Victorian Brown Coal Forum 2015 in Japan

Hydrogen Energy Supply Chain based on Victorian brown coal linked with CCS

Kawasaki Heavy Industries, Ltd.

6 October 2015

Kawasaki
Powering your potential

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1. About Kawasaki Heavy Industries (KHI)
2. Japan’s Energy Policy
3. Hydrogen Energy Supply Chain (HESC) Concept
4. Technologies
5. Progress of the HESC Project
6. Conclusion

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Kawasaki - global leader in innovative technologies

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)

About KHI

Market cap ¥731 billion ($8.7b)

(September 30, 2015)

Net Sales ¥1,486 billion ($17.7b)

(Fiscal year ended March 31, 2015)

Employee 35,471 people

(As of March 31, 2015)

Global Network 29 main product base 95 subsidiaries

Note: Exchange rate: ¥84/1$
Source: Google Finance, 30 September 2015

Hydrogen Products

Fertilizer Plant
(Hydrogen production)

H-II rocket fuel
hydrogen storage tank

Liquid hydrogen
storage tank

Liquid hydrogen container

High pressure hydrogen gas trailer

Contents

Japan's Strategic Energy Plan

- Released in April 2014 by the Japanese Government
- Vision of "hydrogen society" where hydrogen will play a central role in Japan's future energy strategy
- Key features

- Residential use stationary fuel cell
- Fuel Cell Vehicles (FCV)
- Hydrogen power generation
- Large scale production, transportation and storage of hydrogen (derived from unutilized brown coal and other sources)
- "Strategic Roadmap for Hydrogen and Fuel Cell"

Strategic Road Map for Hydrogen and Fuel Cell

Expansion of hydrogen use
Phase 1

2015
Release FCV onto the market

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 / Large scale hydrogen supply system
Phase 2

Mid 2020s
Introduction of hydrogen from overseas

Around 2030
Production, transportation and storage of hydrogen derived from unutilized energy resources imported from overseas

Zero-carbon emission hydrogen supply system
Phase 3

Around 2040
Zero-carbon emission hydrogen with a CCS process or others

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

【Power generation】

【Transportation】

【Process usage】

2014 2020 2025

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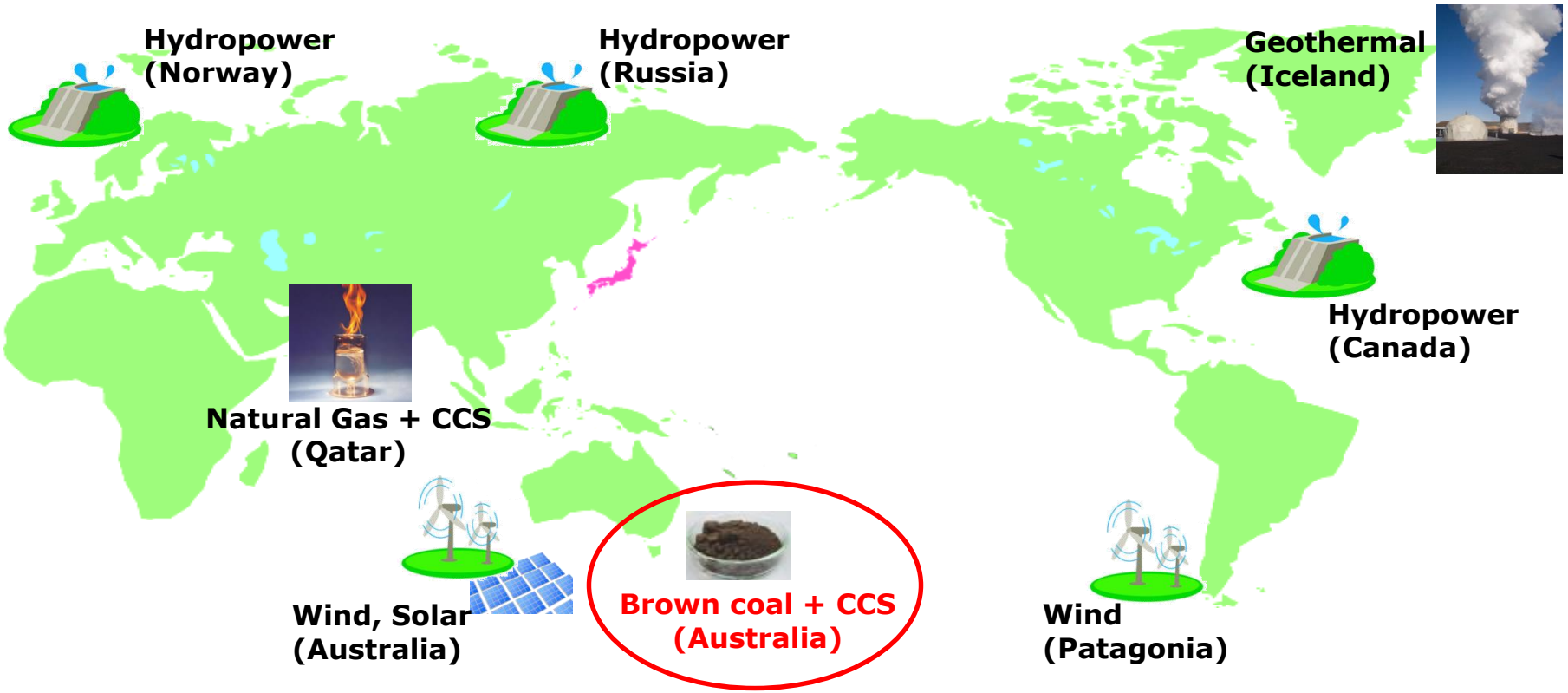
Multiple Sources of Hydrogen Supply

