

2016 CSLF Technology Workshop

# CO2-Free Hydrogen Supply Chain

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Kawasaki Heavy Industries, Ltd.



# Why Hydrogen ?

Hydrogen :

- Does not emit CO2 or any hazardous materials
- Used as rocket fuel (High energy density)
- Produced from various resources (Sustainable)

Clean

Powerful

# Contents

- 1. Circumstances Surrounding Energy**
- 2. The Concept of Hydrogen Supply Chains**
- 3. Hydrogen Infrastructure Technology**

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# Hydrogen Use as a National Growth Strategy

- Cabinet decision of April 2014 for “Strategic Energy Plan”:  
**Hydrogen use is described in detail for the first time**
- The Ministry of Economy, Trade and Industry has formulated a **hydrogen and fuel cell strategic road map**, and specified “**hydrogen production from the as-yet unused resource**” and “**hydrogen power generation**”

# Strategic Road Map for Hydrogen/Fuel Cell

## Phase 1

FCV (Fuel Cell Vehicle)  
Hydrogen Infrastructure

### 2017

- Industrial FC : On market

### Around 2020

- Hydrogen cost: Competitive as HV
- FCV: abt. 40,000, ST: abt. 160 place

### Around 2025

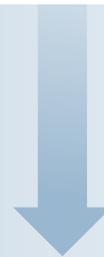
- FCV cost: Competitive as HV
- FCV: abt. 200,000 ST: abt. 320 place

### Around 2030

- FCV: abt. 800,000

## Phase 2

Hydrogen power generation  
Large scale introduction of hydrogen



### Later in 2020s

- Hydrogen CIF cost introduced from overseas: 30Yen/Nm<sup>3</sup>

### Around 2030

- Large-scale introduction of unused energy source hydrogen from overseas
- Large-scale hydrogen power generation

## Phase 3

Introduction of CO<sub>2</sub>-free hydrogen

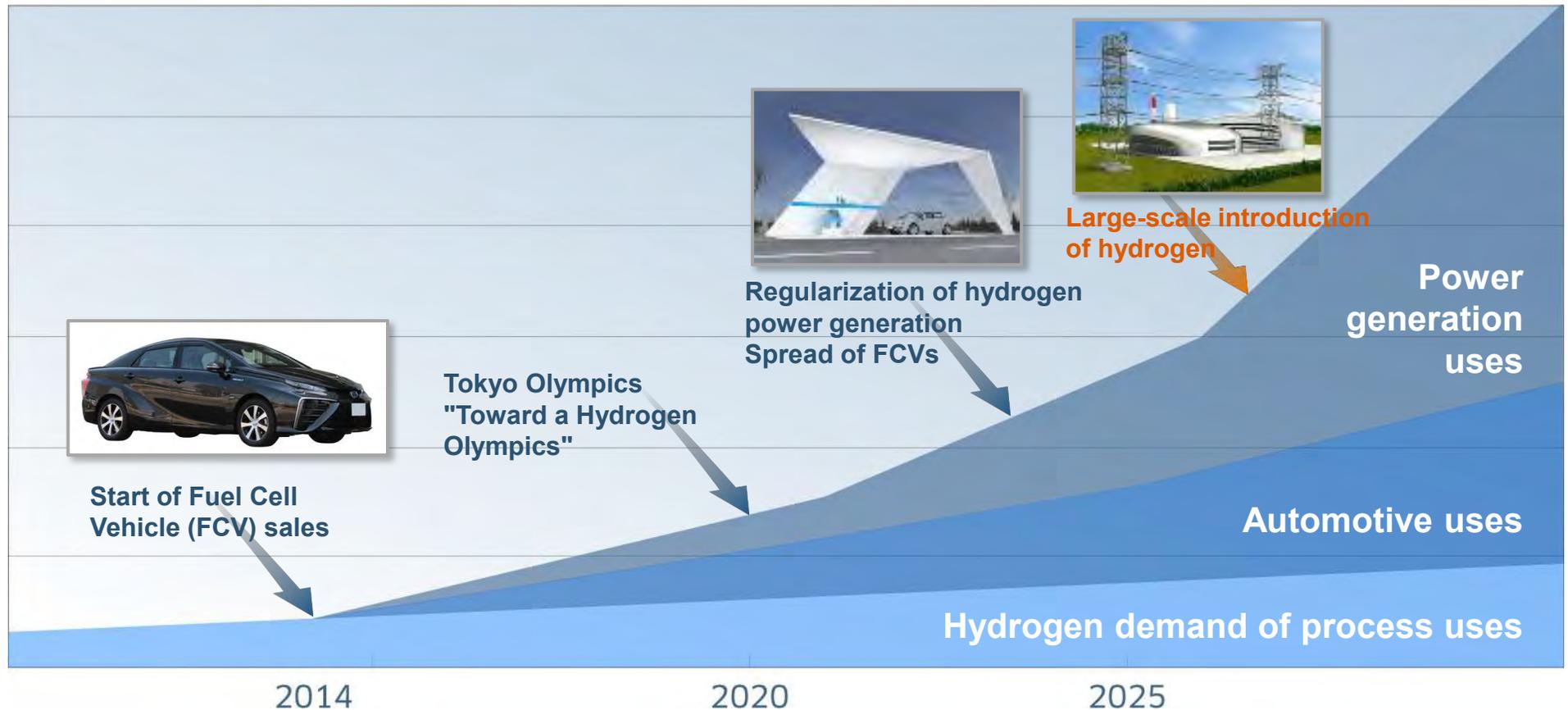


### Around 2040

- Large-scale supply of CO<sub>2</sub>-free hydrogen (using CCS, domestic RE etc.)

