Ammonia, Key Green Energy for Decarbonization

Ammonia = Hydrogen 2.0 Conference

August 22, 2019

Melbourne

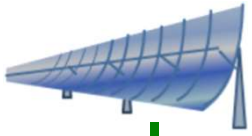
Shigeru Muraki

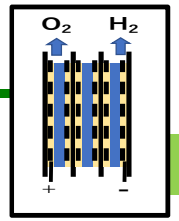
Representative Director

The Green Ammonia Consortium

Hydrogen Energy Carriers for Global Renewables

Renewable Rich Countries
(Australia etc.)





Electrolyzer

H_2 Carriers

Green H_2

Blue H_2

Liquid Hydrogen (LH_2)

Methyl Cyclohexane (MCH)

H_2

Ammonia (NH_3)

Reforming
Gasification

CO_2

CCS/EOR

Oil & Gas Producing Countries

Green & Blue NH_3

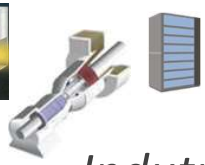
Energy Market
(Japan etc.)

Mobility

Power

Heat *Indutry*

Power



Indutry

Shipping

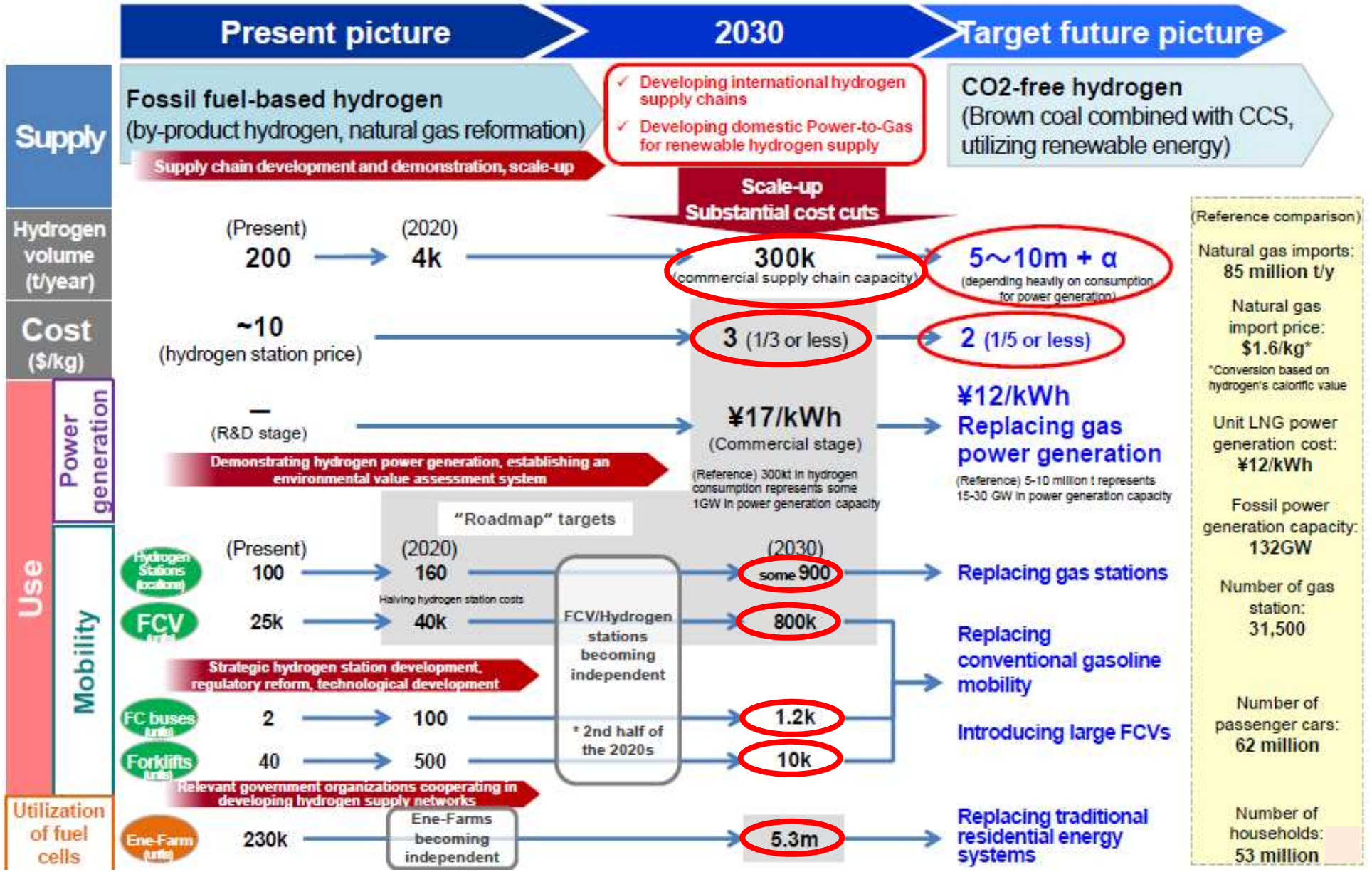
Why Ammonia

- Directly combusted without CO_2 emissions.
- Largest H_2 content among 3 carriers and most efficient in marine transportation.

  （NH_3 121kg-H_2/m^3 liquid , LH_2 71kg-H_2/m^3 , MCH 23kg-H_2/m^3 ）
- Large commercial supply chain is established, and cost structure is clear.
- NOx emissions can be controlled by technologies.

  （Air-fuel ratio , Two staged combustion etc.）

Scenario for Basic Hydrogen Strategy



SIP Energy Carriers (2014-2018)

