

**The KISR–JCCP Joint Conference on Renewable Energy
Petroleum Research Center (Lecture Hall, New Building)
February 3, Wednesday, 2016**

KHI Activity for Hydrogen Supply Chain

**Kawasaki Heavy Industries, Ltd.
Hydrogen Project Development Center
Corporate Technology Division**

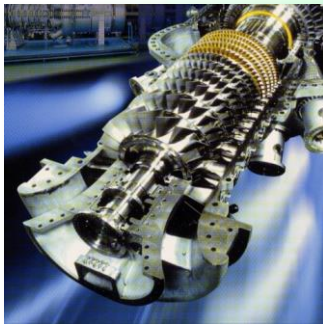
KHI products



Aerospace(Boeing 787)



Motorcycles



Gas turbine power generation

Transportation Energy • Environment



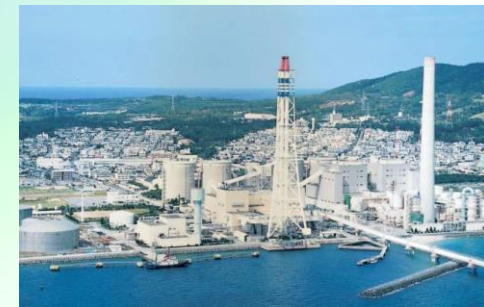
Refuse incineration



Rolling stock
(Shinkansen)



Ships(LNG carrier)



Energy plant
(Coal-fired power generation plant)

- 1. Movement to hydrogen utilization**
- 2. Concepts of hydrogen supply chain**
- 3. Technologies for hydrogen infrastructure**
- 4. Progress of the project**

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Japanese government energy policy

In April 2014, the Japanese government released the “Japanese Basic Energy Plan”. Hydrogen is expected to become one of important future secondary energy sources besides electricity and heat.

Extraction from Japanese Basic Energy Plan

- (1) Spread and expansion of the introduction of Stationary Fuel Cells (Ene-Farm etc.)
- (2) Creating an environment for acceleration of introduction of fuel-cell vehicles
- (3) Realizing new technologies such as hydrogen power generation for full-scale usage of hydrogen
- (4) Promoting development of production and storage/transportation technology for stable supply of hydrogen
- (5) Formulating a road map toward the realization of a “hydrogen society”

Hydrogen/FC Strategic Roadmap

Installation fuel cell Phase 1

2009

Release Micro-CHP FC

2014

Release FCV

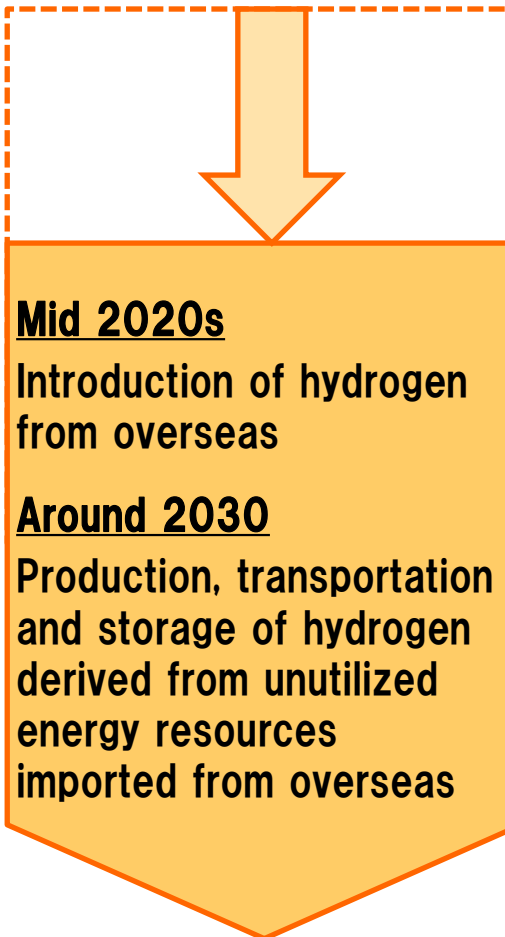
2020

Achieving a reduction of hydrogen price to a level equal to or lower than that of fuels for hybrid vehicles

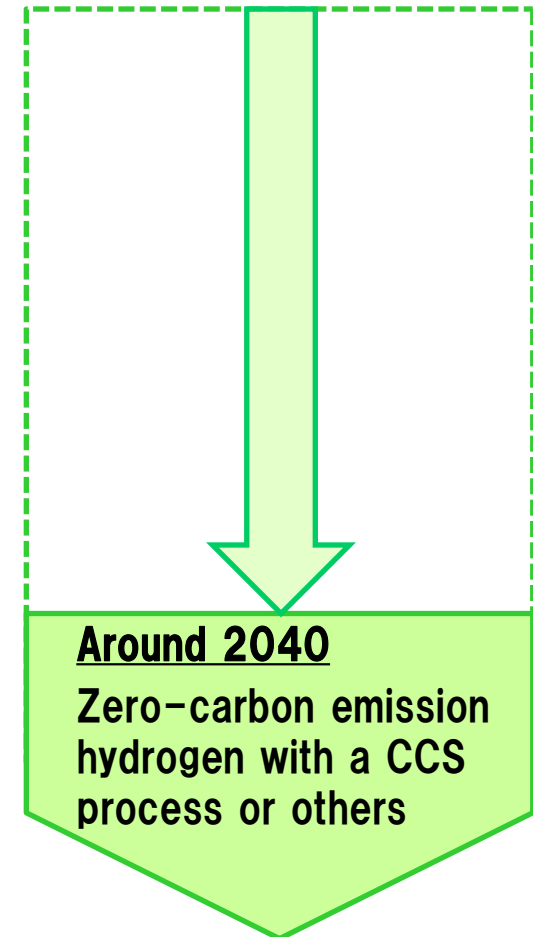
2025

Achieving a reduction of FCV prices to the level of hybrid vehicles

Hydrogen power generation / Mass hydrogen supply chain Phase 2

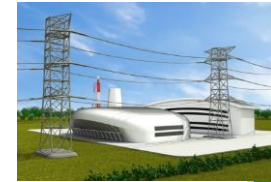


Zero-carbon emission hydrogen (CO2 free hydrogen) supply system Phase 3



Demand growth “FCV to Olympic/Paralympics”

“Process gas” ⇒ “FCV” ⇒ “Power generation”