# Expansion of Hydrogen Demand "From FCVs to the Power generation"

Demand progresses in the order of  
"Processing" ⇒ "FCV" ⇒ "Power generation"

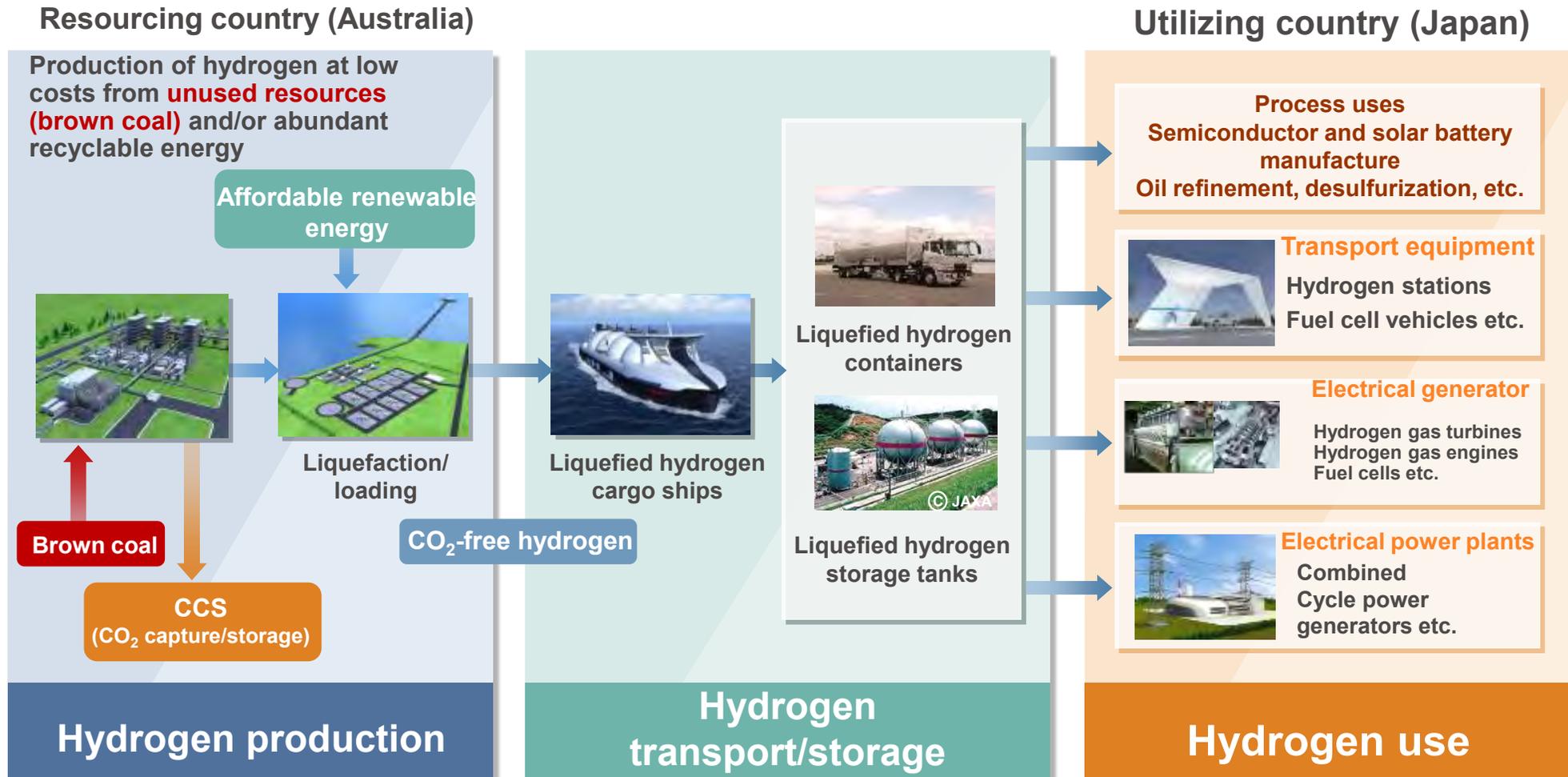


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# The Concept of CO<sub>2</sub>-free Hydrogen Chains

Stably supplying energy while suppressing CO<sub>2</sub> emissions



# Liquefied Hydrogen

## ~ Large-scale Transport Methods for Hydrogen ~

### Characteristics of liquefied hydrogen

- Extremely low temperature (-253 degrees C)
- **1/800** the volume of hydrogen gas
- Transport medium of **proven practical use** in industry and as rocket fuel
- High purity = **no need for refinement** (can be supplied to fuel cells by evaporation alone)



Largest liquefied hydrogen tanks in Japan  
(Tanegashima Rocket Base)



LNG ship  
(large-scale energy transport)