- SIP (Cross-ministerial Strategic Innovation Promotion Program) was launched in 2014 as 5 years national program by the Council for Science, Technology and Innovation under Cabinet Office of Japan to promote R&D of technologies which address the most important social problems facing Japan as well as contribute to the resurgence of Japanese economy.
- Energy Carriers Program aims to promote R&D to contribute to the efficient and cost-effective technologies for utilizing Hydrogen and Hydrogen energy carriers toward low carbon society.

Key Projects

Ammonia direct utilization in Energy sector

Gas turbine, Fuel Cell, Coal fired boiler, Industrial furnace, Marine Engine

- Program Director: Shigeru Muraki, Executive Adviser of Tokyo Gas CO., Ltd.
- Total budget (2014-2018): 16.7Billion yen (150M$)

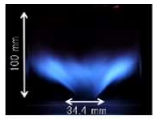
Key Achievements in SIP (1/5)

Ammonia-fueled gas turbine power generation

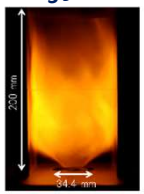
☆ Tohoku University / AIST / Toyota Energy Solutions / IHI Corporation

50kW (100% NH_3) Micro Gas Turbine

CH_4 flame

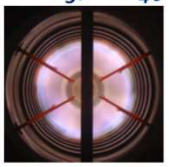


NH_3 flame

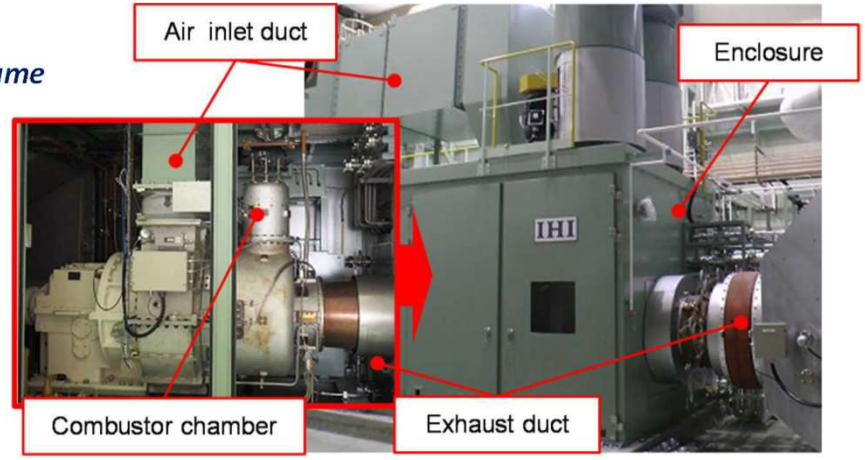


- 50 kW and 300 KW turbines successfully generated power by 100% ammonia with less than 10 ppm NOx emission using an ordinary SCR device.
- Plan to commercialize 50 KW, 300 KW ammonia turbines in 2020

20% NH_3 / CH_4 flame



- Stable flame and low NOx emission were achieved by 2MW class gas turbine under the condition of co-fired 20% ammonia with natural gas.