Vast demand for hydrogen



Diffusion of power generation and FCV

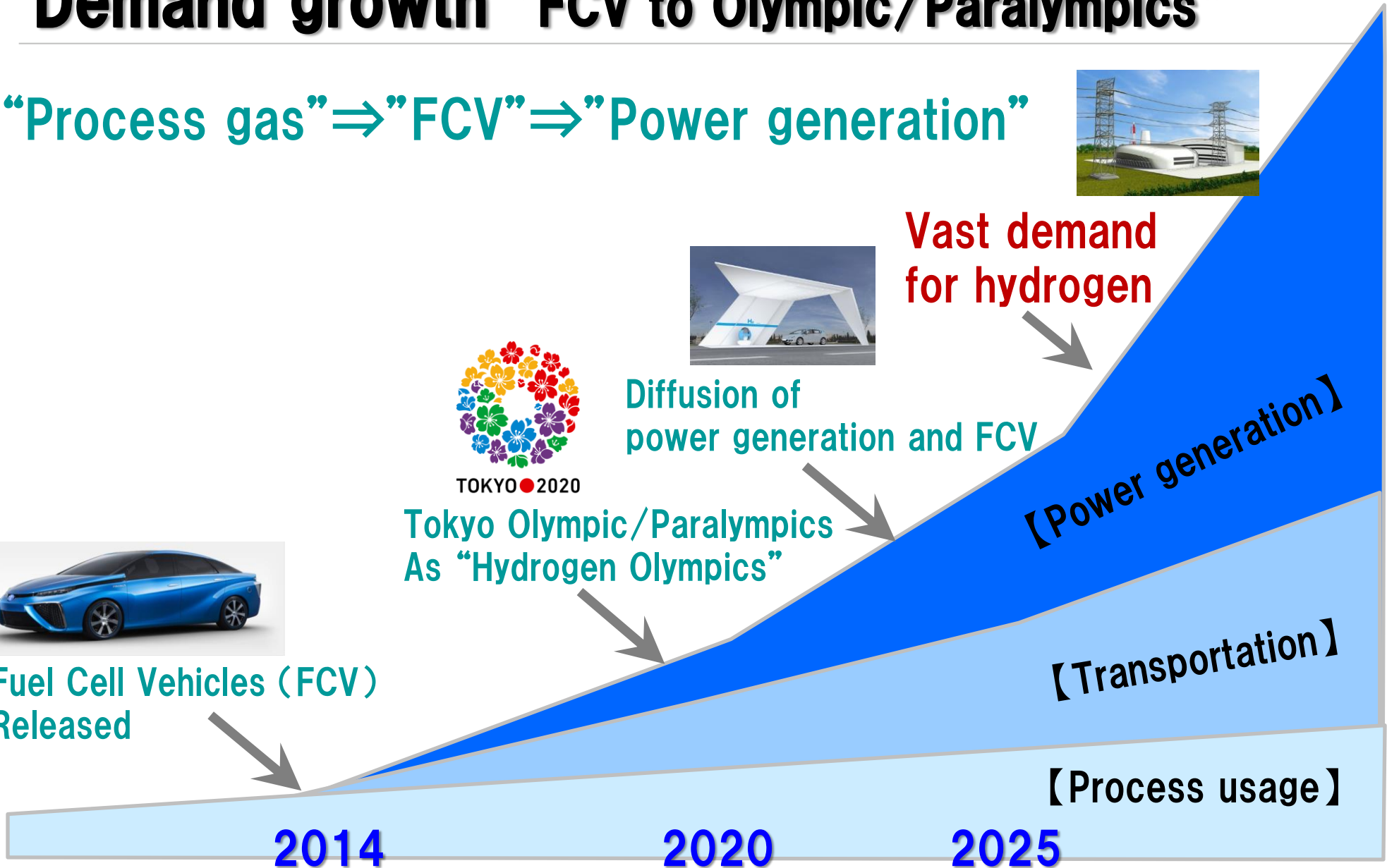


TOKYO ● 2020

Tokyo Olympic/Paralympics As “Hydrogen Olympics”



Fuel Cell Vehicles (FCV) Released



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Concepts of CO₂ free hydrogen supply chain

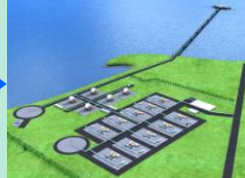
Overseas

Japan

Our target is brown coal in Australia

Fossil energy

Renewable energy



H₂

Liquefaction & storage



Liquefied hydrogen carriers



Liquefied hydrogen container



Liquefied hydrogen storage tanks

CO₂ free H₂

CO₂ Capture Storage (CCS)

CO₂

Hydrogen production

Transport & storage

Use in processes
Semiconductor, solar cell productions
oil refining and desulfurization

