Implementation of Ammonia Energy Value Chain

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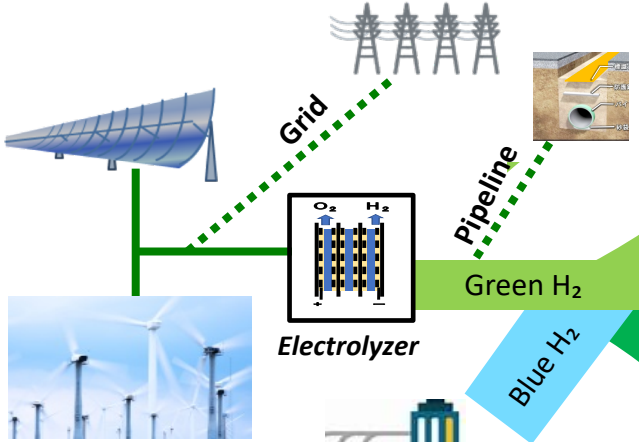
Hydrogen Energy Carriers for Global Renewables

Renewable Rich Countries



Oil & Gas Producing Countries

(USA etc.)

H_2 Carriers for **Marine Transportation**

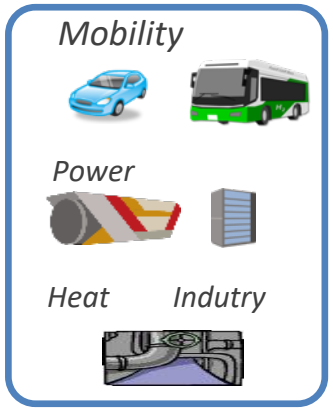
- Liquid Hydrogen (LH_2)
- Methyl Cyclohexane (MCH)
- Ammonia (NH_3)