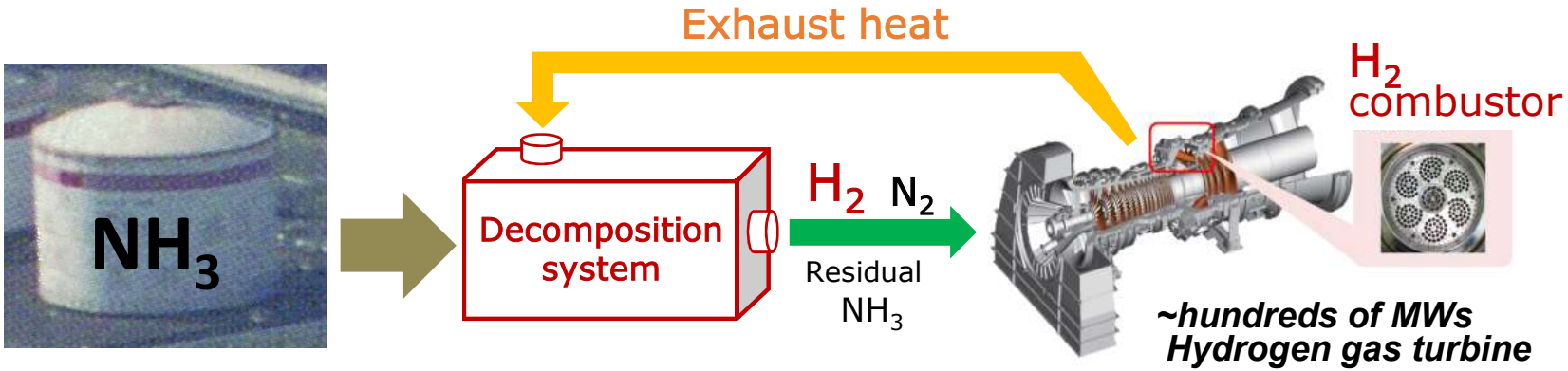


2MW (20% NH_3 / CH_4) Gas Turbine

Key Achievements in SIP (2/5)

Advanced combined cycle gas turbine

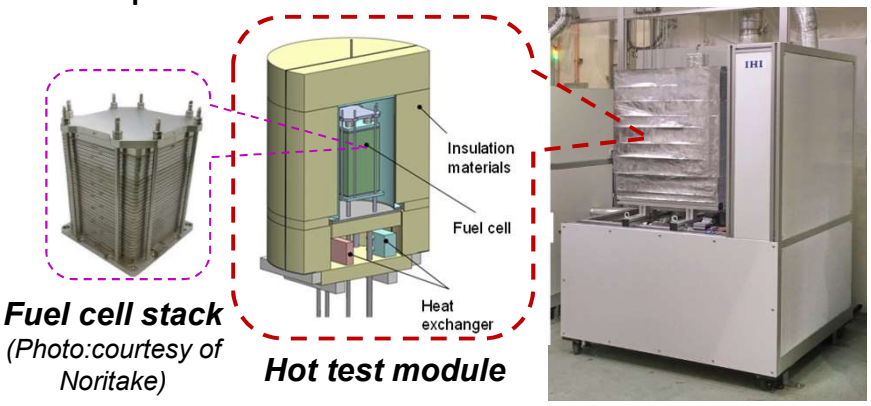
☆ Mitsubishi Heavy Industries Engineering / Mitsubishi Hitachi Power Systems



Direct ammonia-fueled solid oxide fuel cell (SOFC)