- Japan is investigating multiple sources of hydrogen supply
- Australian brown coal with CCS is a potential solution



Hydrogen Energy Supply Chain Concept

Australia

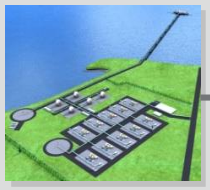
Victoria
The Place To Be

Low-cost hydrogen production from brown coal

Brown coal

Gasification, Gas Refining & Purification

CO_2



Hydrogen Liquefaction & storage

Carbon Capture and Storage

Hydrogen Production

Liquefied hydrogen carriers

Hydrogen Transport & Storage

Liquefied hydrogen trucks

Liquefied hydrogen tanks

Japan

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

Power plants
Combined cycle power plants

Energy equipment
Hydrogen gas engines, gas turbines, boilers, fuel cells

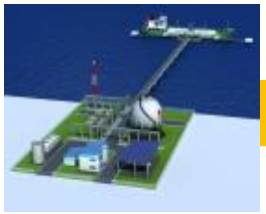
Transportation equipment
Hydrogen cars (Fuel Cell Vehicle)

Hydrogen Use

Hydrogen Energy Supply Chain Project

- Hydrogen produced from the gasification of Victorian brown coal
- Export of liquid hydrogen from Victoria to Japan
- It is one of the most advanced project of the Japanese hydrogen supply initiatives
- Two stages:
  - Pilot
  - Commercial
- Multiple benefits for Victoria:
  - employment
  - increase in State GDP
  - innovation
  - foreign direct investment
  - monetisation of brown coal
  - CarbonNet

Future Scenario towards Hydrogen Society

Technical demonstration(pilot) (Domestic ship scale) 2020	Demonstration chain (Tanker scale) 2025	Commercial 1 chain 2030	20 chains 2040	40 chains 2050
				
		2 ships	40 ships	80 ships
				
		1 plant	20 plants	40 plants
				
		1 plant	20 plants	40 plants

Generation capacity	1GW	20GW	40GW
Rate in Japanese gross generation	0.5%	10%	20%
Reduction of CO_2 emission	3Mt p.a.	60Mt p.a.	120Mt p.a.

Contents

Technologies

Production

● Brown coal gasification
Mill, dry, gasification processes.

● Liquefaction system
Plant, turbine, cryogenic tech.

Transportation and Storage

● Liquid hydrogen carrier
LNG carrier, cryogenic tech.

● Liquid hydrogen tank
Cryogenic tech.

● Liquid hydrogen container
Cryogenic tech.