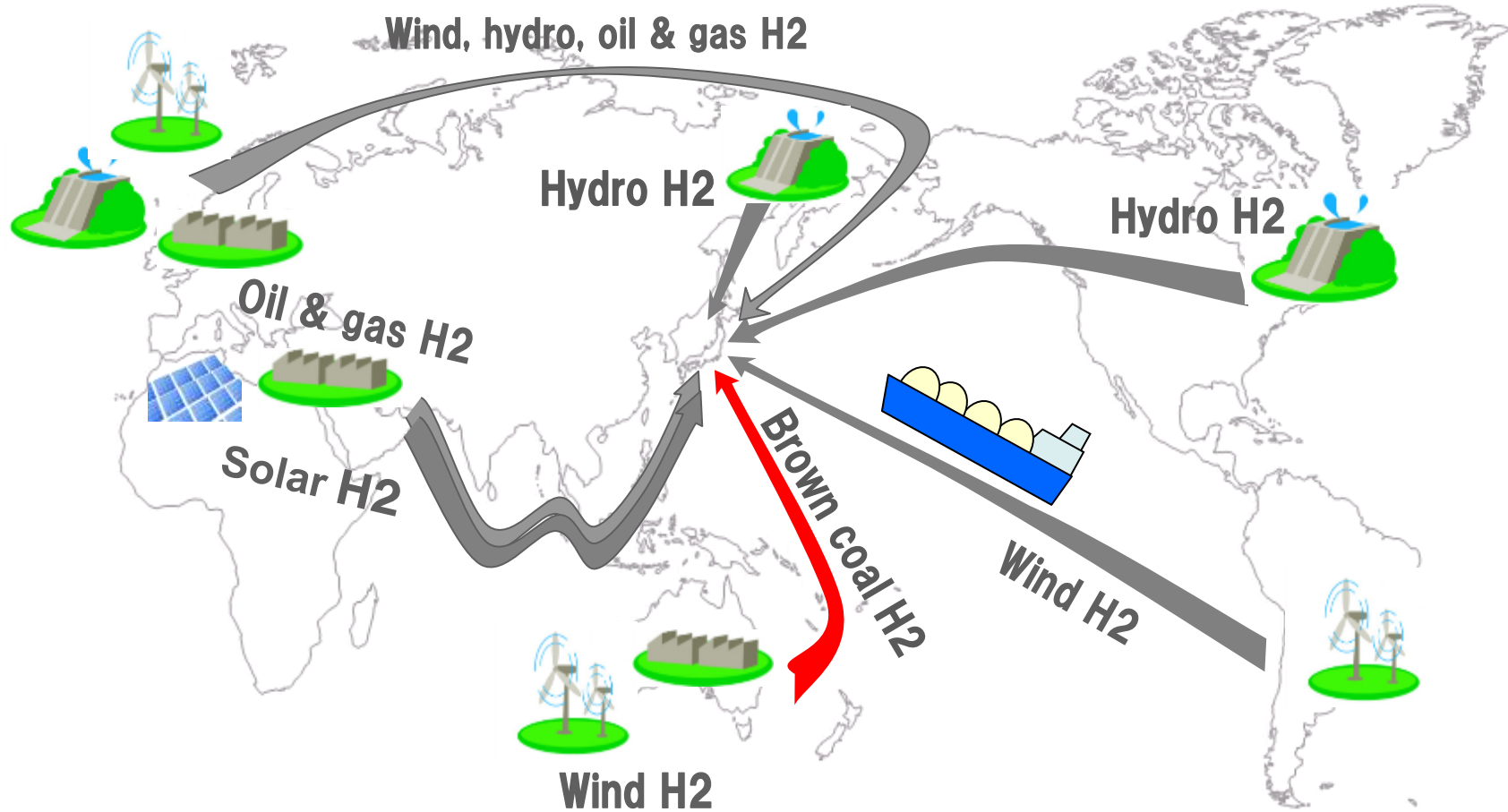
Transportation equipment
Refueling station
Fuel cell vehicles

Distributed power generation
Hydrogen gas turbines and engines, fuel cells etc.

Power plants
Combined cycle power plants

Utilization

Hydrogen potential from overseas



Liquefied hydrogen for mass transport

Feature of liquefied hydrogen

- Very low temperature : boiling point at -253°C
- Volume : **1/800** of gaseous states
- Already implemented transportation medium for process usage and space rocket fuel.
- High purity = no need for refinement (readily usable for fuel cell after vaporization)



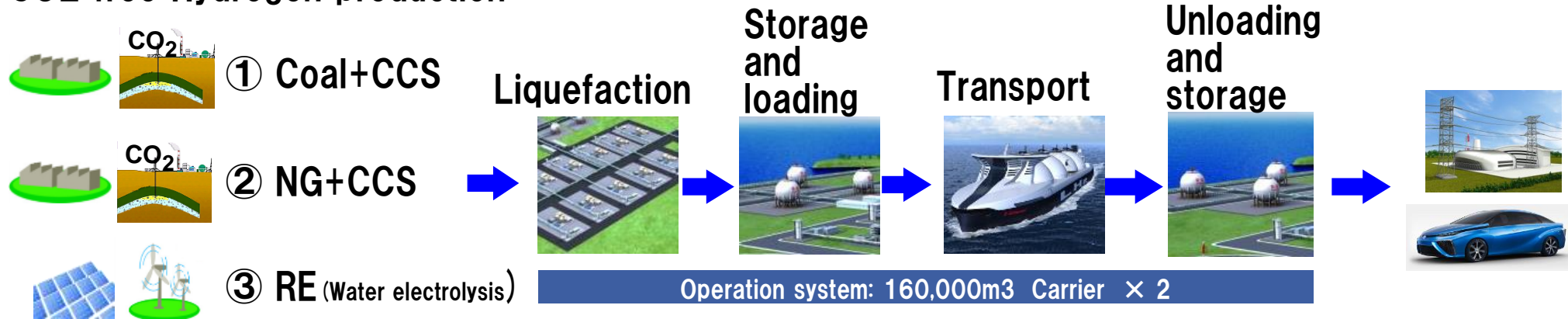
Storage tanks largest in Japan
(Tanegashima rocket launch base)



LNG carrier ship
(mass energy transport)

Rough study on commercial supply chain

CO₂ free Hydrogen production



Hydrogen Production

Transport & Storage

Utilization

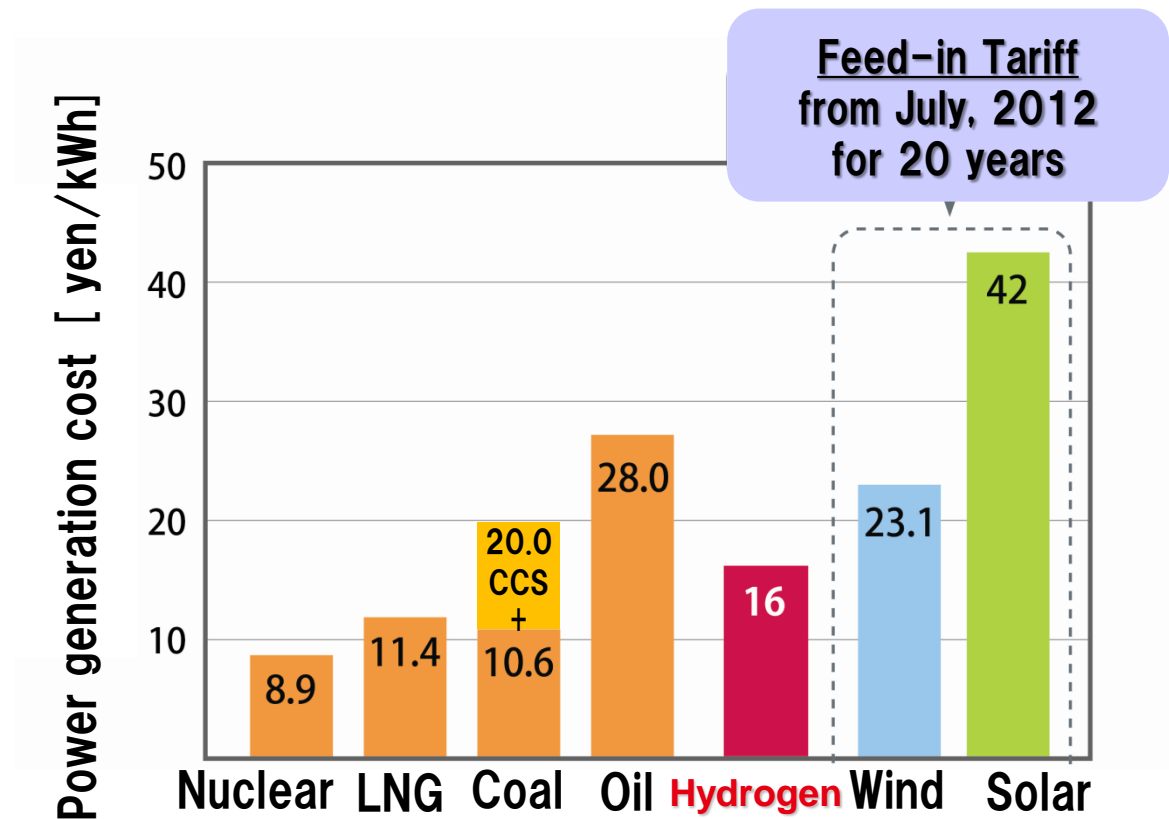
	Material	CCS	Location
①	Brown coal 15\$ AU\$/t	15 AU\$/t-co ₂	Australia
②	Natural gas 5\$ /MMBtu	15\$/t-co ₂	Middle East
③	RE Water electrolysis 20\$/MWh	-	Middle East

