrality in 2050", December 2020 edition

Distribution of Commercial CCS Facilities

***Including Facilities Under Construction / Development**

Places with geological conditions suited to CO_2 storage are distributed widely around the world

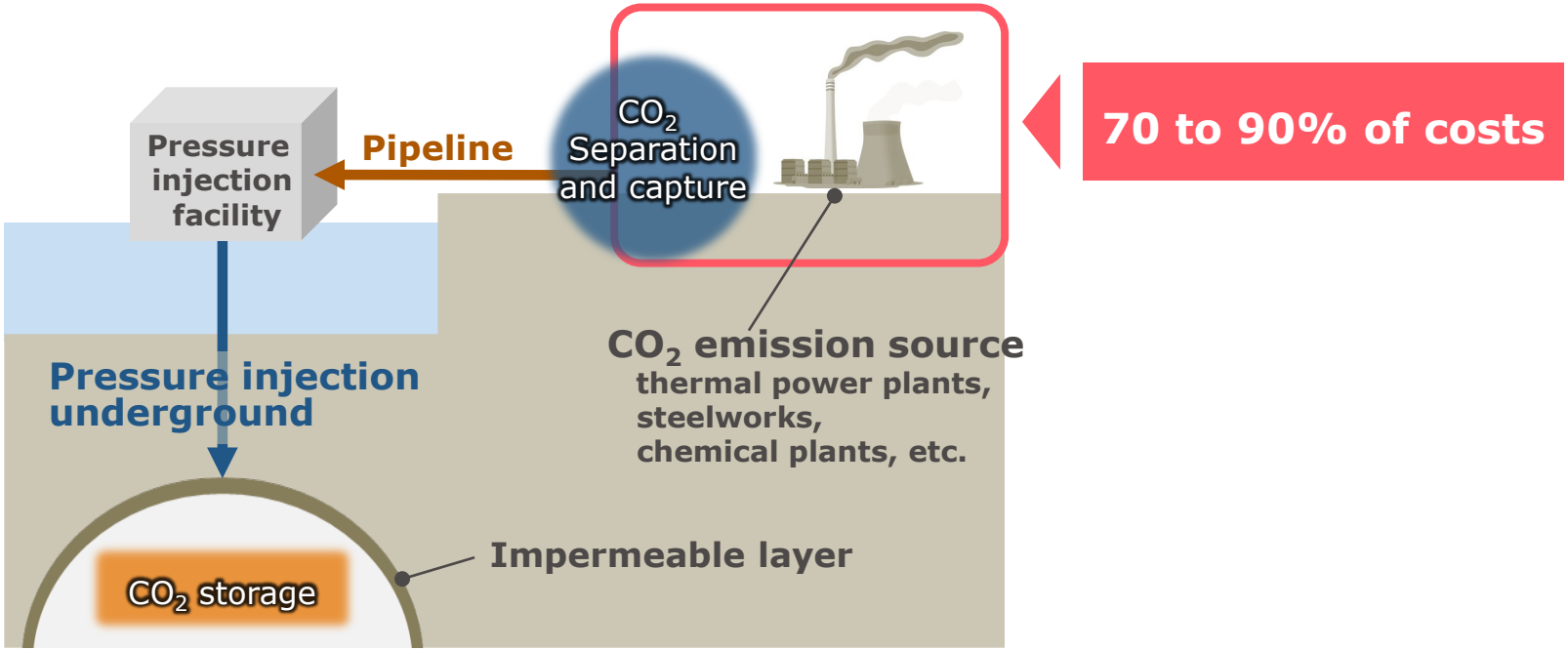


To store CO_2 close to the sources makes the sense

* Created by Kawasaki with reference to the GLOBAL CCS INSTITUTE's "GLOBAL STATUS OF CCS 2021"

Issues of CCS (Carbon dioxide Capture and Storage)

