

# Toward the Realization of a Hydrogen Society

- Introduction of Kawasaki Gas Turbines and Gas Engines

Kawasaki Heavy Industries, Ltd.

カワる、  
サキへ。  
Changing forward

 **Kawasaki**  
Powering your potential

- 1. Wants of the Next Society**
- 2. Kawasaki's Solutions for Carbon Neutrality**
  - Establishment of a CO2-free Hydrogen Chain**
  - Role of the Hydrogen Gas Turbine / Gas Engine**
  - Global & Local Alliance**

# 1. Wants of the Next Society

# National Greenhouse Gas Targets

- At the 2021 Climate Change Summit and COP26, the leaders of major emitters announced ambitious targets for the reduction of greenhouse gas emissions by 2030. In addition, a target of virtually zero emissions by 2050 to 2060 was announced.
- The International Energy Agency reports that 50% of the world's final energy consumption is thermal energy. Hydrogen fuel is indispensable for the decarbonization of heat.

	Japan 	EU 	U.K. 	China 	India 	U.S.A. 
2020						
2030	46% reduction compared to 2013	at least 55% reduction compared to 1990	78% reduction in 2035 compared to 1990	① peak of zero emission: less than 2030 ② 65% reduction compared to 2005	33-35% reduction compared to 2005	50-52% reduction compared to 2005
2040						
2050	Net Zero	Net Zero	Net Zero			Net Zero by whole country
2060				Net Zero		
2070					Net Zero	

# Hydrogen Strategies

- Each country has made progress in various areas such as the use of hydrogen in industrial fields, the introduction of hydrogen power generation, and the investigation of CO2-free hydrogen chain for the import of hydrogen.

Year	Japan 	Germany 	EU 	France 	China 
~2020	<ul style="list-style-type: none"> <li>Mar 2019: formulation of the hydrogen and fuel cell strategy roadmap</li> <li>Dec 2020: formulation of the green growth strategy with the carbon neutrality in 2050</li> </ul>	<ul style="list-style-type: none"> <li>Jun 2020: formulation of the national hydrogen strategy</li> </ul>	<ul style="list-style-type: none"> <li>Jul 2020: announcement of hydrogen strategy</li> </ul>	<ul style="list-style-type: none"> <li>Sep 2020: update of hydrogen strategy</li> </ul>	<ul style="list-style-type: none"> <li>Apr 2020: announcement of subsidies to the formulation of FCV industry supply chain</li> </ul>
2030	<ul style="list-style-type: none"> <li>Establishment of 3 million ton per year commercial-scale supply chain</li> <li>Hydrogen supply cost: 30 JPY/Nm<sup>3</sup></li> <li>Commercialization of hydrogen from renewal energy sources around 2032</li> <li>Commercialization of hydrogen power generation around 2030, target cost: 17 JPY/kWh</li> </ul>	<ul style="list-style-type: none"> <li>Hydrogen production capability target: 5 GW</li> <li>Green Hydrogen supply target: 14TWh</li> </ul>	<ul style="list-style-type: none"> <li>Electrolytic hydrogen production capacity target: 40 GW by 2030</li> <li>Green Hydrogen supply target: 10 mil t/year</li> </ul>	<ul style="list-style-type: none"> <li>Electrolysis equipment installation target: 6.5 GW by 2030, produce 0.6 million tons of green hydrogen per year</li> </ul>	
2040		<ul style="list-style-type: none"> <li>Increase to 10 GW</li> </ul>			
2050	<ul style="list-style-type: none"> <li>Hydrogen power generation cost target: 20 JPY/Nm<sup>3</sup> (*less than gas-fired)</li> </ul>				

## **2 . Kawasaki's Solutions for Carbon Neutrality**

# From Kawasaki “Group Vision 2030” (1/3)

- 3 Keywords to Achieve Group Vision



Frontier

## Pioneering the technology frontier with our challenger “DNA”

Since our founding, we have always identified ourselves as challengers. Throughout a history studded with the world’s first and Japan’s first achievements in many sectors, including shipbuilding, rolling stock, and aerospace, we have been leveraging our cutting-edge technologies and fostering a “DNA” characterized by the spirit of pioneering the frontier that draws on our unique perspective. Based on that unique prospective, we will continue to respond to the frontier of the new era’s social challenges to create a hopeful future.



**To Realize Hydrogen Society:**

## **Establishment of a CO2-free Hydrogen Chain**

# From Kawasaki “Group Vision 2030” (2/3)

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- 3 Keywords to Achieve Group Vision

**New Values**

## **Providing innovative solutions for the problems faced by the world**

Currently, the world is facing a variety of problems, including environmental deterioration, energy challenges, expanding populations, graying societies, natural disasters, and pandemics.

We are committed to providing new and high-add value solutions to a wide range of customers and communities, by focusing on the reliable technologies that we have been building and the knowledge that we have been assimilating in order to provide innovative solutions and rapidly accommodate social change.



**To Realize Hydrogen Society:**

**Development/Popularization of Hydrogen Gas Turbine & Gas Engine**

# From Kawasaki “Group Vision 2030” (3/3)

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- 3 Keywords to Achieve Group Vision



Cross Over

**Becoming a creative challenger that continues to grow by breaking barriers**

To provide innovative solutions focused on social challenges, we will continue to be an open-minded, free-thinking, and creative team that goes beyond the boundaries of internal and external organizations and of product/service categories, thereby leveraging our rich diversity. Moreover, we will continue to grow as an organization and as individuals by expanding our potential and boldly taking up challenges in unfamiliar domains and learning from the experience.