It's very reasonable cost as CO₂ free hydrogen in Japan

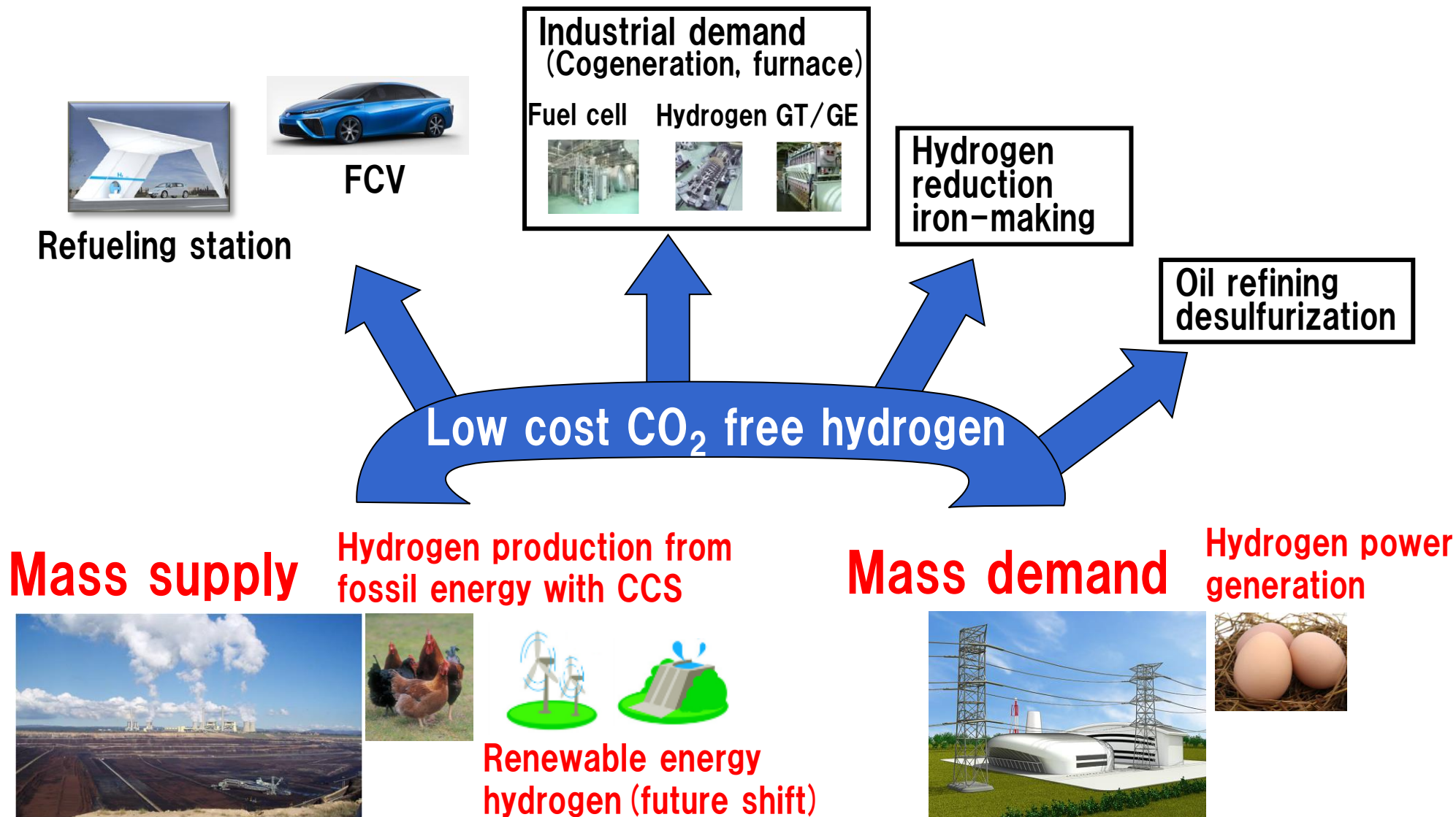
Equate Hydrogen CIF cost 30 JPY/Nm³

Comparison of power generation costs

It is More expensive than fossil fuels, but **cheaper, more stable and massively available than renewable energy** among CO₂ free energy