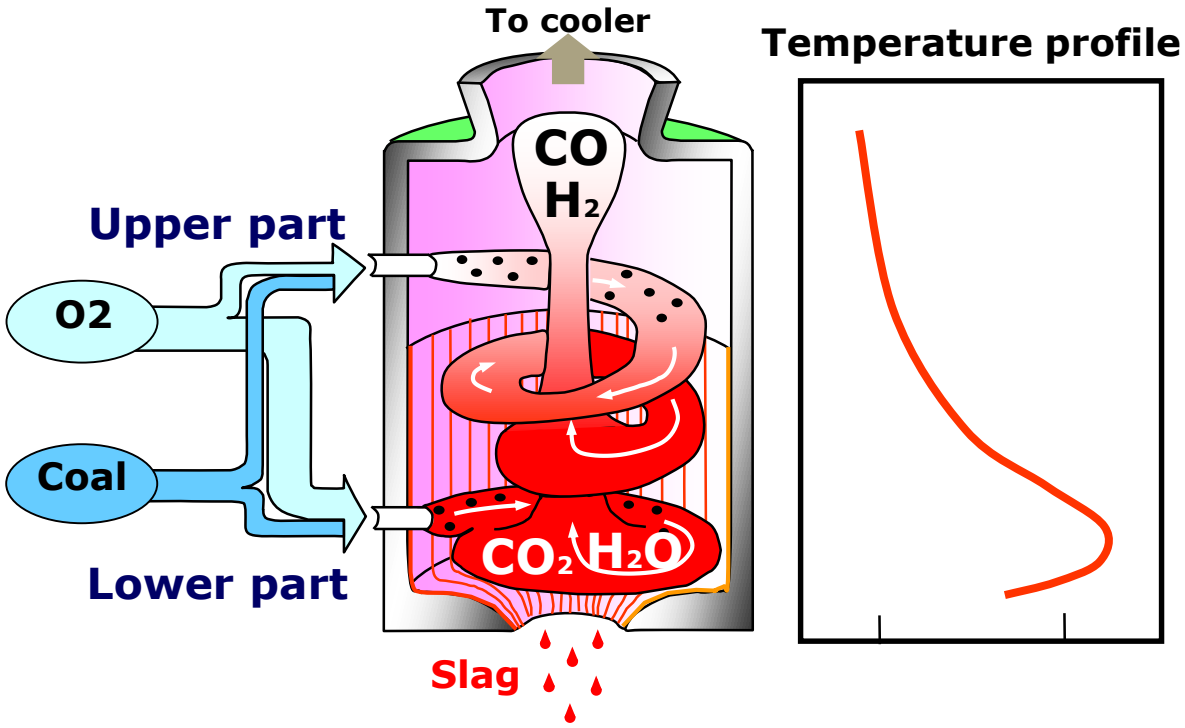
● High pressure gas trailer
Composite material tech.

Utilization

● Hydrogen gas turbine
Clean combustion tech.

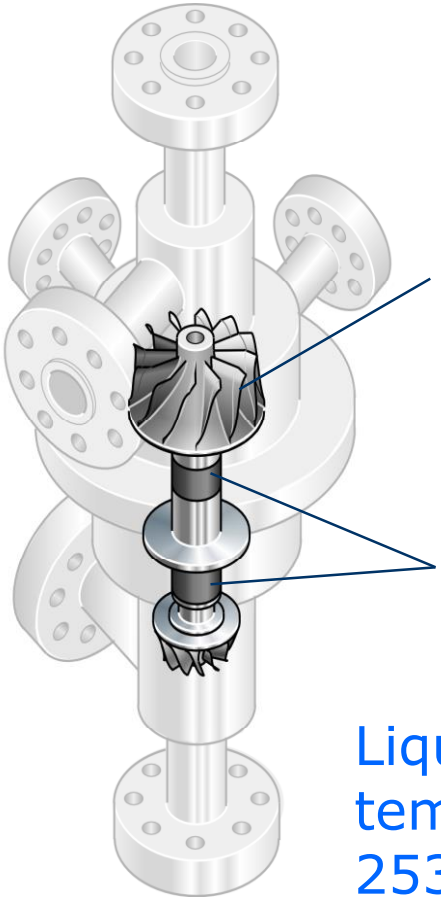
Brown Coal Gasification

- '**EAGLE gasifier**', O2 blown entrained flow gasifier, will be applied, which recently achieved the world highest efficiency with black coal
- Combination of successful pilot scale demonstration with brown coal and experiences of scaling up with black coals could enable commercial scale gasifier for brown coal application