# What is brown coal?

- It is young coal, plentiful, and occurs widely around the world
- Water content is high at 50-60%
- Since it naturally ignites easily when dried, it is not suitable for transport, and it can only be used for on-site power generation



- Because it **cannot be transported**, overseas transaction is impossible and **"unused resource" = "reasonable" and "easy rights acquisition"** only for mining rights
- Among the many hydrogen production methods, **hydrogen production from brown coal is one of the most economical methods**

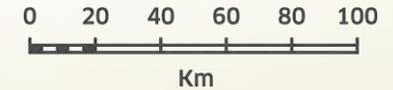
# Australian brown coal



**There is a brown coal layer to the horizon**  
**One layer is up to 250 meters below the surface**  
**There are also layers further down (Here, there is brown coal equivalent to Japanese total energy generation for 240 years)**

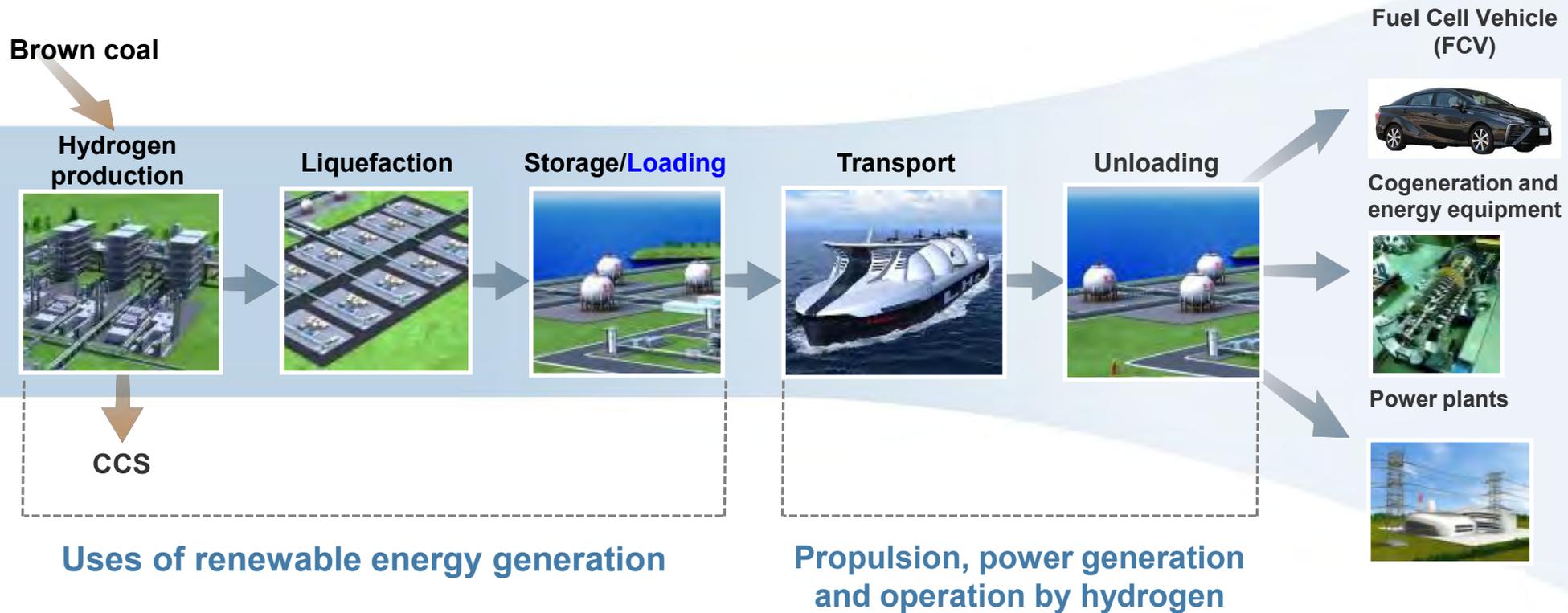
# CCS/CO<sub>2</sub> Storage Sites

(CCS: CO<sub>2</sub> Capture and Storage)



The Commonwealth and Victorian governments are promoting the "CarbonNet" CCS Project

# CO<sub>2</sub>-free Hydrogen Commercial Chain Feasibility Study

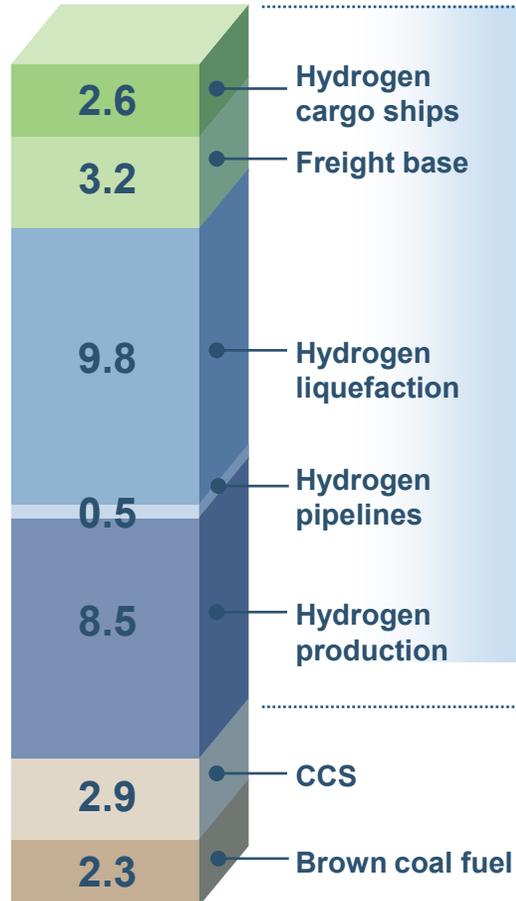


- **Hydrogen source: Australian brown coal**
- **Byproduct CO<sub>2</sub> processing: On-site storage ⇒ CO<sub>2</sub> free**
- **Amount of hydrogen production (use): 770 t/day,  
Equivalent to fuel for 3 million FCVs or  
1 GW of thermal power generation**