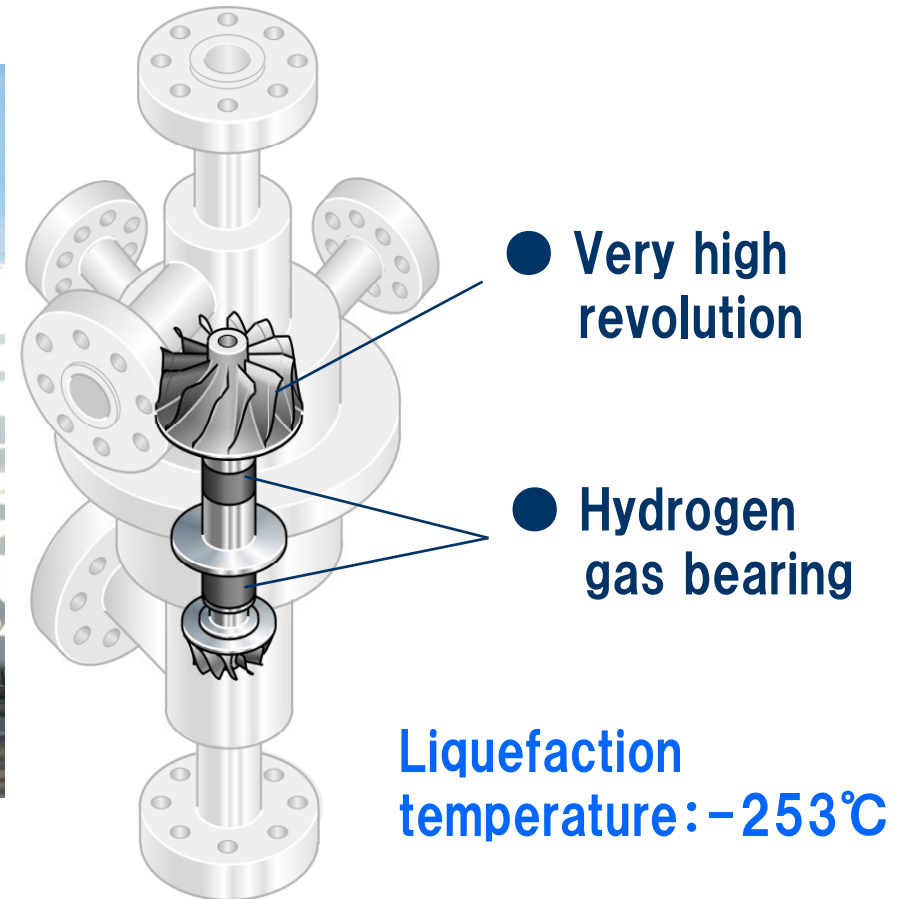
Concept of mass hydrogen introduction



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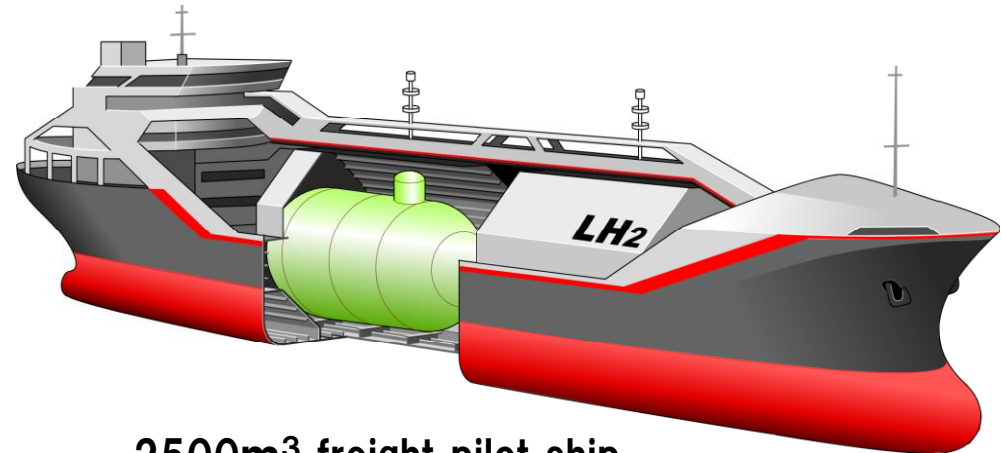
Hydrogen liquefaction

Original key hard, expansion turbine, realizes hydrogen liquefaction system

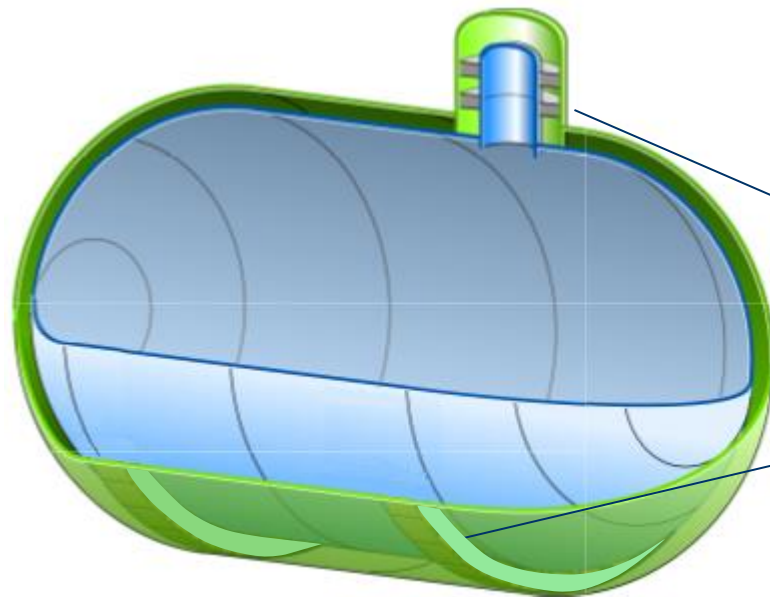


Liquefied hydrogen carrier ship

For realization of the world first liquefied hydrogen carrier ship



2500m³ freight pilot ship



Cargo tank

- Unique dome structure to keep vacuum
- Vacuum dual shell with stainless steel
- Highly insulated support structure

Approval in principal is provided from ClassNK

Storage of liquefied hydrogen

Liquefied hydrogen tank



Boil off rate: 0.18%/day

Specifications	
Type	Spherical double-shelled tank
Volume	540m ³
Pressure	0.686MPa + vacuum
Temperature	-253°C
Thermal Insulation	Vacuum perlite powder insulation