☆ Kyoto University / Noritake Co., Limited / IHI Corporation

- Development of 100% ammonia-fueled 1 KW SOFC system (direct supply of ammonia)
- The performance attained is equivalent to the hydrogen fueled SOFC.
- Target capacity is 10KW ~ 200 KW



Fuel cell stack *(Photo:courtesy of Noritake)*

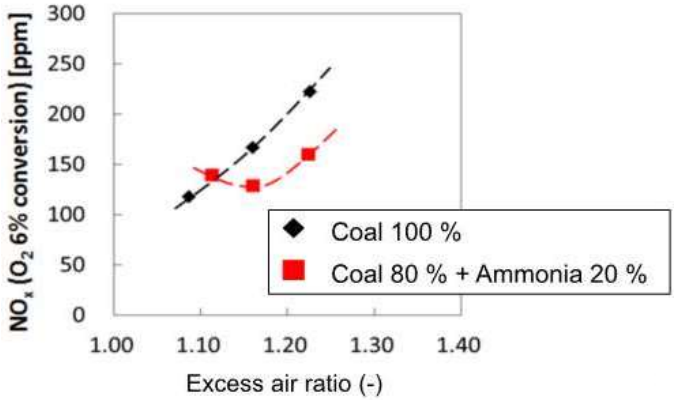
Hot test module

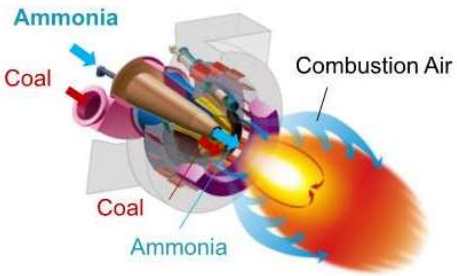
SOFC system

Key Achievements in SIP (3/5)

Coal firing test furnace

☆ IHI Corporation





- Ammonia was safely combusted.
- NOx is under 200 [ppm].
- There is no ammonia slip in the exhaust gas.

Co-fired ammonia at the commercial coal power plant

☆ The Chugoku Electric Power

1MW-NH_3 feed / 120MW-Electricity
(Coal fired boiler and steam turbine)

The Chugoku Electric Power Co., INC.
Mizushima Power Station

Key Achievements in SIP (4/5)

Industrial furnaces

☆ Osaka University / Taiyo Nippon Sanso

・Successfully controlled NOx generation below the environmental standard.

・Developed oxygen enriched combustion and staged combustion.

10kW model furnace

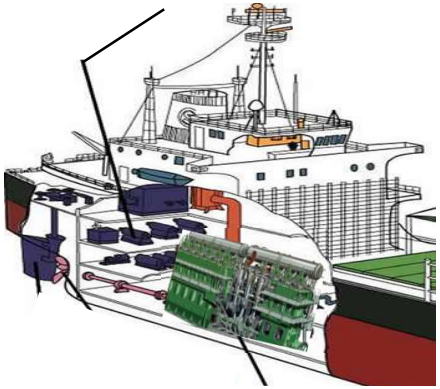
Marine Engine

☆ JFE Engineering / National Institute of Maritime, Port and Aviation Technology

・Development of Ammonia Diesel Engines.

・Adaptability to the new IMO GHG emission regulations.

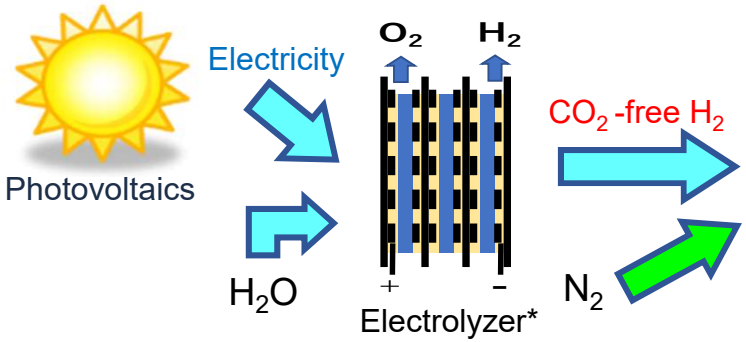
Sub Engine



Maine Engine

Key Achievements in SIP (5/5)