# Commercial Chain FS Results

## Hydrogen cost (CIF)

29.8 yen/Nm<sup>3</sup>



Japanese technologies and products

## [Scale]

3 million FCVs



FCV

or

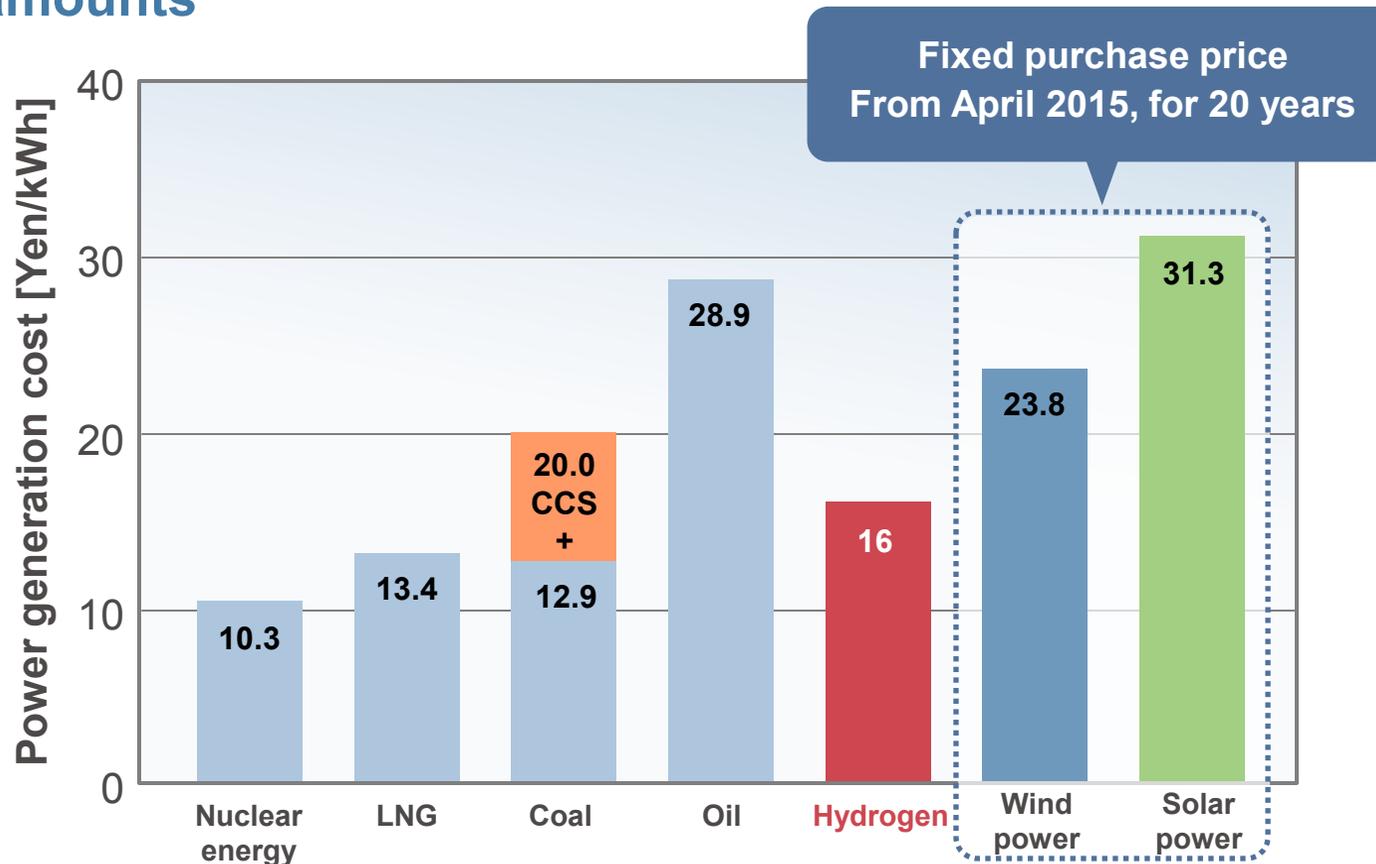
Equivalent to one 1 GW hydrogen power plant



Hydrogen power plant

# Power Generation Cost Comparison

Although more expensive than fossil fuel generation, among CO<sub>2</sub>-free energies, it is **cheaper and more stable** than renewable energy and usable in large amounts