Onshore transport of liquefied hydrogen

Liquid hydrogen container truck

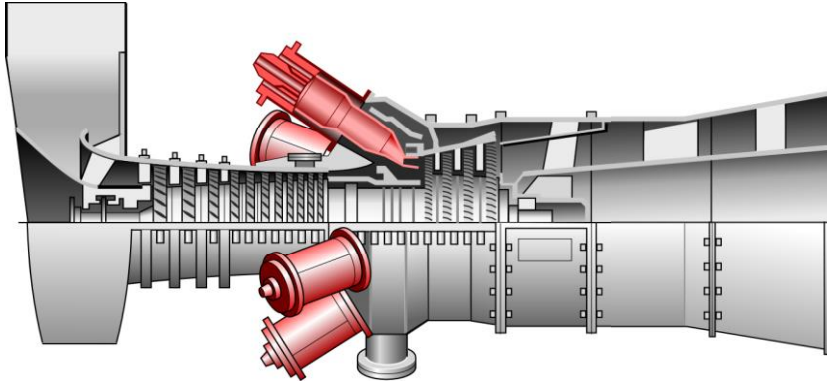


Specifications	
Type	ISO 40ft-type container
Volume	45.6m ³
Liquid H2 Load Capacity	2.9 tons
Thermal Insulation	Vacuum multilayer insulation
Auxiliary	Evaporator for pressurized gas



Hydrogen gas turbine generator

Combustion technologies
being developed

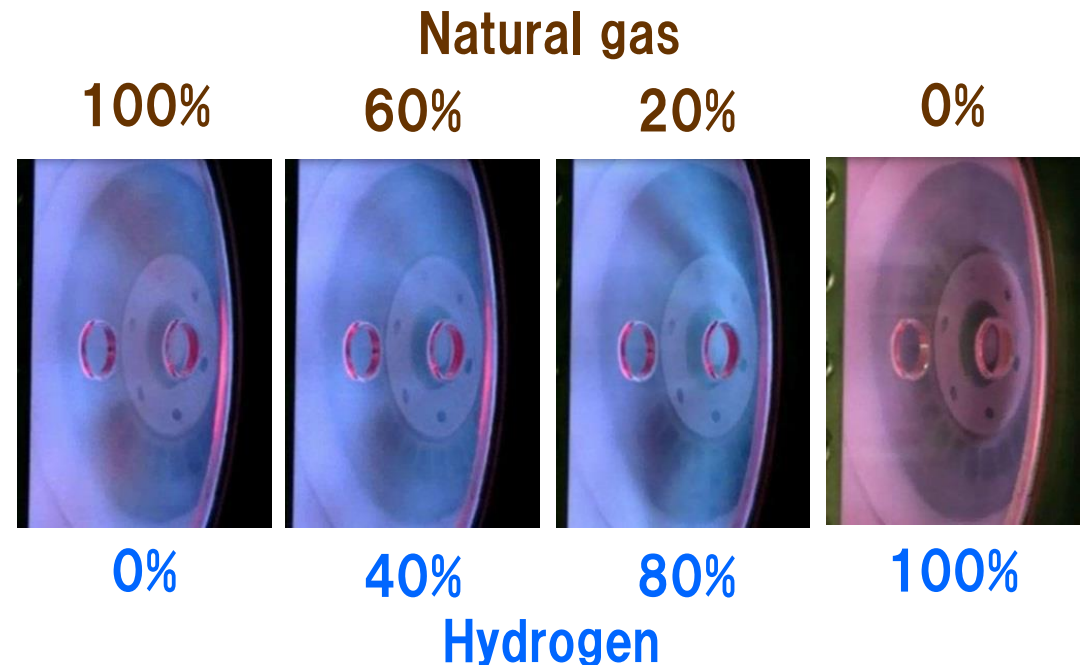


Key hard : combustor



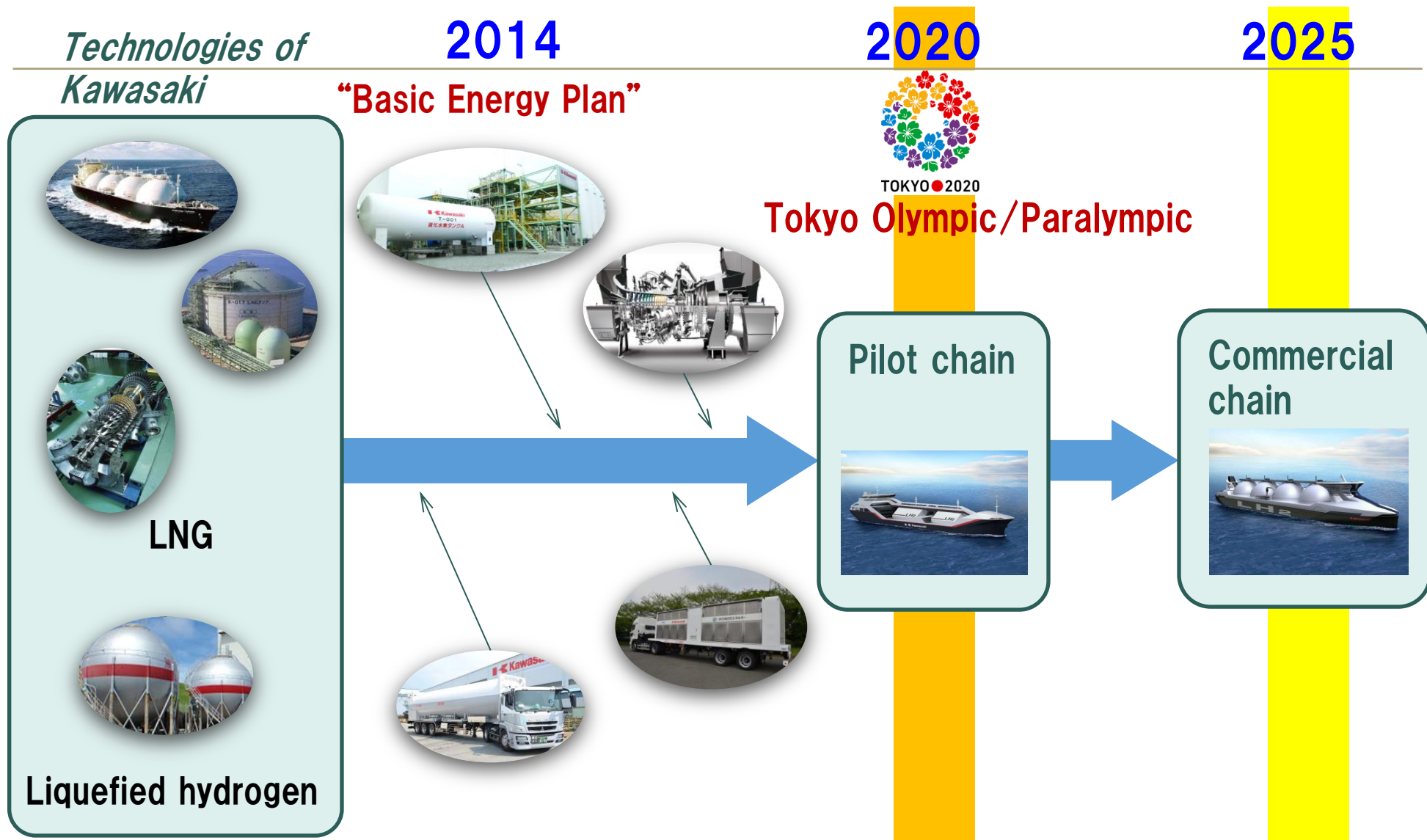
Hydrogen burner

- Original burner attains stable combustion and suppression of NOx emission
- Fuel flexible with hydrogen and natural gas