H_2

Green & Blue NH_3

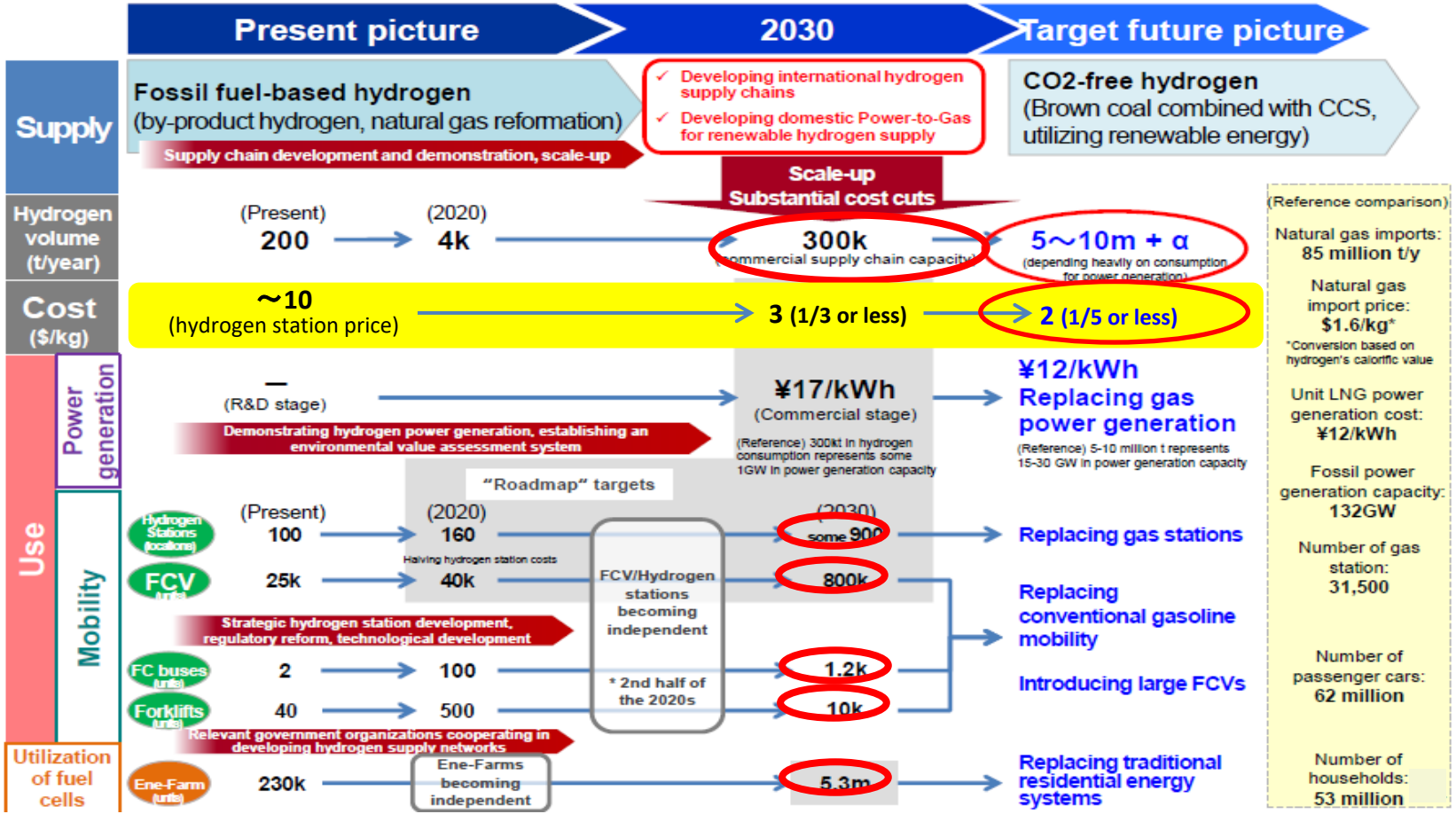
Energy Market

(Japan etc.)



Considering all elements of cost and efficiency, Ammonia is the most economical and viable option.

Scenario for Basic Hydrogen Strategy



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 47kg-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.）
- Technologies are becoming ready for commercial use.

- Safety standards are practically used in chemical and power industries.
- Primary markets are controlled facilities with trained operators
  such as power plant, industrial factories and data centers.

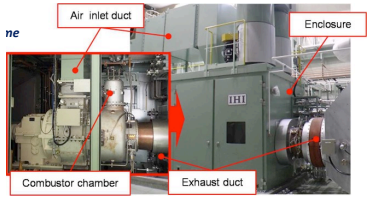
Key Technologies of Ammonia Utilization in the Energy Market

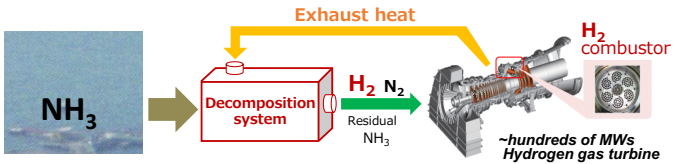
Gas turbines

50 kW, 300 KW：NH_3 Single Fuel

2MW：20% NH_3 in Natural Gas

ACCGT：Decomposition of NH_3 using part of exhaust heat and H_2 is supplied to turbine.
Efficiency is equivalent of CH_4.