Hydrogen Liquefaction

Original key hard, expansion turbine, realizes hydrogen liquefaction system

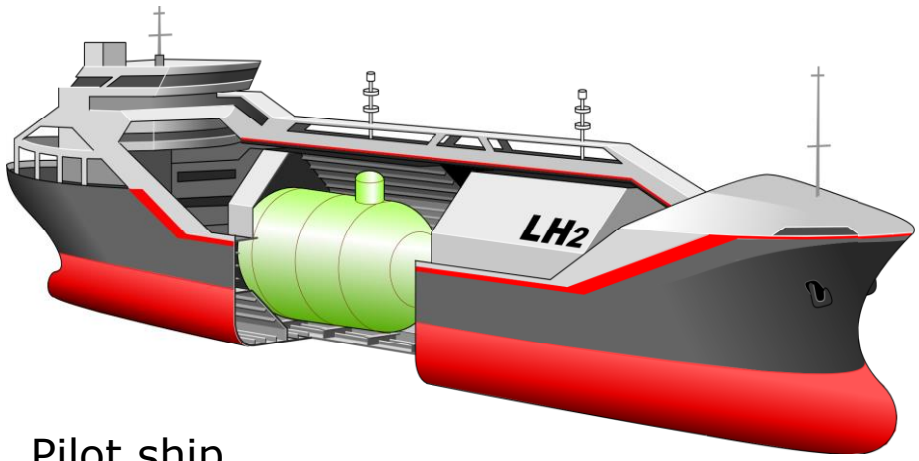


- Very high revolution
- Hydrogen gas bearing

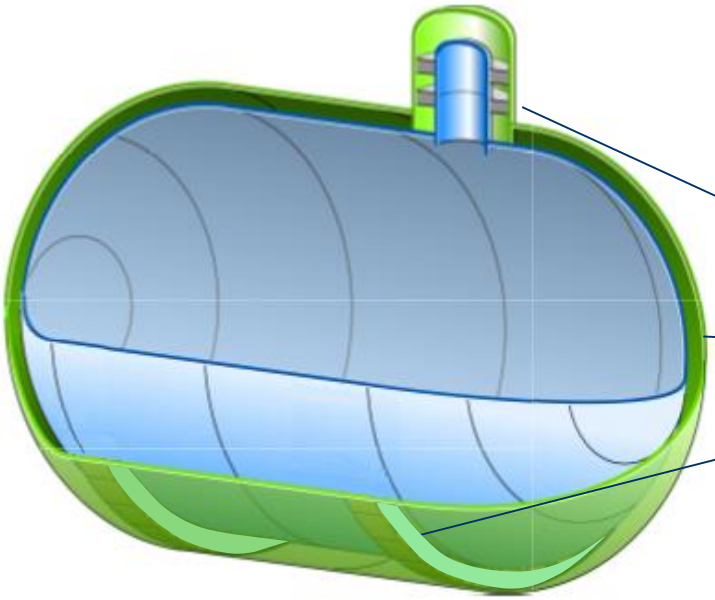
Liquefaction temperature:-253℃

Liquid Hydrogen Carrier Ship

Realization of the world first liquid hydrogen carrier ship



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 Liquid Hydrogen

Liquid hydrogen tank

Boil off rate: 0.18%/day

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

Onshore Transport of Liquid 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

Onshore Transport of Gas Hydrogen

High pressure composite (CFRP) bottle trailer, the Japan first.