Development of ammonia synthesis process from CO_2 free hydrogen



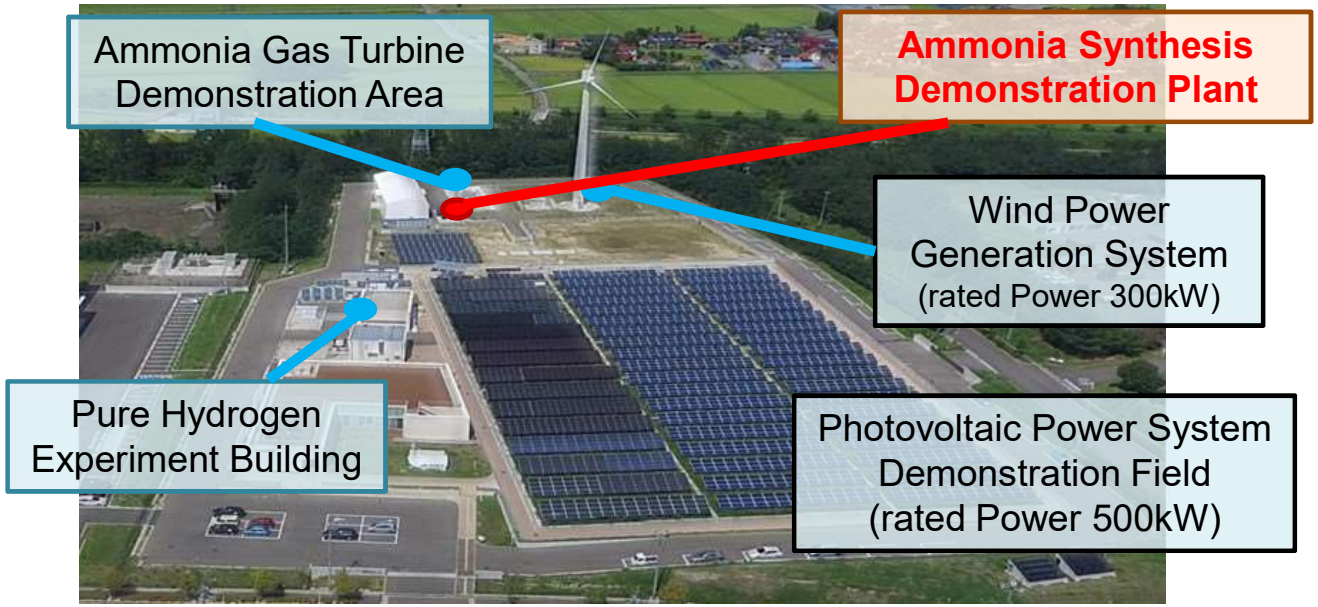
Ammonia Synthesis Demonstration Plant

CO_2 -free NH_3

Green Electricity

Location

Fukushima Renewable Energy Institute, AIST (FREA)



Feasibility Studies -CO_2 Free NH_3 delivered to Japan-

Supply

Utilization

Blue Ammonia

Natural Gas

HB NH_3 Plant

CO_2

CCS/EOR

Estimated Import Price
$330 ~ 340/ton ($2/kg-H2)