**To Realize Hydrogen Society:**

**Establishment of Global/Local Alliance**

Frontier

# Establishment of a CO<sub>2</sub>-free Hydrogen Chain

# Concept of CO2-free Hydrogen Chain

- Kawasaki will take on the challenge of creating a CO2-free hydrogen chain before the rest of the world does.

## Resource Country (Australia)

Produce low cost hydrogen from fossil fuels combined with CCS\* or abundant renewable energy

Low Cost Renewable Energy



Fossil Fuel

CCS



Liquefaction/ Loading

PRODUCE

CO2 Free Hydrogen



HySTRA

Liquefied Hydrogen Carrier



Liquefied Hydrogen Trailer



JAXA

TRANSPORT/  
STORE

CO2 Free Hydrogen

## Country of Use (Japan)

### Process Use

Semiconductor, Solar battery, Oil refining, Desulfurizing etc.



Transport Equipment

H2 station, Fuel cell vehicles, etc.



Distributed Power Plants

Hydrogen Gas Turbines / Gas Engines, Fuel cells, etc.



Electricity Plants

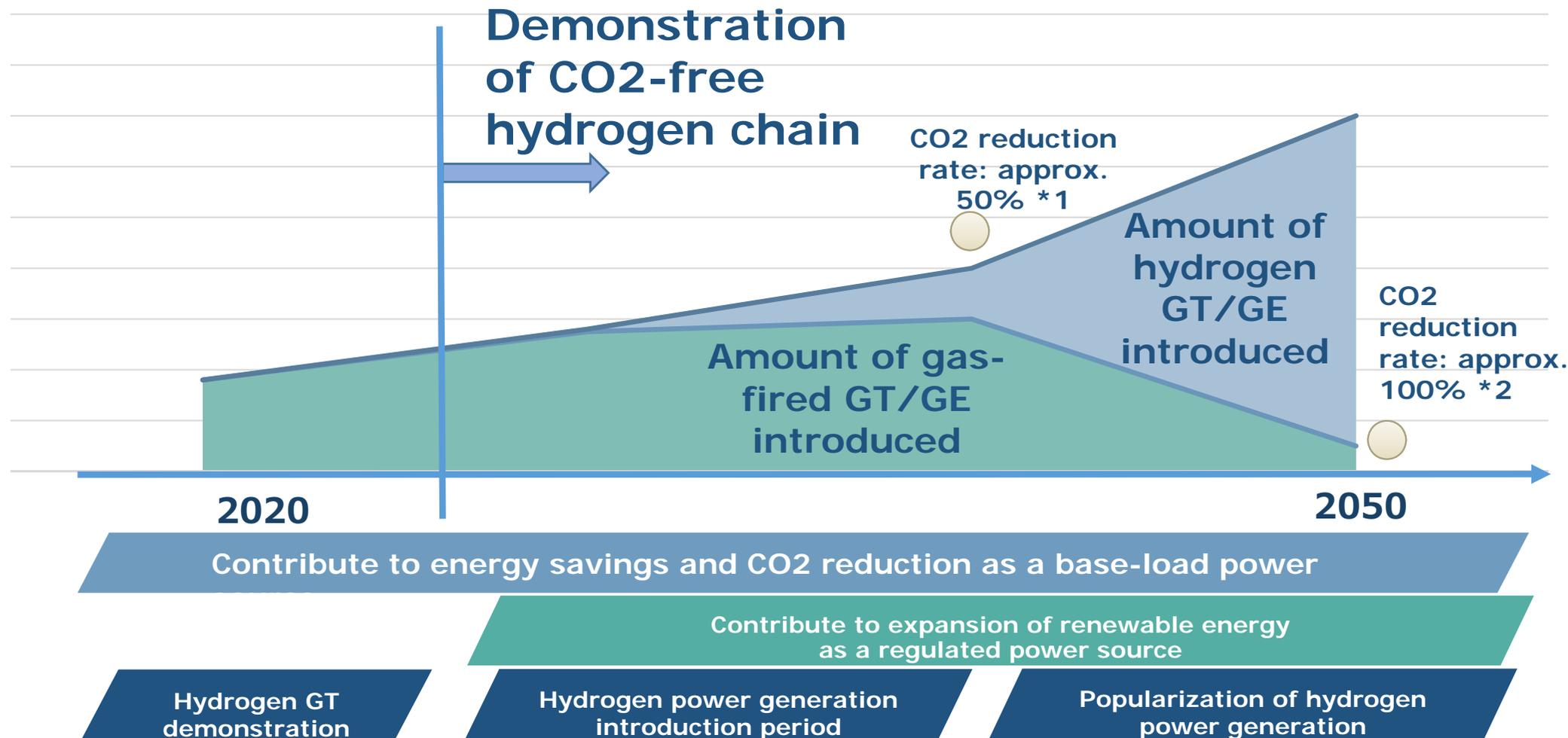
CCPP, etc.

USE

\*CCS: Carbon Dioxide Capture and Storage

# Image of CO2 Reduction Rate and Gas Turbine / Gas Engine Installation

- Contribution to CO2 reduction through fuel conversion from natural gas to hydrogen gas turbine / gas engine and introduction of hydrogen gas turbine.