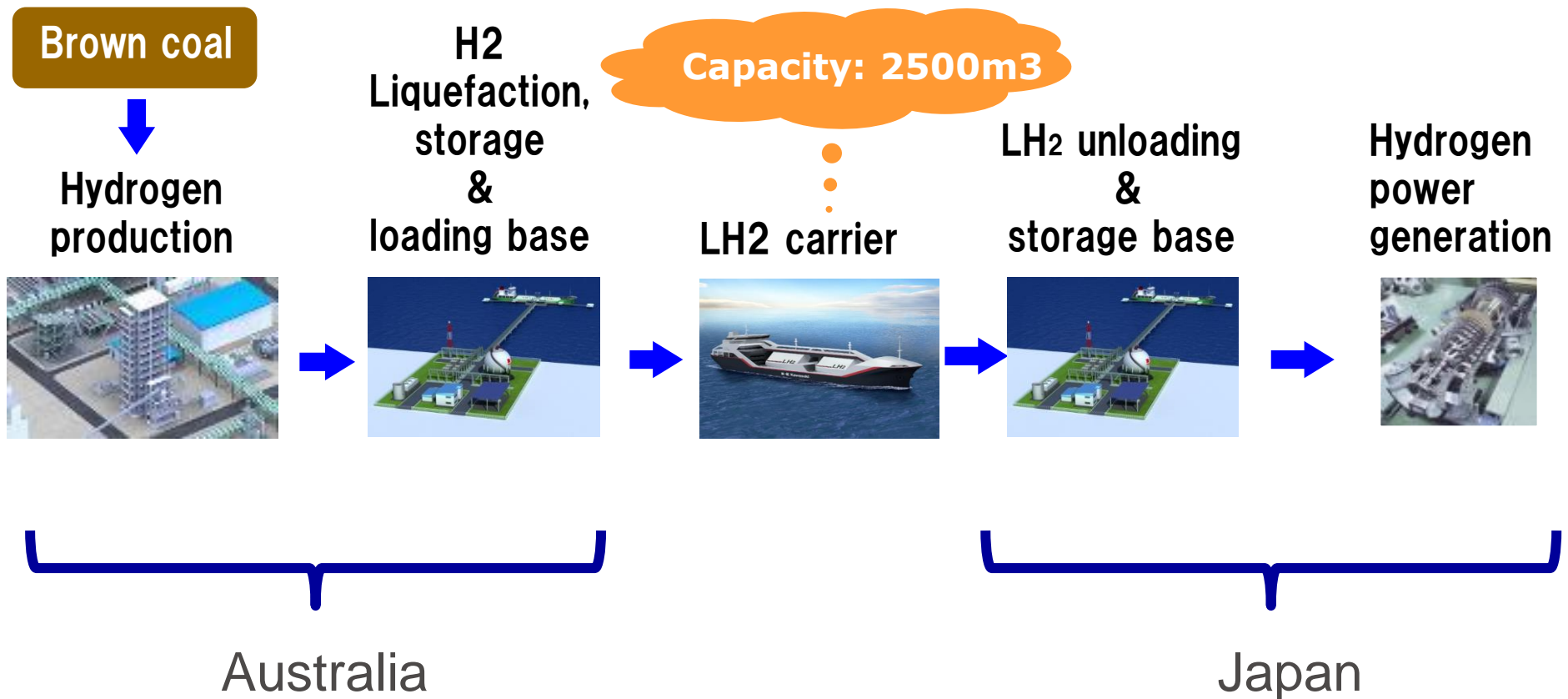
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Progress of the project