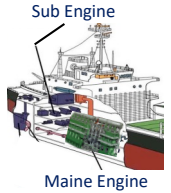
Mix combustion in coal fired boilers

20% NH_3 in Coal

SOFC 10kW～200kW

Industrial Furnaces

Marine Diesel Engine



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

Electrolyzer

H2

NH_3 Plant

Australia, US, Middle East Countries

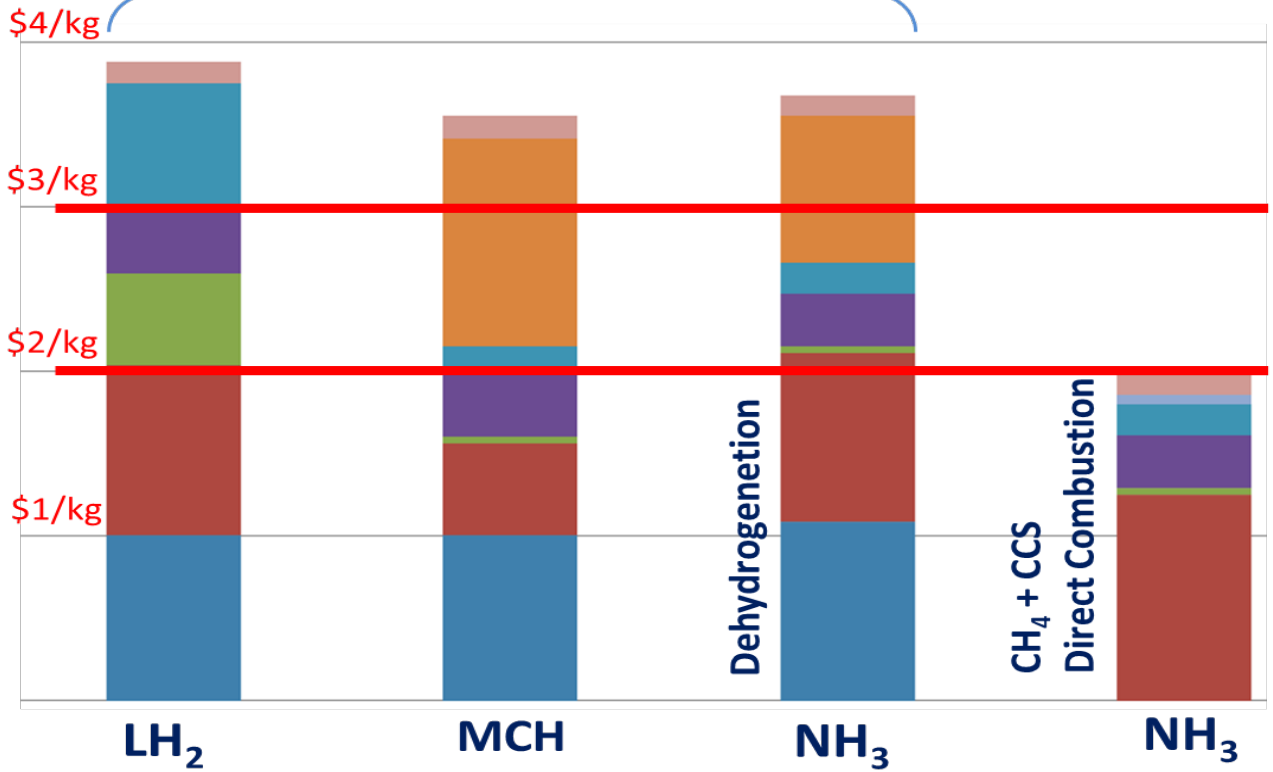
- Cost comparable with renewables in Japan
- Viable low carbon option for coal power

Cost Comparison of Energy Carriers

Hydrogen [USD/kg]