\*1 Source: CO2 reduction rate of fuel conversion from heavy oil to city gas based on the calculation and report manual of greenhouse gas emissions (2012), enforcement regulations of the Law Concerning the Rational Use of Energy (2012), interim report of the meeting scenario subcommittee of the Global Environment Committee of the Central Environment Council (2001)

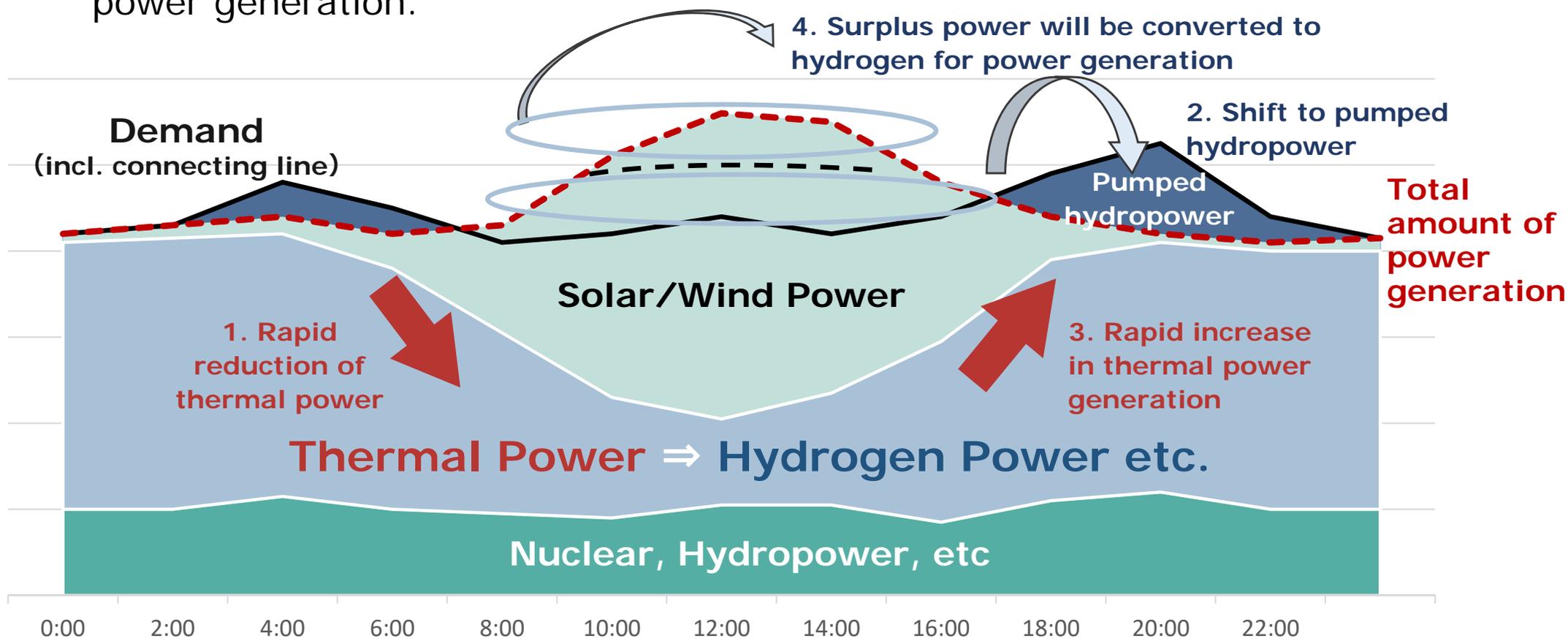
\*2 CO2 reduction rate in gas fired GT / GE with CCU/S and hydrogen power generation