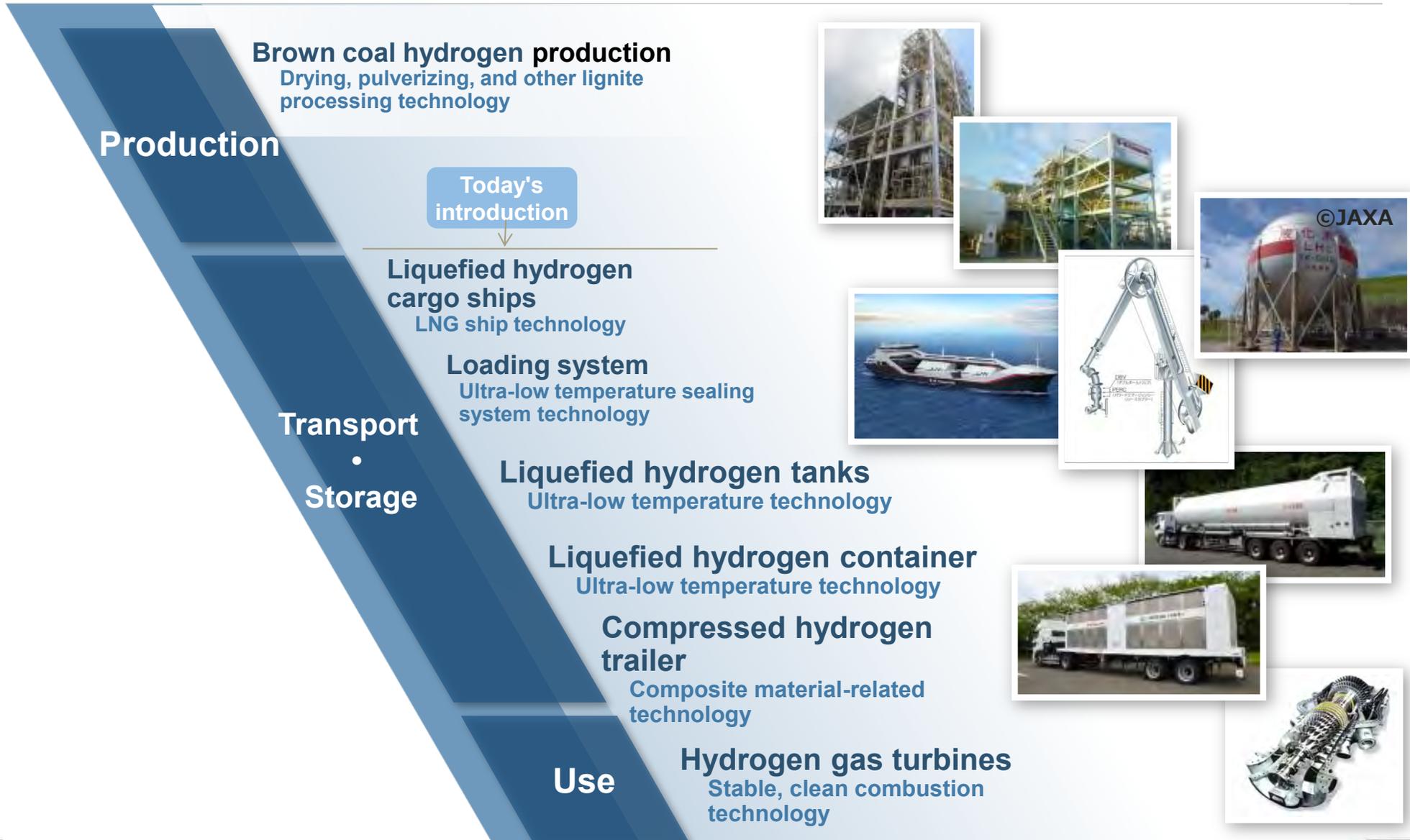


Reference: "Power Generation Cost Work Group Verification Report 2030 Model Plant, May 2015"

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# Hydrogen Infrastructure Technology Development



# Liquefied Hydrogen Storage

Hydrogen  
production

Transport/Storage

Hydrogen use

## Liquefied hydrogen storage tanks



### Liquefied hydrogen storage tank specifications

Models	Spherical double-hull tank
Storage capacity	540 m <sup>3</sup>
Design pressure	0.686 MPa + Vacuum
Design temperature	-253°C
Thermal insulation method	Vacuum perlite thermal insulation



# Land Transport of Liquefied Hydrogen

Hydrogen production

Transport/Storage

Hydrogen use

## Liquefied hydrogen transport container



### Liquid hydrogen transport container specifications

Models	ISO 40 ft container
Internal volume	45.6 m <sup>3</sup>
Unladen weight	22.3 ton
Hydrogen load capacity	2.8 ton
Thermal insulation method	Vacuum lamination thermal insulation
Accessories	Pressure evaporator



# Overland Transport of High Pressure Hydrogen

Hydrogen production

Transport/Storage

Hydrogen use

Compressed hydrogen transport trailer with high-pressure composite container (first in Japan)

Transports enough hydrogen for 52 FCVs



2012 NEDO collaborative research project  
Cooperation:  
The Research Association of Hydrogen Supply/Utilization Technology (HySUT)  
JX Nippon Oil & Energy

Compressed hydrogen transport trailer specifications	
Total length*	10,260 mm
Total width	2,500 mm
Total height	3,500 mm
Weight*	19,310 kg
Number of containers loaded	24
Hydrogen load capacity	260 kg