Pulverized Coal + NH_3

3 Coal Fired Power Plants
- Remodeling of Coal Boiler
- NH_3 Unloading, Storage & Supply Facilities

Green Ammonia

Renewables

H2

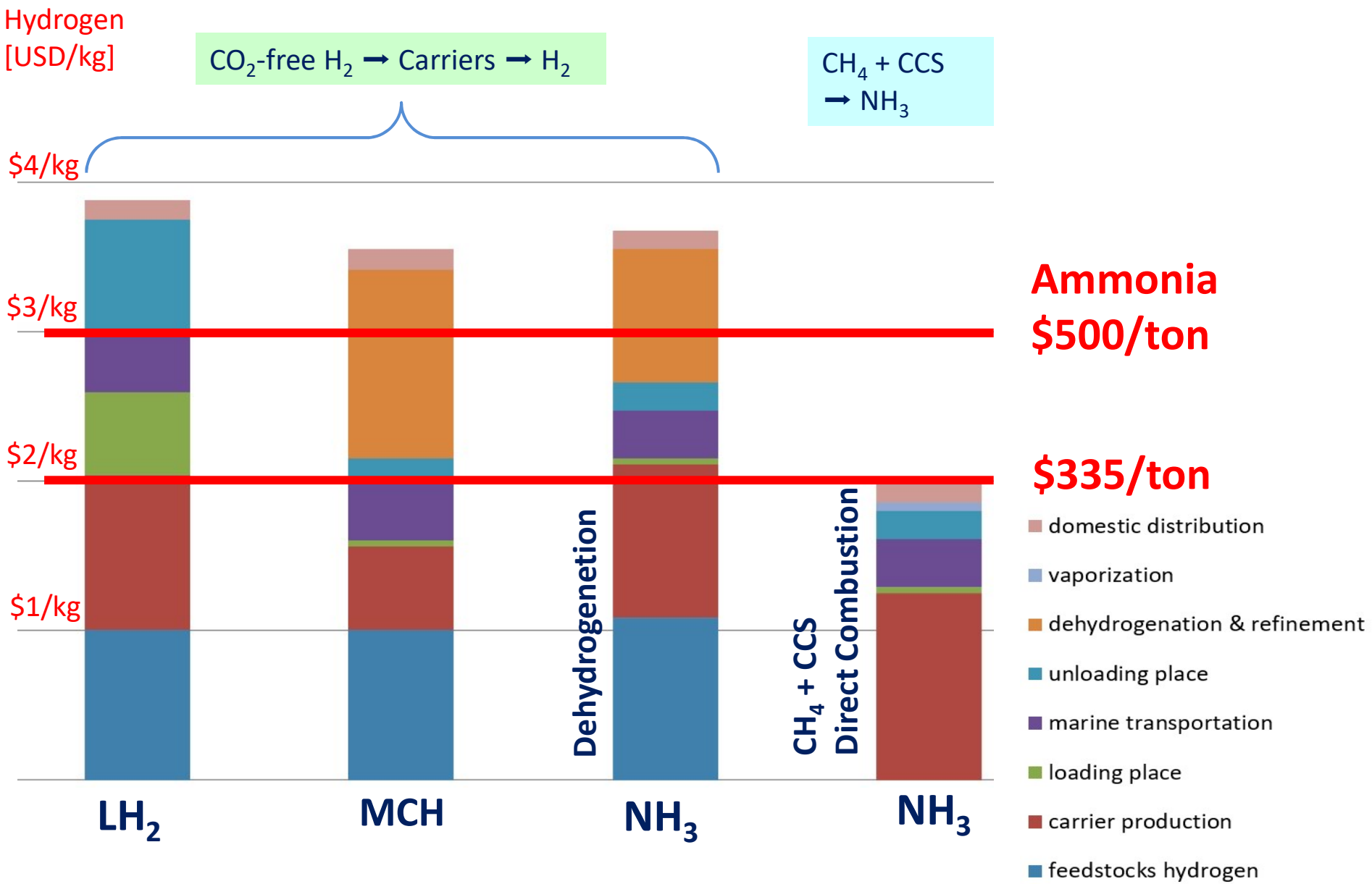