**New Values**

# **Role of the Hydrogen Gas Turbine and Gas Engine**

# Role of Thermal Power Generation in the Era of Mass Introduction of Renewable Energy

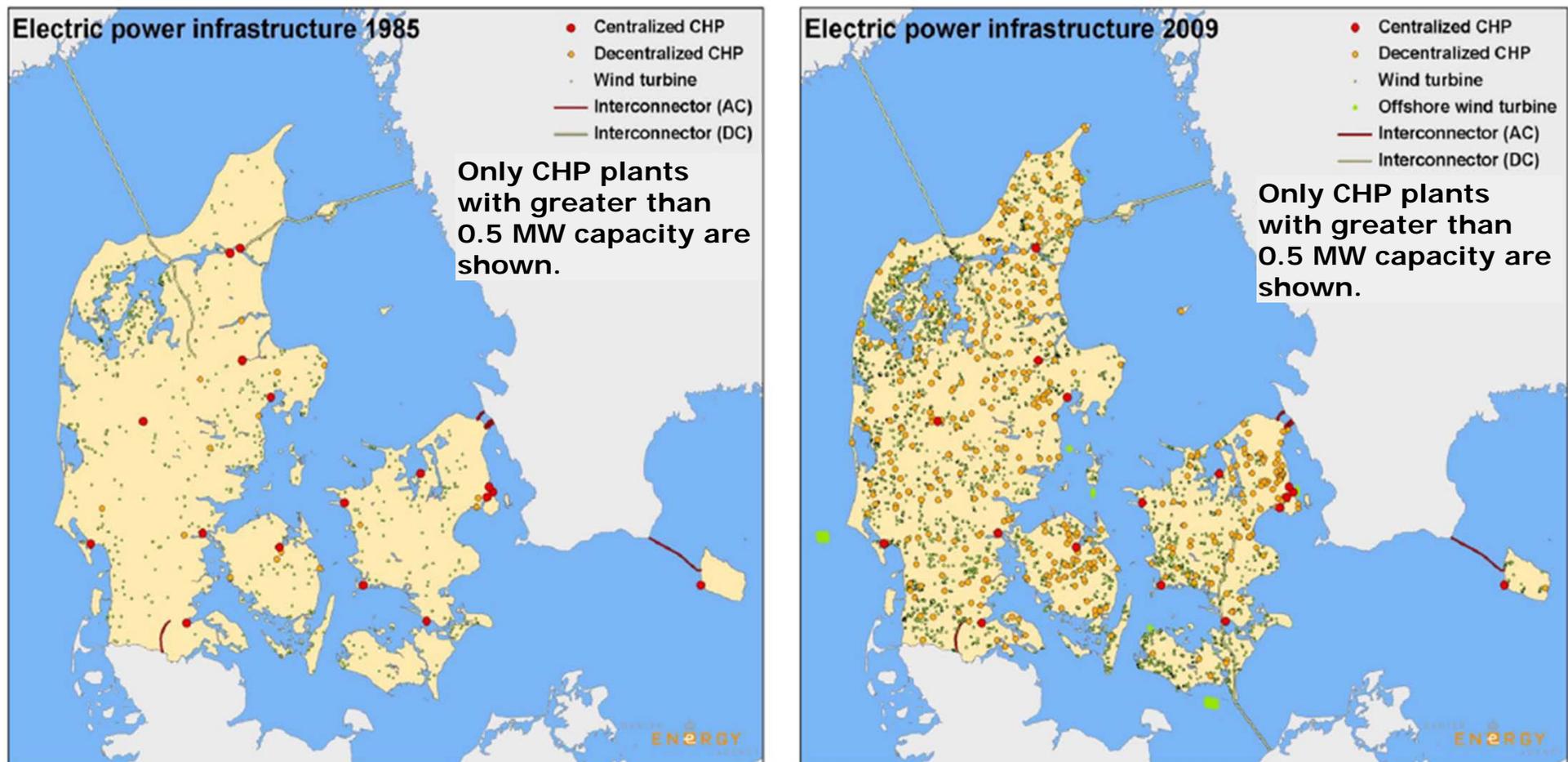
- Thermal power generation can contribute to the expanded introduction of variable renewable energy, such as solar and wind power, as they can adjust the balance between power supply and demand.
- Thermal power plants will be replaced by CO<sub>2</sub>-free hydrogen power plants, and surplus power from renewable energy sources will be converted to hydrogen for power generation.



# Example of Transition of Electric Power Infrastructure due to the Advancements in Renewable Energy: Denmark

- Denmark introduced a large amount of variable renewable energy\*, and distributed power generation is also widespread throughout the country.
- Cogeneration systems that can utilize waste heat and are excellent for energy savings are the mainstream of distributed power generation.

\*The share of renewable energy in total energy supply increased from approx. 7% in 1990 to approx. 22% in 2010



# Features of Kawasaki Gas Turbine: Product Lineup

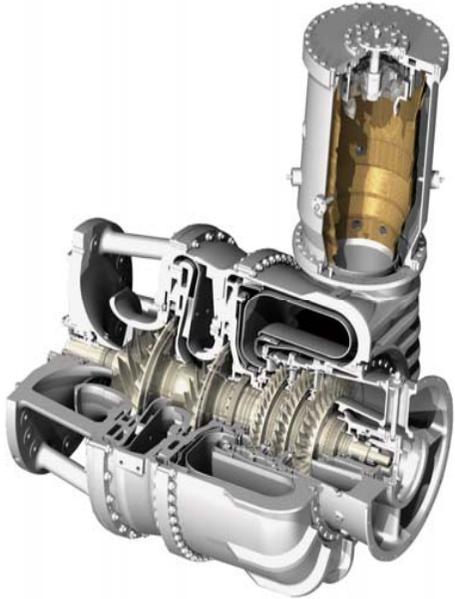
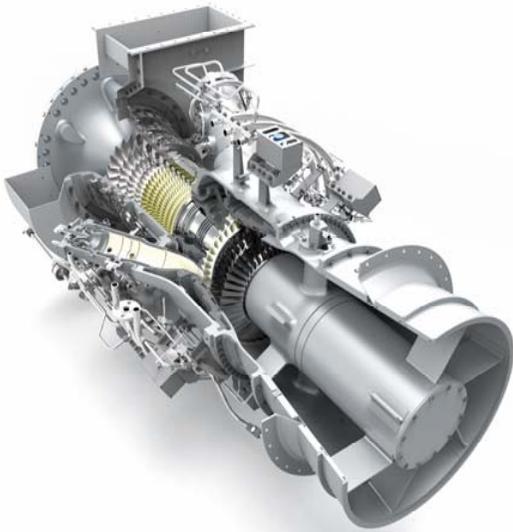
- Kawasaki Gas Turbine is suitable for distributed cogeneration.