45 MPa class composite container specifications	
Total length	3,025 mm
Diameter	436 mm
Weight	220 kg
Pressure	45 MPa
Internal volume	300 L
Container type	Type 3

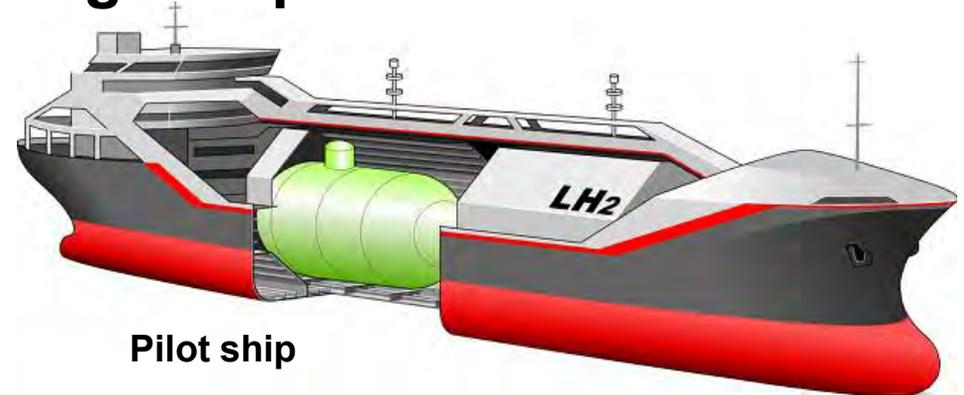
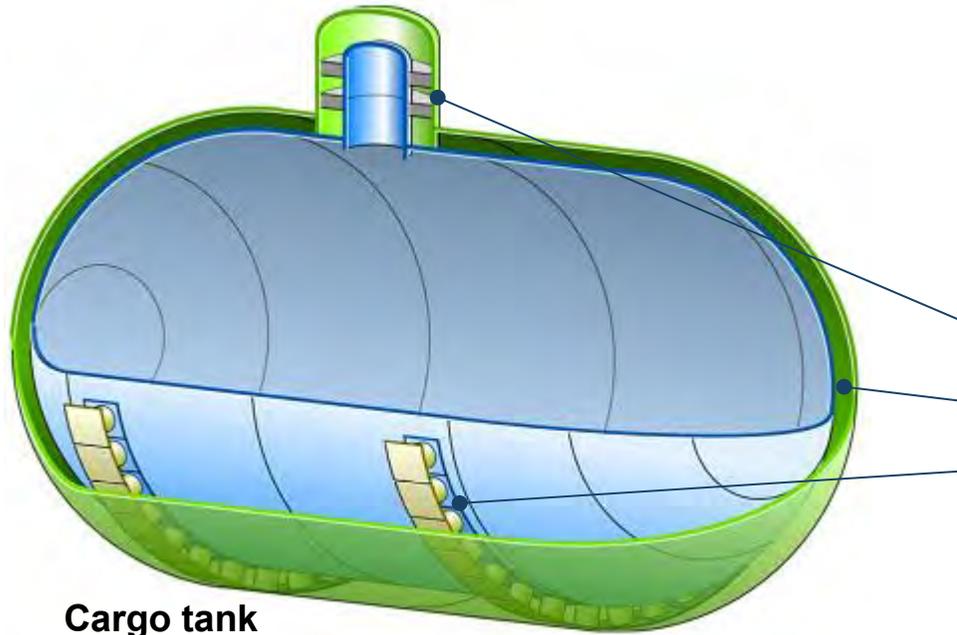
\*Minus tractor



# Liquefied Hydrogen Cargo Ships



## World's first liquefied hydrogen cargo ship: toward realization



- Special dome structure for maintaining vacuum
- Stainless steel vacuum thermal insulation double hull
- High thermal insulation supporting structure

**December 2013**  
Basic certification obtained from Nippon Kaiji Kyokai

→ **September 2016**  
Interim recommendations on safety requirements were approved at IMO CCC3 held in London

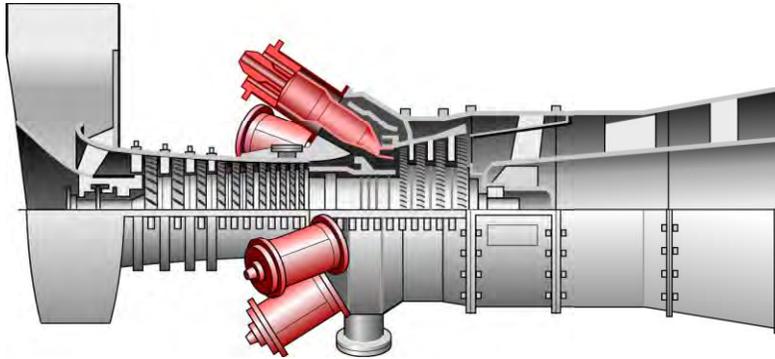
\*IGC code: International regulations relating to the structure and equipment of vessels for transporting bulk shipments of liquefied gas  
IMO: International Maritime Organization CCS3: the 3<sup>rd</sup> Carriage of Cargoes and Containers