Supported by NEDO, HySUT and JX Nippon Oil & Energy

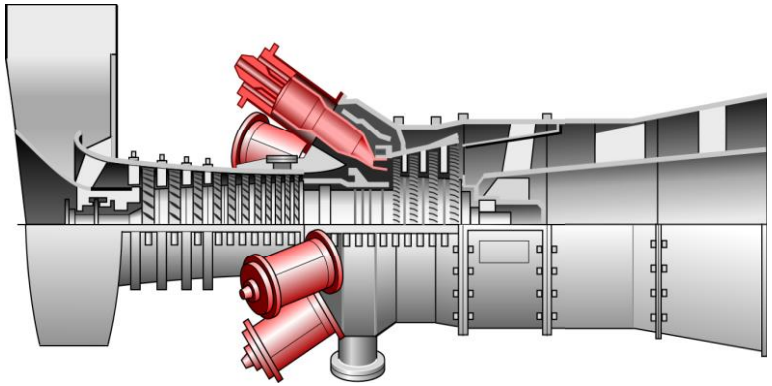
Trailer Specifications	
Length※	10,260mm
Width	2,500mm
Height	3,500mm
Weight※	19,310kg
Number of bottles	24
Gas hydrogen load weight	260kg

Bottle Specifications	
Length	3,025mm
Diameter	436mm
Weight	220kg
Pressure	45MPa
Volume	300L
Type	3

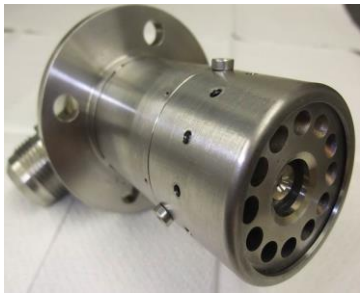
※ Except the tractor

Hydrogen Gas Turbine

Combustion technologies being developed



Key hard : combustor

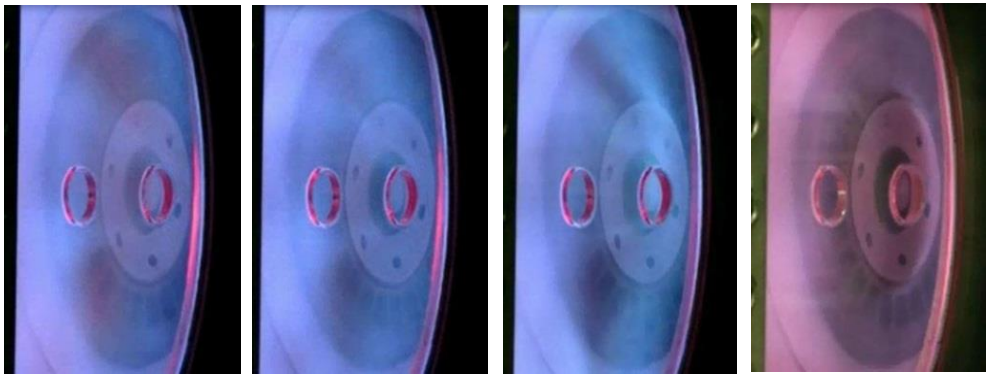


Hydrogen burner

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

Natural gas

100% 60% 20% 0%



0% 40% 80% 100%

Hydrogen

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Timing

KHI Technologies

2014 2020 2025

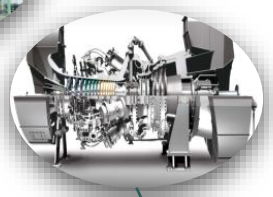
"Strategic Energy Plan"

TOKYO 2020

Tokyo Olympic/Paralympic

LNG

Liquid Hydrogen



Pilot Supply Chain Project

Commercial Chain

Plan of Pilot Supply Chain Project

- Test for the commercial scale supply chain
- Liquid hydrogen to be transported to Japan by liquid hydrogen pilot ship
- Demonstration of large hydrogen volume transportation in 2020, Tokyo Olympic/Paralympic year

Grant from NEDO

(New Energy and Industrial Technology Development Organization)