Electrolyzer

NH_3 Plant

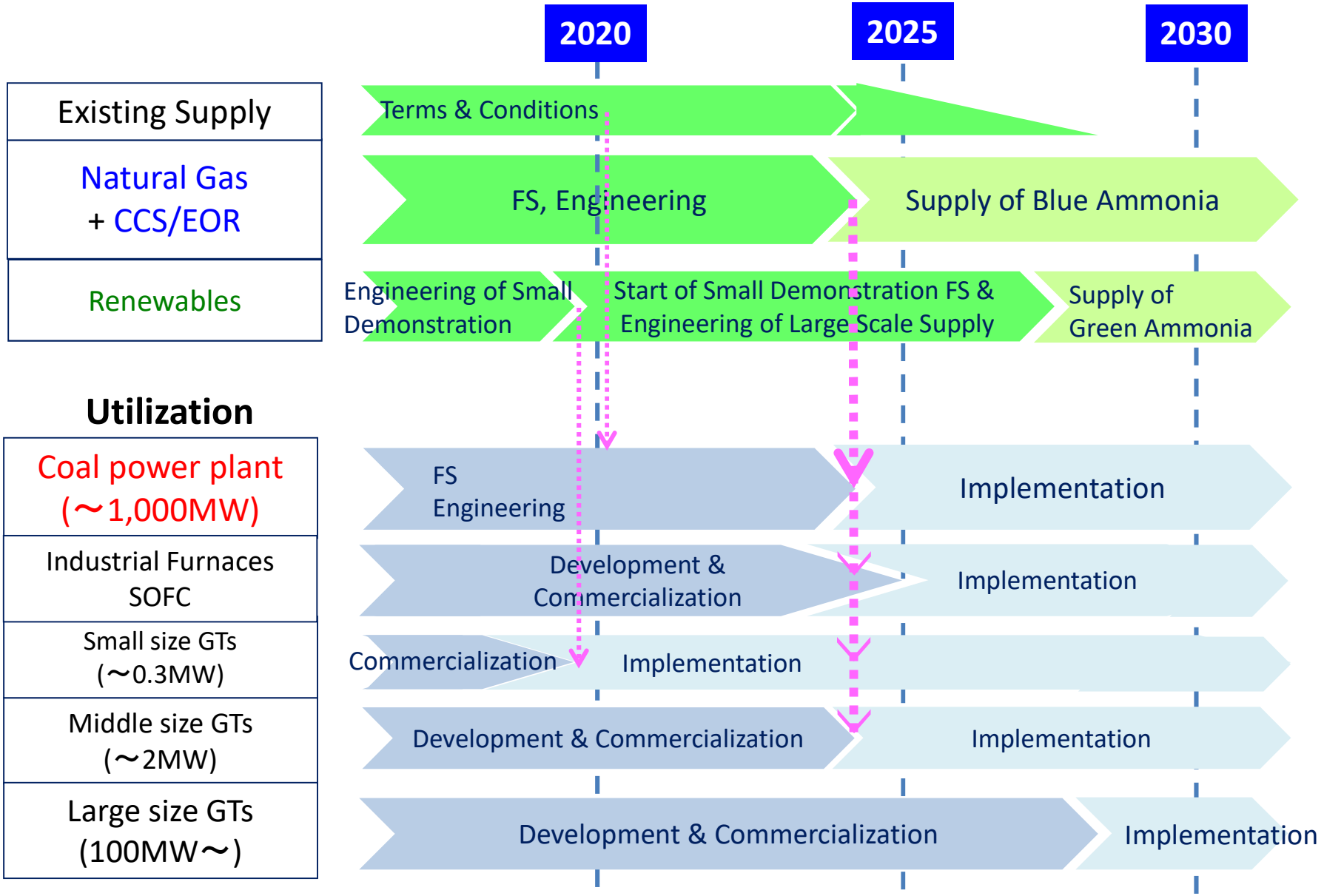
Australia, US, Middle East Countries

- Cost comparable with renewables in Japan
- Viable low carbon option for coal power