CO_2-free H_2 ➡ Carriers ➡ H_2

CH_4 + CCS ➡ NH_3

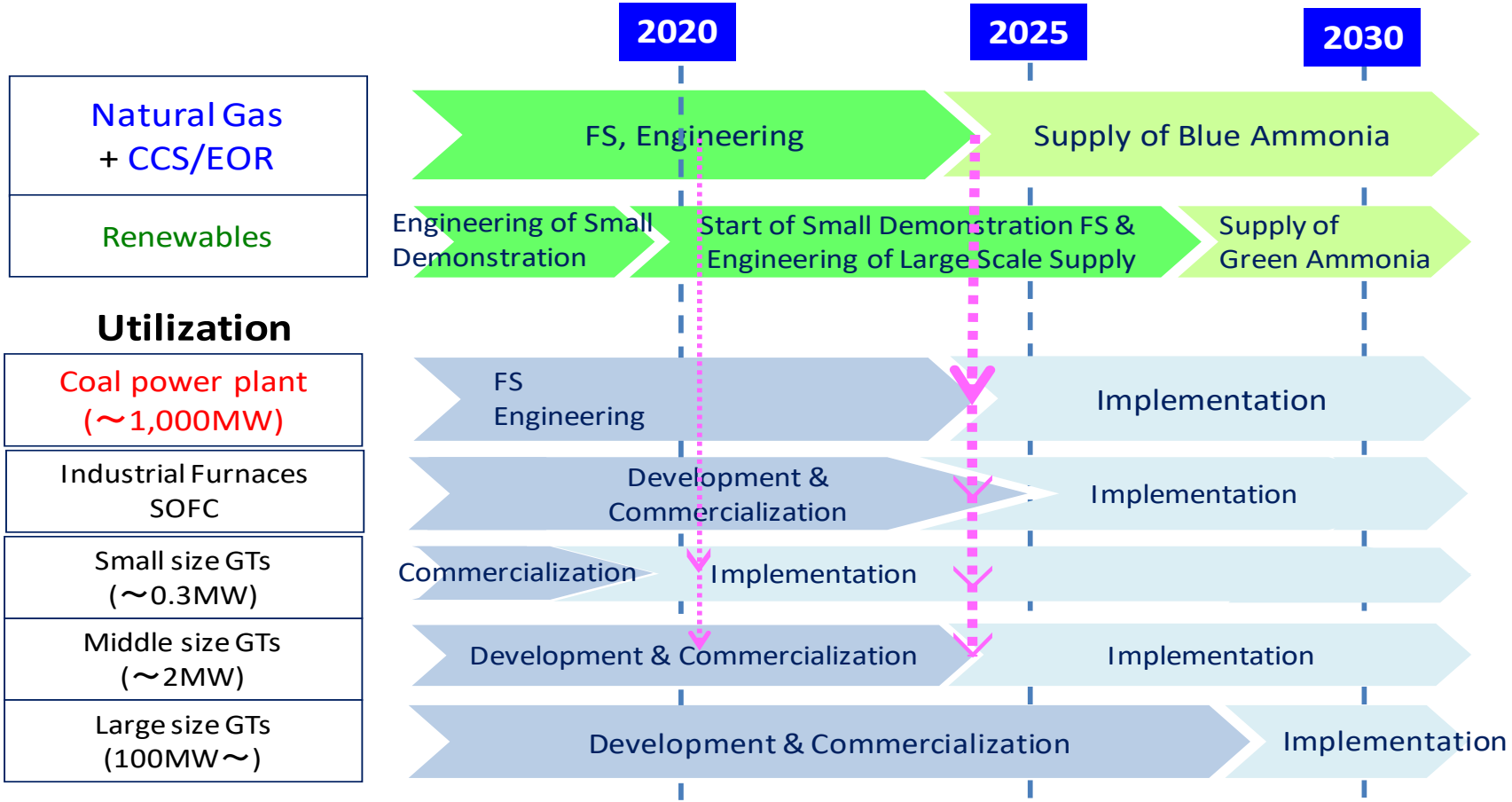


Ammonia $500/ton

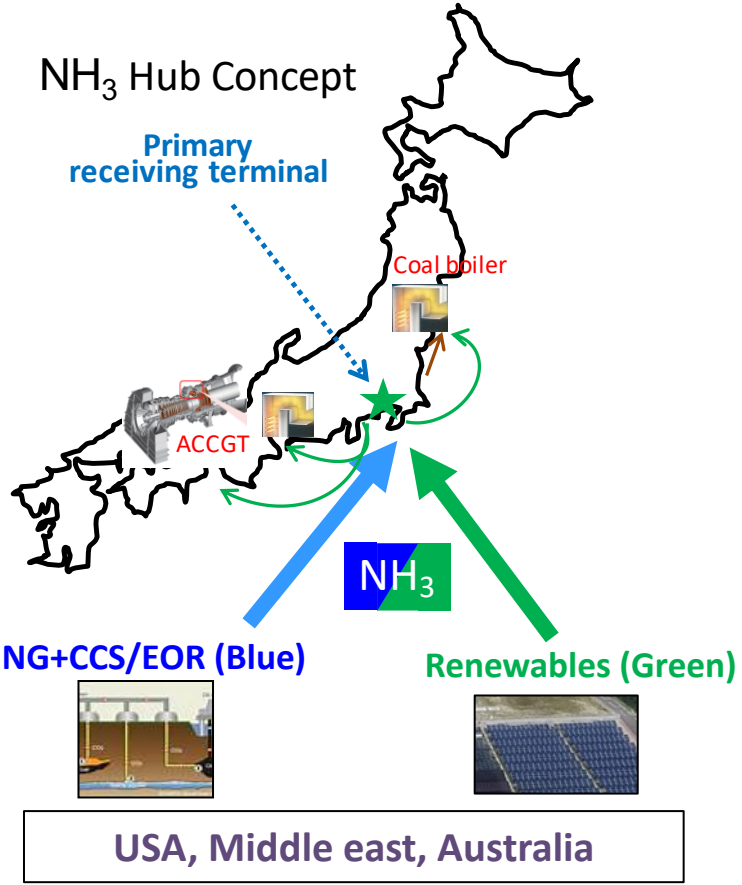
$335/ton

- domestic distribution
- vaporization
- dehydrogenation & refinement
- unloading place
- marine transportation
- loading place
- carrier production
- feedstocks hydrogen

Roadmap of Ammonia Supply Chain（GAC）



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

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 / Oil and Gas / Engineering and Manufacturing / Chemical / Trading / Financial / Research Institutes / Government Offices

International Collaboration Activities

- Affiliation with Ammonia Energy Association (AEA)
- Framework for Green & Blue NH_3 and Certifications

Organization of GAC

Thank you for your attention.