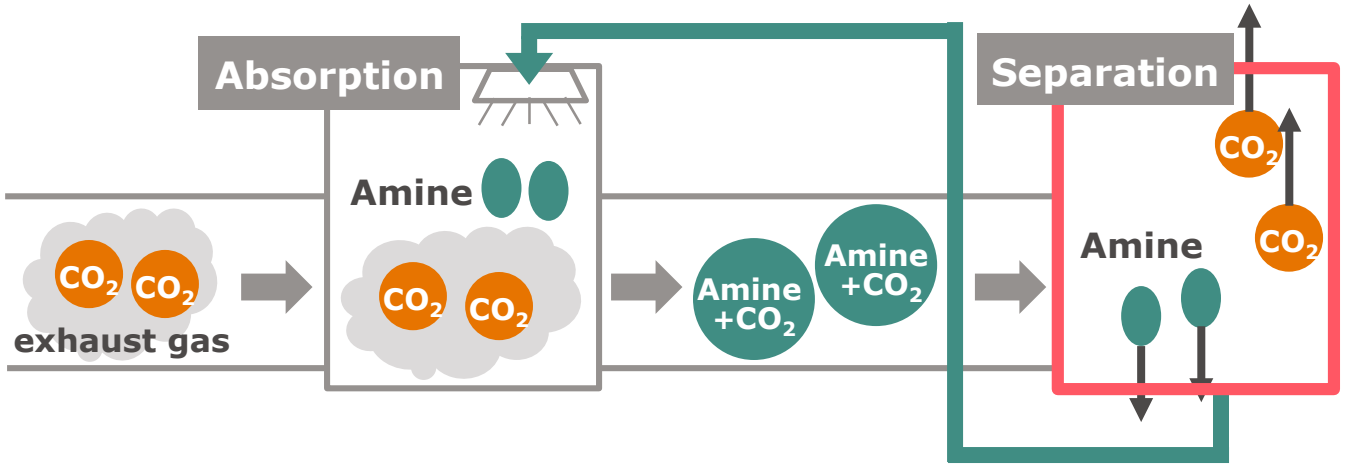
In cases where the sources of CO_2 generation and storage sites are close, the proportion of separation and capture costs is high



Steps in CO_2 Separation and Capture from Exhaust Gas

We have developed **solid sorbent comprising a porous material containing amine** suitable for CO_2 absorption

Introduce alkaline aqueous solution "amine solution" to absorb CO_2 in the exhaust gas