DLE combustion capable of hydrogen co-firing and exclusive firing (under demonstration)

Hydrogen co-firing (to be commercialized)

Capable of hydrogen co-firing

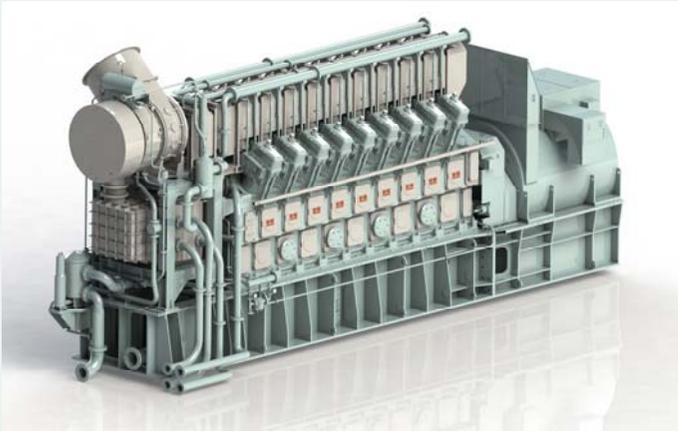
L30A hydrogen co-firing (to be commercialized)

G T series	M1	M5	M7	L	
GT model	M1A-17	M5A	M7A-03	L20A	L30A
output	1.7 MW	5 MW	8 MW	18 MW	30 MW
package	PUC17D	PUC50D	PUC80D	PUC180D	PUC300D
structural diagram of each models					

# Features of Kawasaki Green Gas Engine: Product Lineup

- Kawasaki Green Gas Engine achieves world's highest level of performance

## Hydrogen Co-firing is Planned for All Models

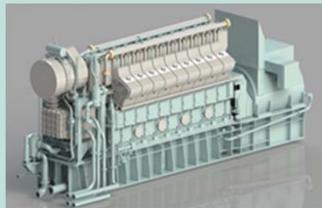
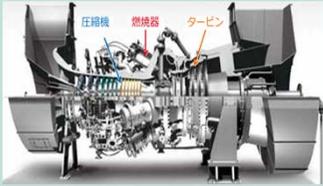
GE Model	KG-12	KG-18	KG-18-V	KG-18-T
output*	5.2 MW	7.8 MW		
efficiency	49.0 %		49.5 %	51.0 %
supercharging method	Bypass Valve		High-Efficient Supercharging	Two Stage Supercharging
外観	-			

\*50Hz, 750rpm

# Advantages of Hydrogen Gas Turbines / Gas Engines

- Hydrogen gas turbines / gas engines have multiple environmental and economic benefits. Transition to hydrogen combustion is possible by remodeling the combustor.

## Reduction of investment costs



Hydrogen combustion can be achieved by :

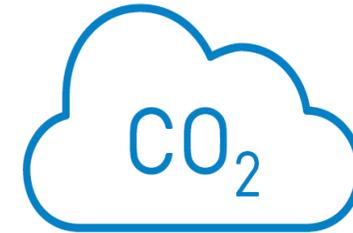
- replacing the combustor of the existing natural gas turbine; and
- replacing control devices of the existing gas engine; and
- adding safety covers (for GE)

## Mixed combustion



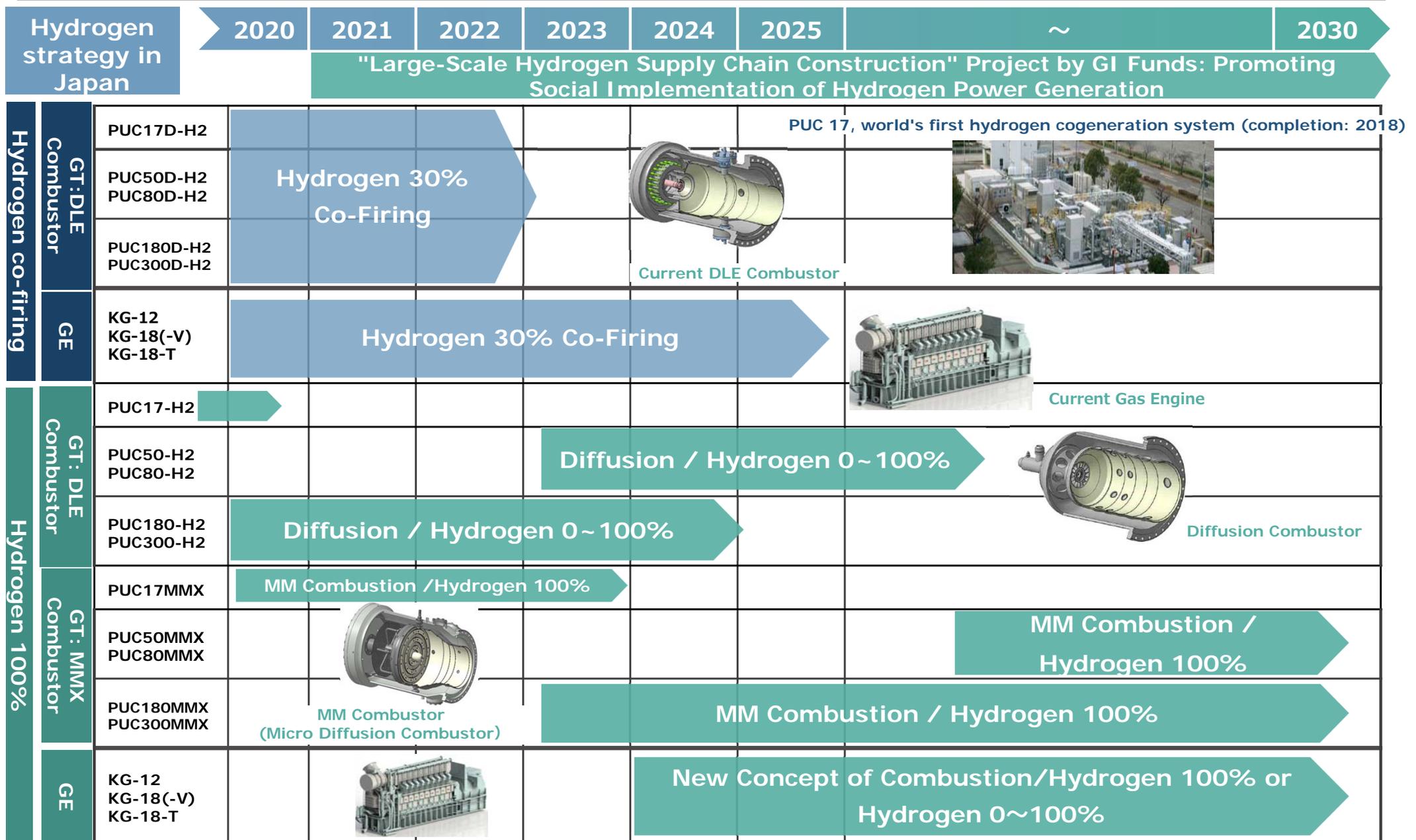
Mixed combustion of city gas and hydrogen achieves fuel flexibility and stable operation. Flexible transition from low-carbon to decarbonized society.