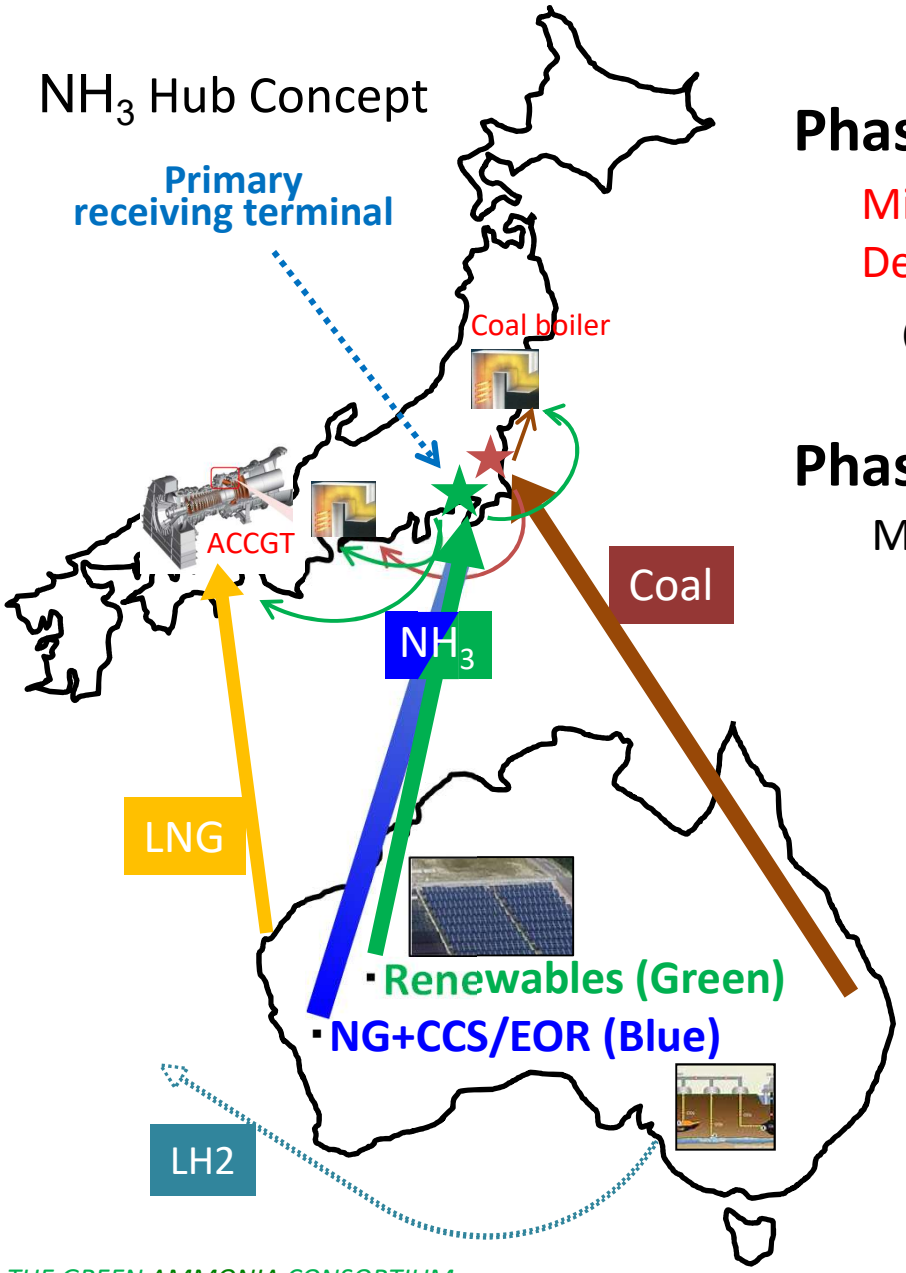
Cost Comparison of Energy Carriers



Roadmap of Ammonia Supply Chain



Implementation plan of green ammonia



Phase Ⅰ

Mixed combustion in Coal Power

Development of NH_3 supply infrastructure

（Primary receiving terminal + Delivery system）

Phase Ⅱ

Mixed combustion in ACCGT

Distributed Power

(Small & Mideum GTs, SOFC)

Industrial Furnaces

Marine Engine

＜C-free Power Generation＞

NH_3 ACCGT

Replacement of Coal Power to NH_3 ACCGT

（ACCGT：Advanced Combined Cycle Gas Turbine）

The Green Ammonia Consortium

Established in July 2017 under SIP
April 2019: Independent & Open Organization for Global Industry

Objective:

- Promotion of collaborations between industry, government and academia
- Commercialization of CO_2 free NH_3 value chain
- Strategy & Policy making
- International collaboration

Members:

More than 70 companies/ Institutes from Japanese and Global industries
Power industry / Oil and Gas industry / Engineering and Manufacturing industries / Chemical industry / Trading industry / Financial industry / Research institutes

Affiliation with Ammonia Energy Association (AEA)

International Collaboration Activities
Framework for Green & Blue NH_3 and Certifications

Thank you for your attention.