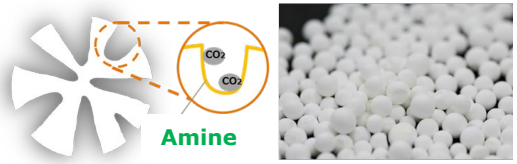
Challenge

Heating to 120℃ because the solvent must be evaporated to separate CO_2

Separation and capture of CO_2
Re-use of amine

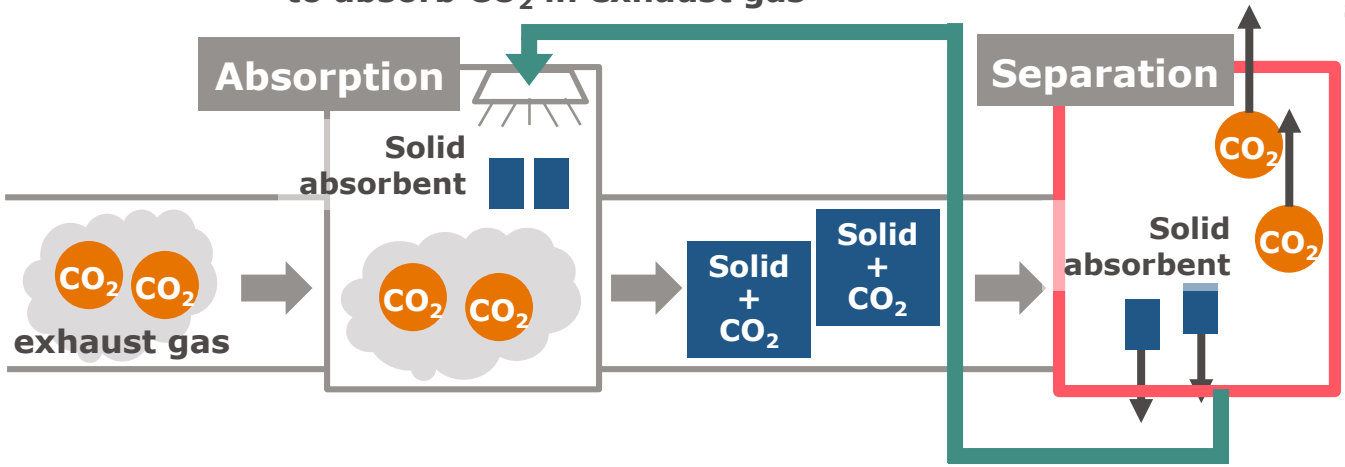
Additional energy is required

Solid Absorbent Method



"Waste heat" can be used, which is normally thrown away in thermal power plants

Input our unique **solid absorbent** to absorb CO_2 in exhaust gas



Heating temperature to separate CO_2 is **60℃** because evaporation of the solvent is not required

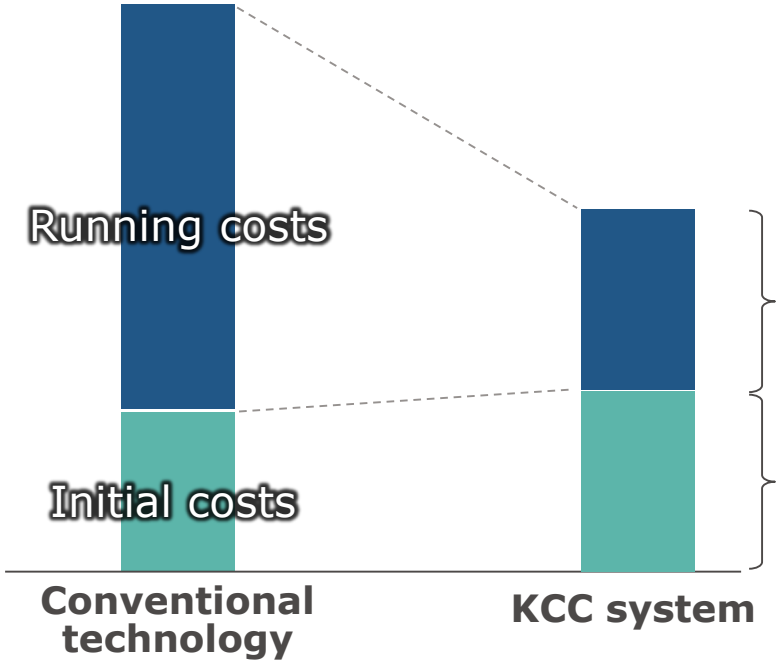
Heating to 120℃ because the solvent must be evaporated to separate CO_2

Additional energy is required

Separation and capture of CO_2
Reuse solid absorbent

CO_2 Separation and Capture Costs

Kawasaki's unique KCC (Kawasaki CO_2 Capture) system enables significant reductions in CO_2 separation and capture costs