Hydrogen production

Transport/Storage

Hydrogen use

## Development of hydrogen gas turbines

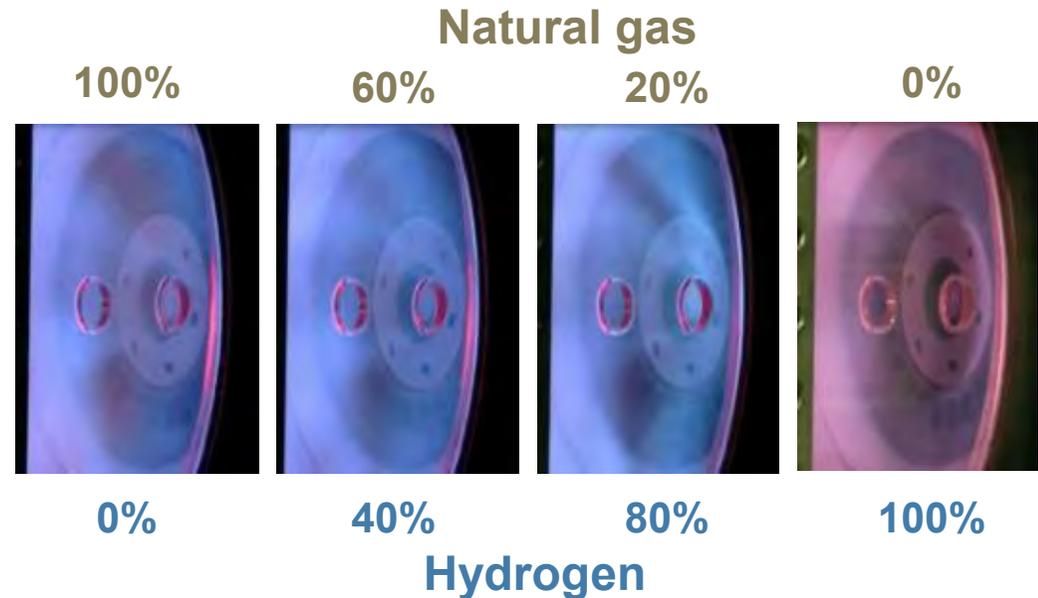


Combustion chamber is key hardware

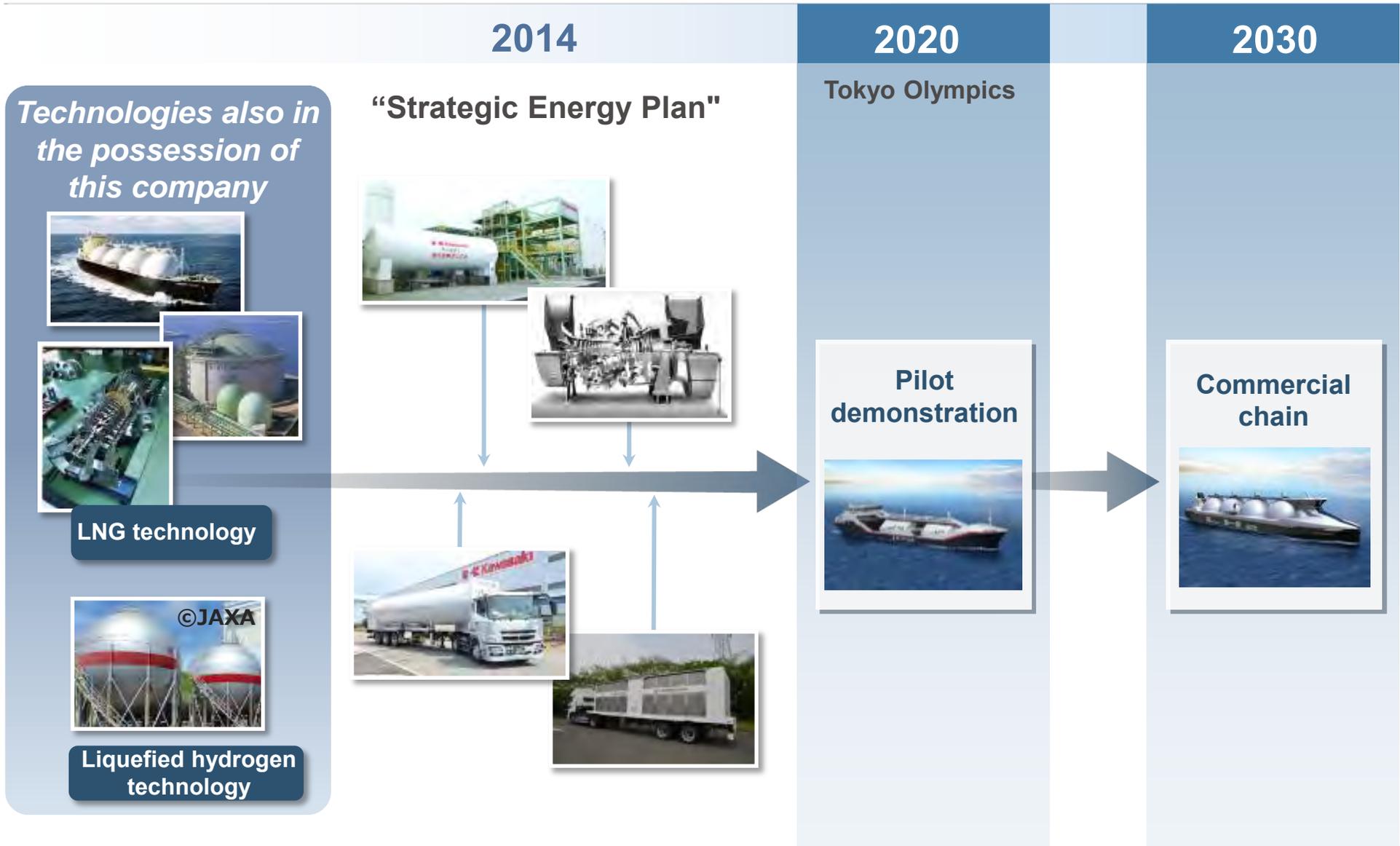


Hydrogen burner

- Independently developed hydrogen burner that suppresses NO<sub>x</sub> creation and realizes stable combustion
- Freely switchable between natural gas and hydrogen density



# Development of Hydrogen Project



# Pilot Demonstration

- **Brown coal gasification technology**
- **On-shore base for liquefied hydrogen technology for loading/unloading between ships**
- **Marine transport technology for large volumes of liquefied hydrogen**
- **Technology demonstration of feasibility in fiscal 2020 when the Tokyo Olympics is held**



# Selection of NEDO Projects

- Select NEDO's promotion services relating to hydrogen supply chain and hydrogen cogeneration demonstration
- Hydrogen supply chain: Kawasaki Heavy Industries, Ltd. (organizer), Iwatani Corporation, J-Power
- Implement press conference hosted by NEDO



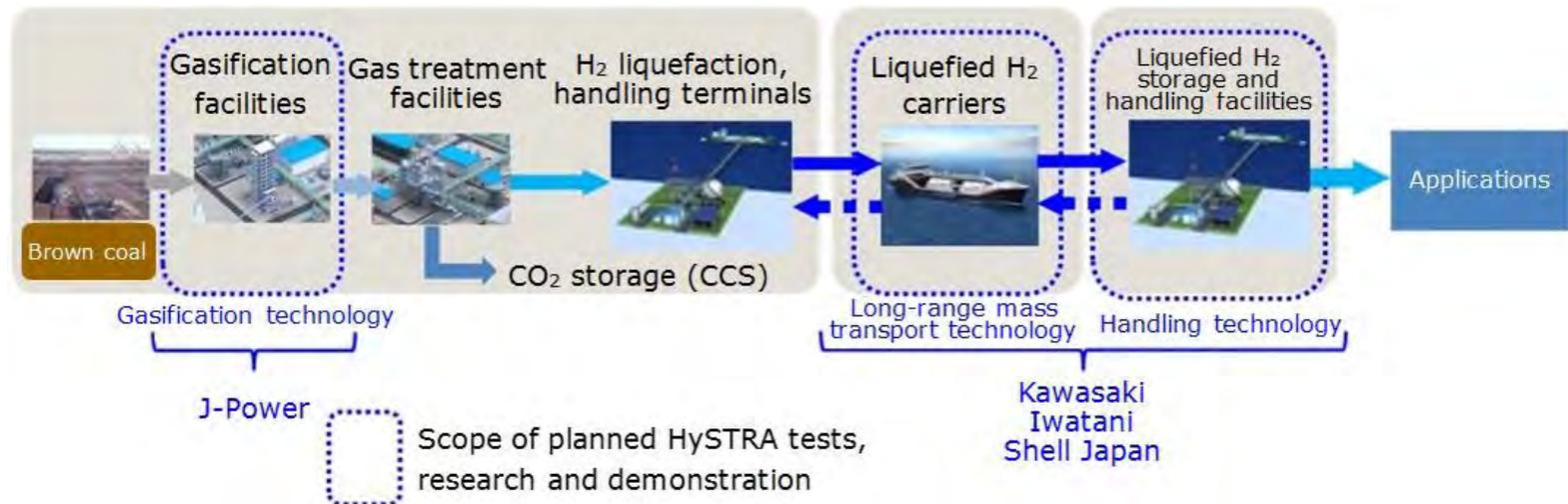
# Established Technical Research Association

**Name of TRA: CO<sub>2</sub>-free Hydrogen Energy Supply-chain  
Technical Research Association  
(Abbreviation: HySTRA)**

**Established date: February in 2016**

**Member: KHI, Iwatani Corporation, Shell Japan, J-Power**

**President: Eiichi Harada(Executive Officer, KHI)**



# The Significance and Utility of CO<sub>2</sub>-free Hydrogen Chains

## 1 Stability of supply

- **Brown coal: World-wide distribution, enormous reserves**  
Currently has no price, acquisition of independent rights is easy  
→ **Contribution to energy security (240 years worth in Australia alone)**

## 2 Environmental

- **No CO<sub>2</sub> emissions during use (only water is emitted)**  
→ **"Ultimate clean energy"**

## 3 Improvement of industrial competitiveness

- **Energy security for Japanese technology and products** → **Suppression of national resource outflow**
- **Related industries will grow due to spread of hydrogen** → **Contribution to growth strategies  
Development toward infrastructure export**

**Thank you for listening**  
**Kawasaki, working as one for the**  
**good of the planet**  
**“Global Kawasaki”**

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