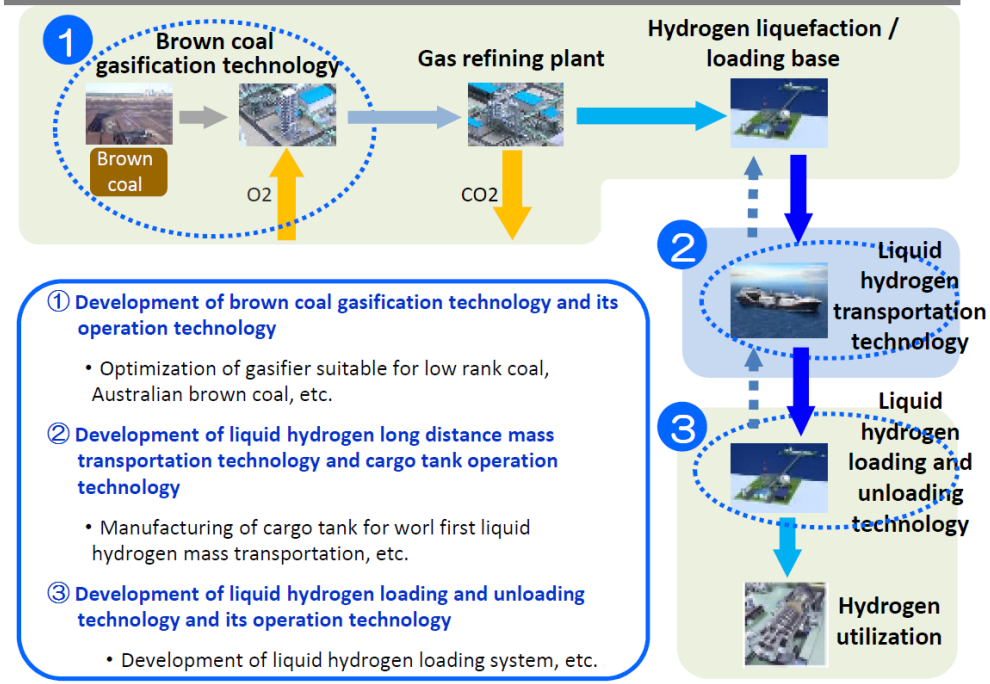
- Pilot Supply Chain Project was awarded NEDO funding
- Pilot Supply Chain Project: KHI(lead), Iwatani corp., J-Power
- NEDO undertook a press conference for the award in June

Overview of the NEDO Project

①Demonstration project for establishment of mass hydrogen marine transportation supply chain derived from unused brown coal

- Aiming at establishment of liquid hydrogen supply chain integrating hydrogen production from unused Australian brown coal, storage, transportation and utilization of hydrogen
- For its realization, this project will implement research and development of '① brown coal gasification technology', '② liquid hydrogen long distance mass transportation technology', '③ liquid hydrogen loading and unloading technology' among technologies in the supply chain

Schematic diagram of supply chain, Demonstration items



① **Development of brown coal gasification technology and its operation technology**

- Optimization of gasifier suitable for low rank coal, Australian brown coal, etc.

② **Development of liquid hydrogen long distance mass transportation technology and cargo tank operation technology**

- Manufacturing of cargo tank for worl first liquid hydrogen mass transportation, etc.

③ **Development of liquid hydrogen loading and unloading technology and its operation technology**

- Development of liquid hydrogen loading system, etc.

Organization for execution, Schedule

< Organization for execution >

JPOWER	KHI	Iwatani
① Brown coal gasification technology	②Transportation technology ③ Loading and unloading technology	③ Loading and unloading technology

< Preliminary Schedule >

FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Elemental test Basic design	Design, Manufacturing, Commissioning, etc.				Demo operation

Importance of the Pilot Supply Chain Project

- To demonstrate successful **integration of technologies and a supply chain** to stakeholders
- To confirm **interface** between individual elements
- To confirm **safety** of operation of a full supply chain
- To assist developing **regulations and codes/standards** for hydrogen in Australia
- To obtain **social acceptance** for mass handling of hydrogen in Australia
- To **transfer hydrogen relevant technologies** to Australia and to **assist in developing hydrogen market in Australia**

Governments' supports are necessary for successful implementation of the Pilot Supply Chain Project

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Key takeaways

- Hydrogen Energy Supply Chain is a complex project
- It presents significant opportunities for Victoria
- KHI has achieved strong in-principle support in Australia and Japan
- Various technologies are required, but largely proven
- There is strong interest from many Japanese companies
- There are a number of challenges to work through
- KHI is confident it can deliver the Hydrogen Energy Supply Chain Project with its partners

Thank you for your attention

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

"Global Kawasaki"

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