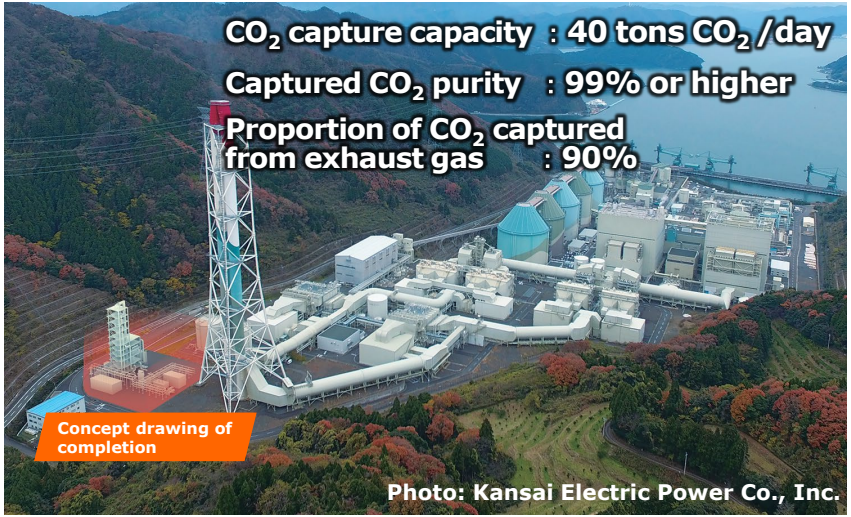


With KCC system,
CO_2 can be separated with steam at about 60℃

- **Surplus waste heat** that was previously thrown away **can be used**
- **Absorption material can has longer life** as it is reused at low temperature

Moving bed system, absorption materials, etc.

Towards Commercialization



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

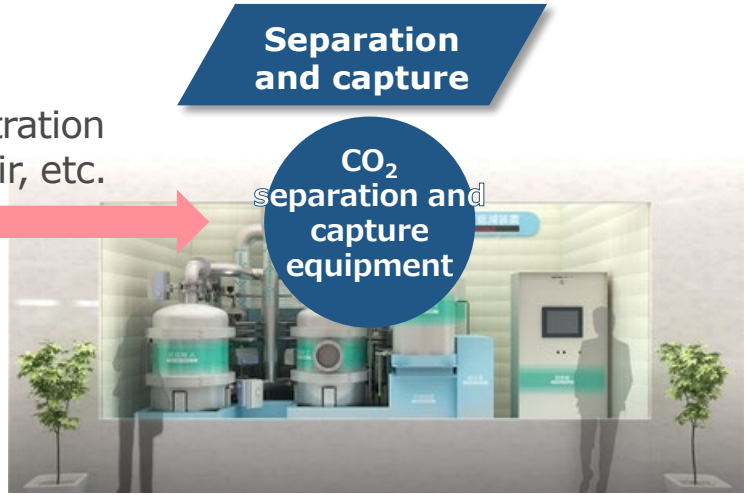
* Ministry of the Environment "Environmentally friendly CCUS demonstration base / supply chain construction project"
Joint implementation with Japan Coal Frontier Organization (JCOAL)

DAC : Direct Air Capture

DAC is one of the negative emissions technologies* required for achievement of the 1.5℃ target.

CO_2 is directly captured from the air by taking advantages of our unique solid sorbent

Low concentration CO_2 gas in air, etc.



We are advancing laboratory experiments and plan on demonstrations around 2025

* Technology that captures and removes CO_2, which is deemed to be the largest contributor to the greenhouse effect and was emitted and accumulated in the atmosphere in the past

Challenge to achieve Carbon Neutrality

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5. **Together with various partners**

Together with various partners

As a leading company in the field of hydrogen, Kawasaki group, together with many partners, will accelerate the various initiatives to

realize carbon neutrality through hydrogen

Hydrogen Council
129 member companies
Kawasaki and other 12 companies
at the foundation in 2017

JAPAN HYDROGEN ASSOCIATION

Japan Hydrogen Association (JH2A)
253 member companies
Kawasaki and other 87 companies
at the foundation in 2020

Hydrogen Energy Supply Chain（HESC) Project

HySTRA

CO_2-free Hydrogen Energy Supply-chain Technology Research Association*
*Japanese portion of the HESC project
7 member companies
Kawasaki and other 3 companies
at the foundation in 2016

Major partners at hydrogen-related projects

METI MLIT MOE Kobe City NEDO Iwatani Shell Japan J-POWER Marubeni ENEOS "K" LINE Obayashi KEPCO Japan Engine Yammer Power Technology Toyota Motor Yamaha Motor INPEX Victoria State Government Australian Government AGL Energy and others

*in random order