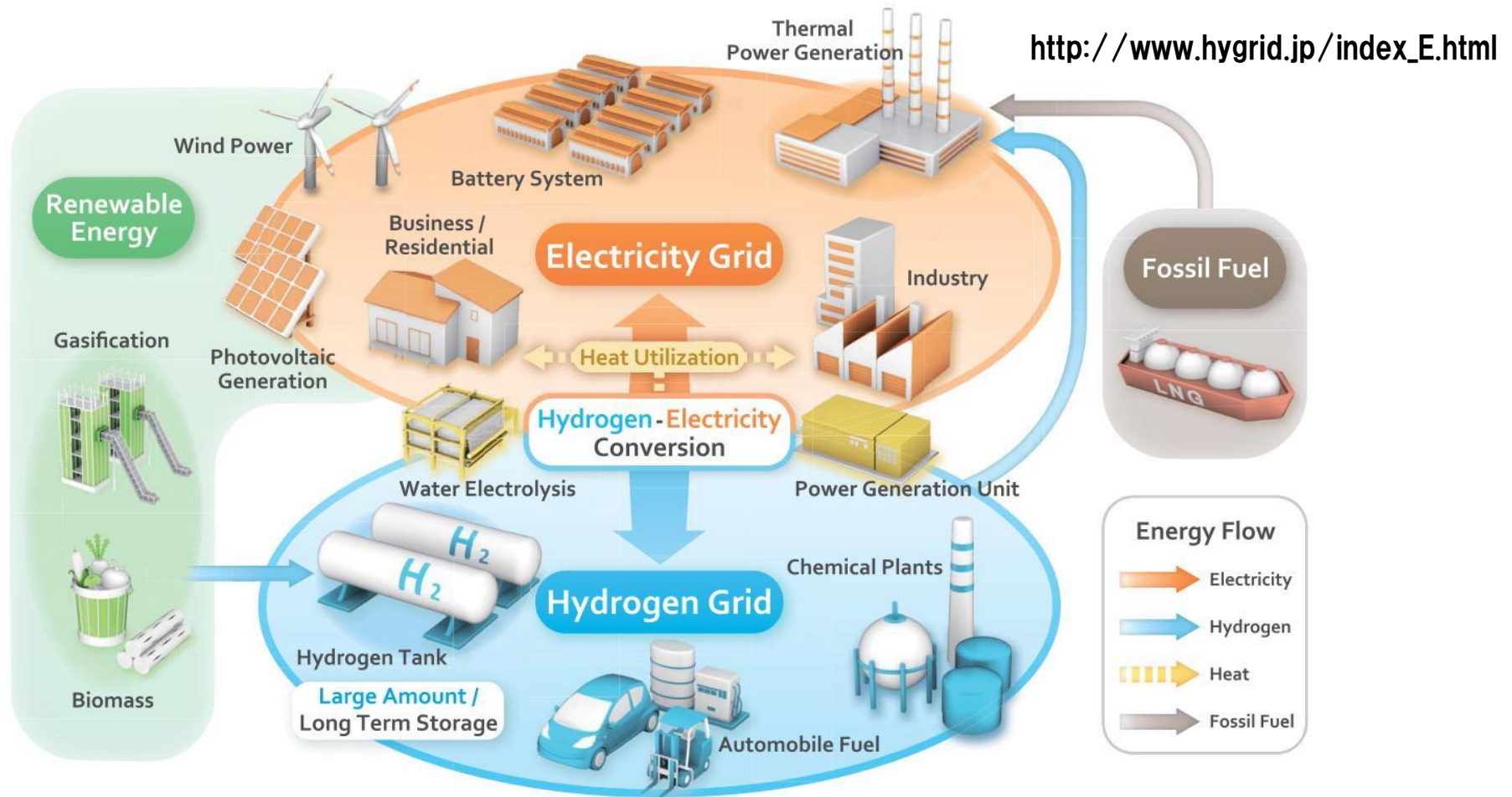
Pilot chain demonstration project

Under planning toward 2020



“HyGrid” society for the study on smart energy

Society comprised of diversified energies via electricity and hydrogen

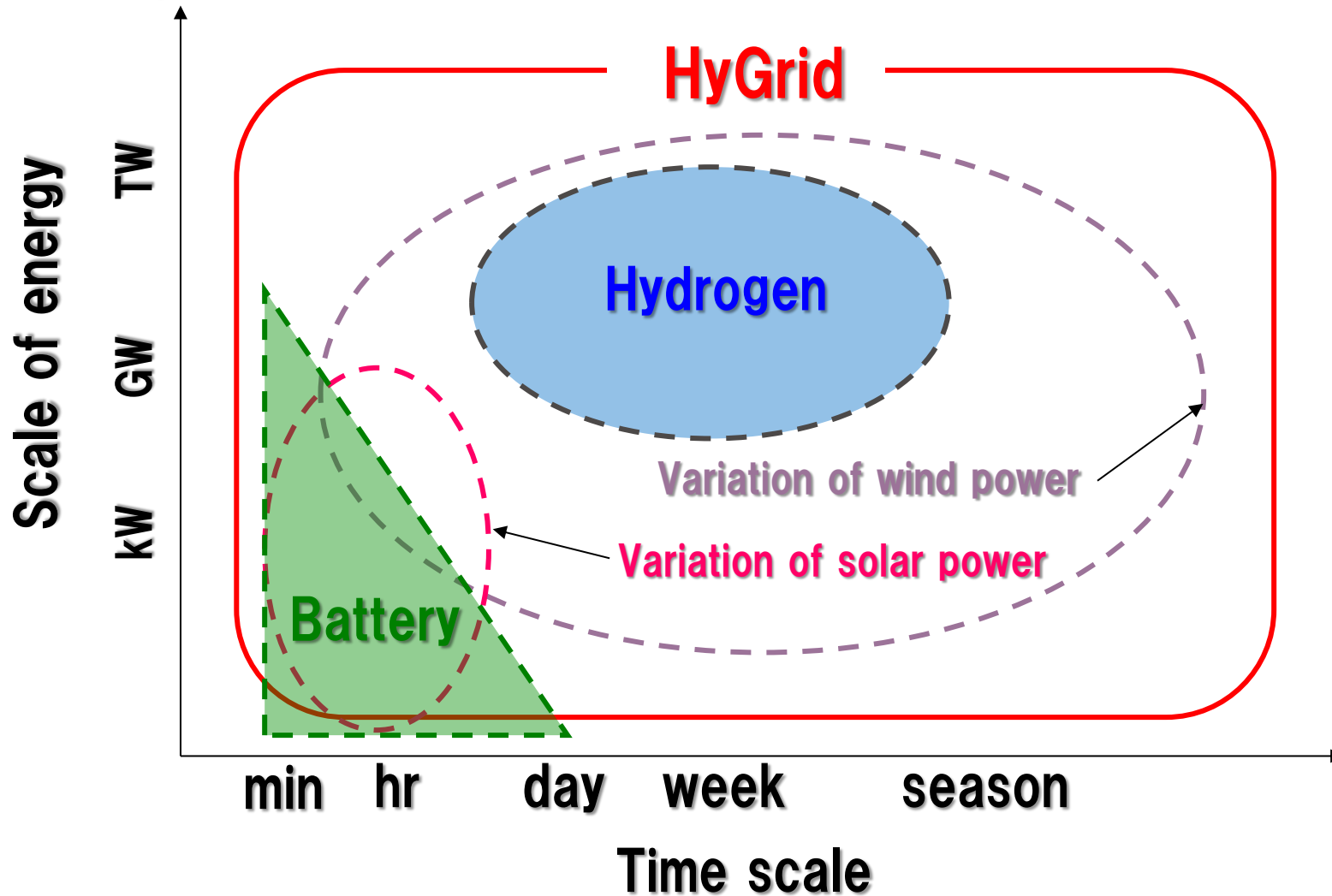


◆Members

Iwatani corp., Kawasaki Heavy Industries, Ltd. (chair), International Institute for Carbon-Neutral Energy Research (I2CNER), Research Institute for Systems Technology, Technova Inc. (secretariat), Toyota Motor Corporation, Toyota Tsusho corp., Nissan Motor Co., Ltd., Honda R&D Co., Ltd., Mitsui & Co., Ltd., Roland Berger Strategy Consultants. (As of Dec., 2013)

Role of hydrogen in HyGrid

Compensate large fluctuation of renewable energies



Thank you for your attention

Create new value—for a better environment and
a brighter future for generations to come

“Global Kawasaki”