## Reduction of CO<sub>2</sub> emission



By using hydrogen as fuel, CO<sub>2</sub> emissions from gas turbines can be reduced through high energy efficiency.

# Road Map of Hydrogen Gas Turbine / Gas Engine Development

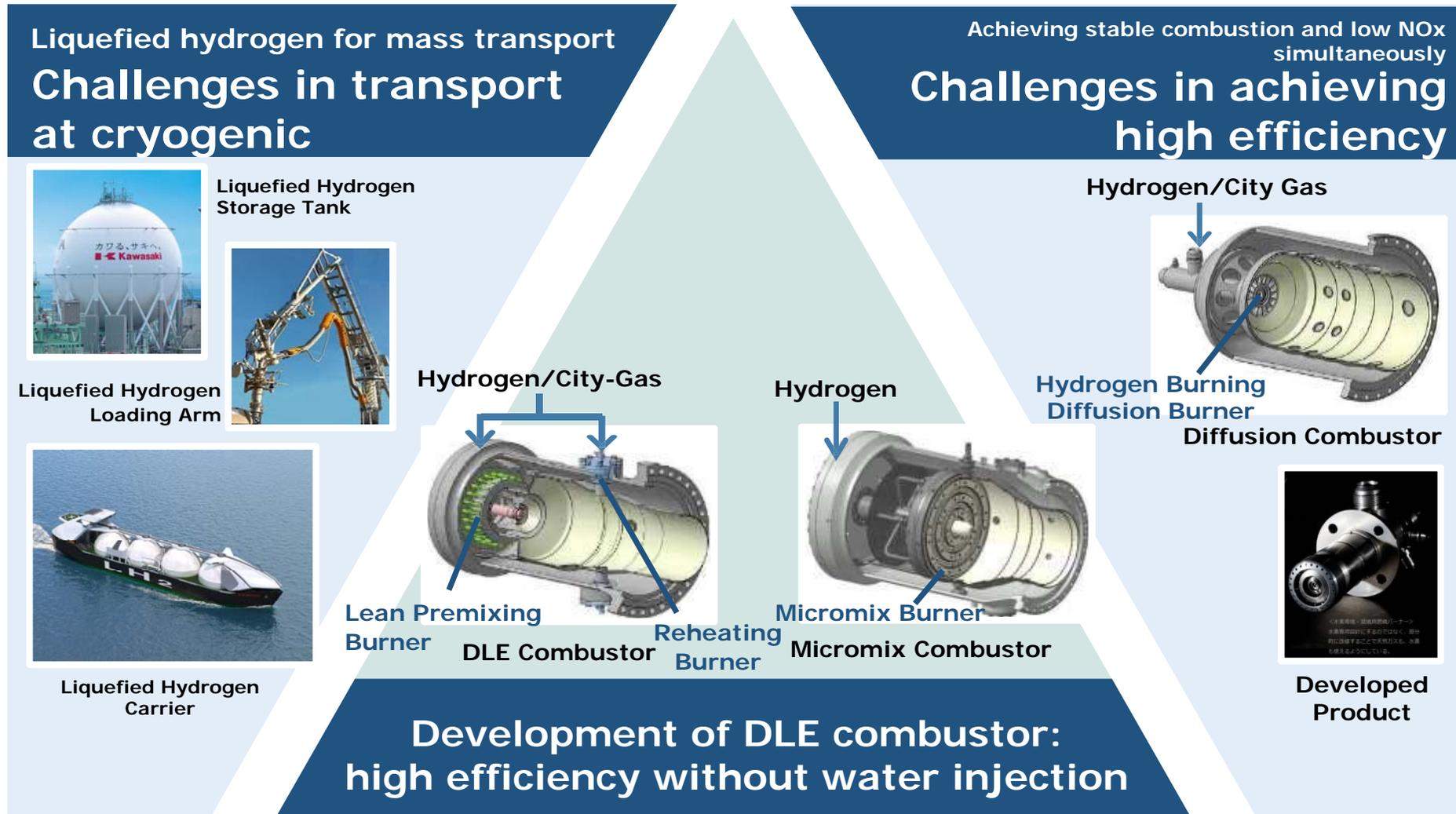


Cross Over

# Global & Local Alliance

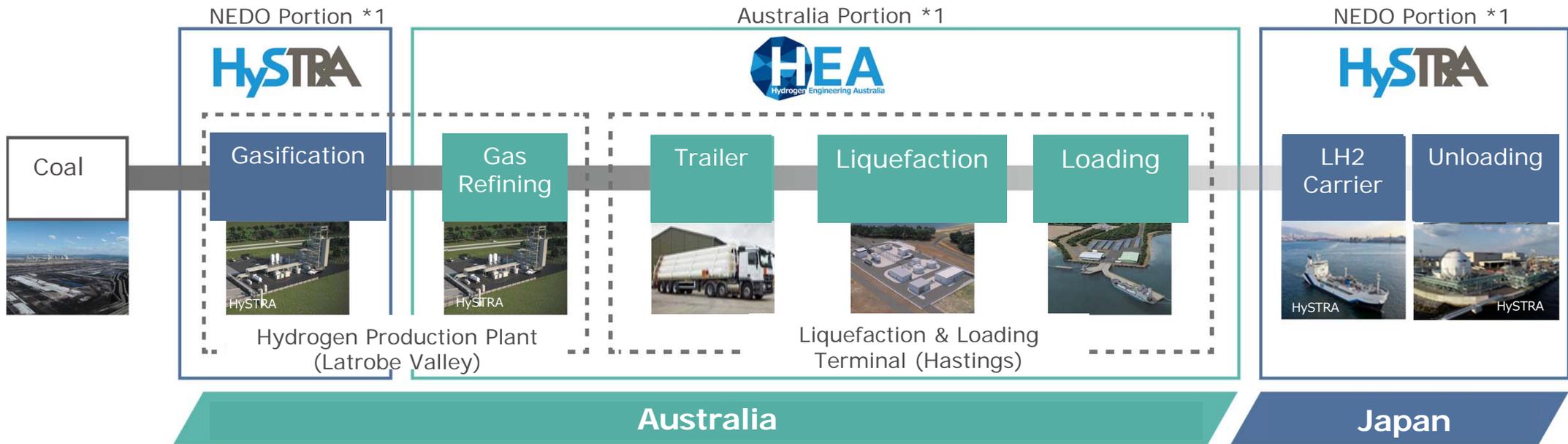
# Technology Development Issues (Examples)

- Challenging issues of hydrogen mass transport and hydrogen gas turbines in the construction of a CO2-free hydrogen chain



# Japan-Australia Hydrogen Supply Chain Pilot Demonstration

- Government agencies and private companies in Japan and Australia began cooperating in 2015 to demonstrate hydrogen supply chain. Kawasaki has completed construction of a hydrogen liquefaction/loading plant in Australia, the LH2 carrier, and a hydrogen unloading plant in Kobe, Japan. Demonstration will continue until 2022.



**【 Government of Australia 】**  
 Australian Federal Government  
 Victorian State Government  
**【Hydrogen Engineering Australia (HEA)】**  
 Kawasaki Sumitomo Corp. Iwatani J-POWER  
 Marubeni AGL J-POWER Group

**【 Government of Japan 】**  
 Ministry of Economy, Trade and Industry NEDO  
**【CO2-free Hydrogen Energy Supply-chain Technology Research Association (HySTRA)】**  
 Kawasaki Iwatani J-POWER Shell  
 Marubeni ENEOS "K"LINE

\*1 From 2015 to FY 2022 NEDO Grant Program for Technological Development for Industry with Issues "Demonstration Project for Construction of Large-scale Marine Transport of Hydrogen Derived from Unused Brown Coal and Supply Chain"

# Evaluation and Study of Next Generation Hydrogen Combustor (DLE Combustor, Hydrogen 100%)

- Developed next-generation combustor by collaborating with Aachen University of Technology
- NOx level of 40 ppm\* achieved under actual gas turbine operating conditions and under 50% to 100% rated load operating conditions
- Combustor was held for 2 hours under the condition corresponding to the rating of 100%; no fire damage to the combustor after the test
- The operation was carried out in the hydrogen gas turbine cogeneration demonstration facility in Port Island, Kobe, in fiscal 2020.



Hydrogen 100% DLE Combustor test in Aachen University of Technology)



Hydrogen Combustion



Combustor interior after 2h test

\*Residual oxygen 16% equivalent

Results of this research were obtained through below:

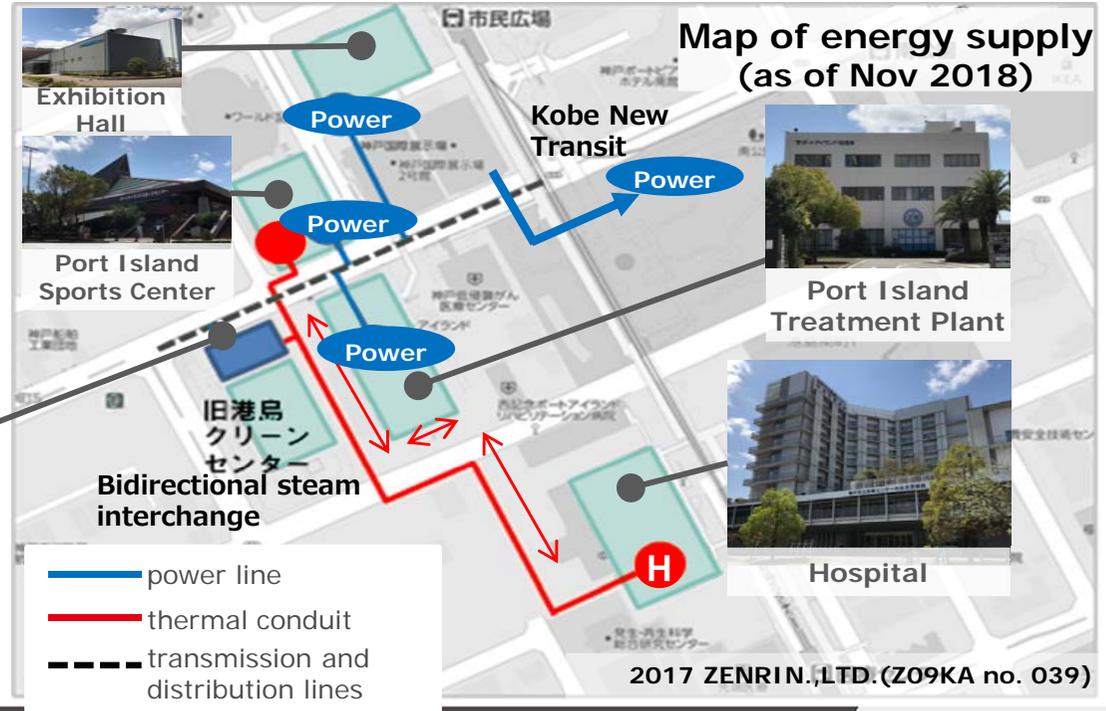
- FY 2014 – 15: SIP (Strategic Innovation Creation Program) "Energy Career" (Managed by JST)
- Fiscal 2016 – 18: NEDO's Hydrogen R & D Initiative Business and Large-scale Hydrogen R & D "Research and development of hydrogen gas turbine combustion

# World's First 100% Hydrogen Regional Combined Heat and Power Supply (Port Island, Kobe)

- Technology development and demonstration of a system to use "Power", "Hydrogen" and "Heat" efficiently at the regional level were carried out using a 1 MW class gas turbine power generation facility fueled by hydrogen and natural gas.
- FY 2017 & 2018: Demonstration tests of hydrogen gas turbine equipped with diffusion combustors that can handle 100% natural gas / 100% hydrogen / mixture of natural gas and hydrogen (0 ~ 100%). NOx amount conformed to meet the air pollution control law regulation value of 70 ppm or less (16% O2 equivalent).
- FY 2019 & 2020: Development and demonstration of hydrogen gas turbine using DLE combustor, that can enable 100% hydrogen. NOx amount was 70 ppm or less (16% O2 equivalent), which is the same as that of a diffusion combustor.
- Business Structure: Kawasaki Heavy Industries, Obayashi Corporation, Kobe city, Kansai Electric Power, Iwatani Corporation, Kenes, Osaka University, Kansai University

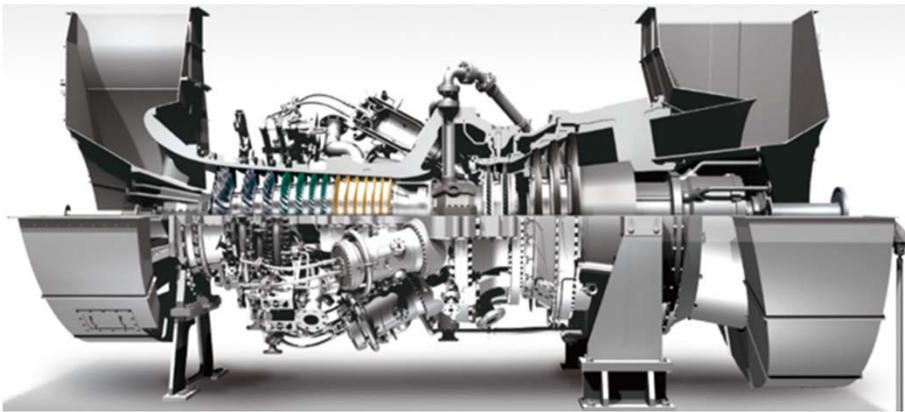


**Hydrogen Gas Turbine Energy Center**



# Hydrogen-to-Power Demonstration in Europe

- Kawasaki started discussion with RWE, a major German electric power company, to commence demonstration operation of 100% Hydrogen-to-Power generation.



**30MW Class Gas Turbine**



**Planned Site: Lingen, Lower Saxony  
(Germany)**

# Toward the Realization of a Hydrogen Society

- With a target for commercial launch in 2030, technology development, commercialization system construction, and social environment improvement has begun in an integrated manner.

## Technical Development

Establish technology to increase the size of liquid water carriers by the end of FY 2022  
Commercialization of gas turbine power generation facilities by mid-2020s

**Hydrogen Society  
Commercialization  
will start in 2030  
after demonstration  
in mid-2020s**

## Establishment of Business Model

Formation of consortium  
Building trust with our partners

## Improvement of Social Environment

Supporting institutional design for hydrogen society in cooperation with government agencies (from commercialization demonstration to self-reliance)

Kawasaki, working as one for the good of the planet

**“Global kawasaki”**