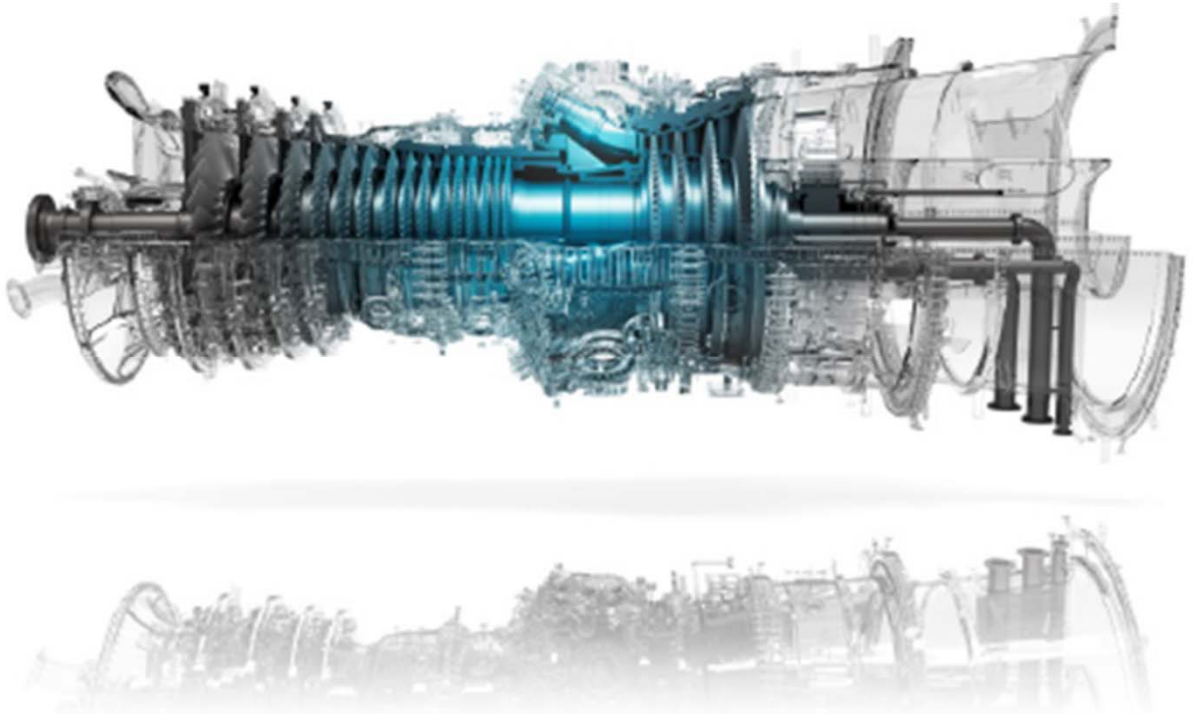
ETN's 15th Annual General Meeting & Workshop
27-28 March 2019, Pau, France

H2 Gas Turbine for Low Carbon Society



Satoshi Tanimura

Mitsubishi Hitachi Power Systems, LTD.

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1. Company introduction

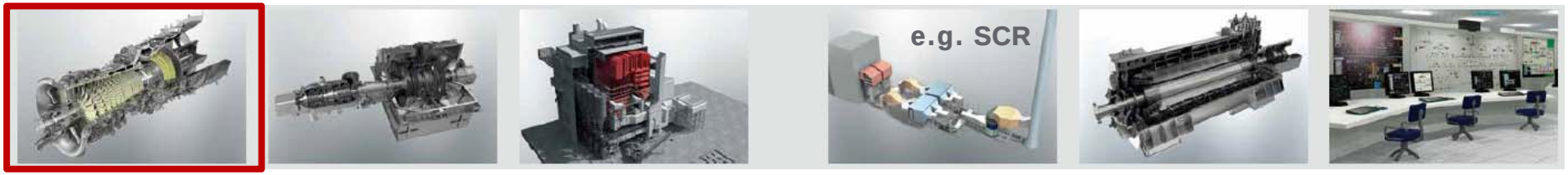
MHPS is a company for the thermal power generation system in MHI group

MHPS

Mitsubishi Heavy Industry (MHI) group

Products

Gas Turbine | Steam Turbine | Boiler | Environmental Products | Generator | ICT solutions



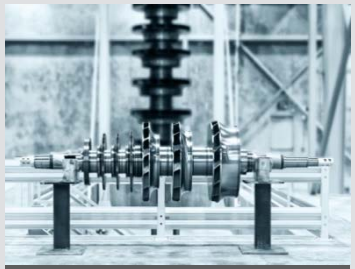
1. Company introduction
H2 related technologies in MHI group

As MHI group, we can contribute to key technology in global supply chain

Production


Gasification Plant


CO_2 Capture Plant


Compressor

Offshore wind turbines

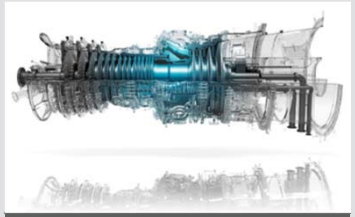

Geothermal

Carrier

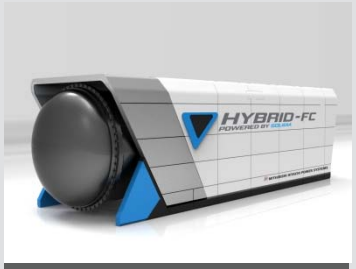

Ammonia & Methanol Co-production plant


LNG carrier

Demand


H2 Gas Turbine


Steam power



Hybrid fuel cell generator

1. Company introduction
H2 related activities in MHI group

Various activities related to H2 are on-going in MHI group

Global Alliances

Hydrogen Council

ALIGN CCUS

SIP

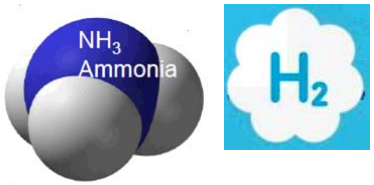
(Strategic Innovation Promotion Program)

AHEAD

Research & Development

H2 Gas Turbine

Ammonia cracking system



Reuse of captured CO_2

(as synthetic fuel)

Large-scale energy storage and conversion

Active Projects

H2 Gas Turbine

Nuon Magnum

- Convert 1 GTCC to 100% H2-firing by 2025
- 1.3 M tons/year CO2 reduction

Solid Oxide Fuel Cell (SOFC)

Kyushu University

- In operation – 6 sites
- Under construction – 1 site

Mixed fuel to Steam Plant

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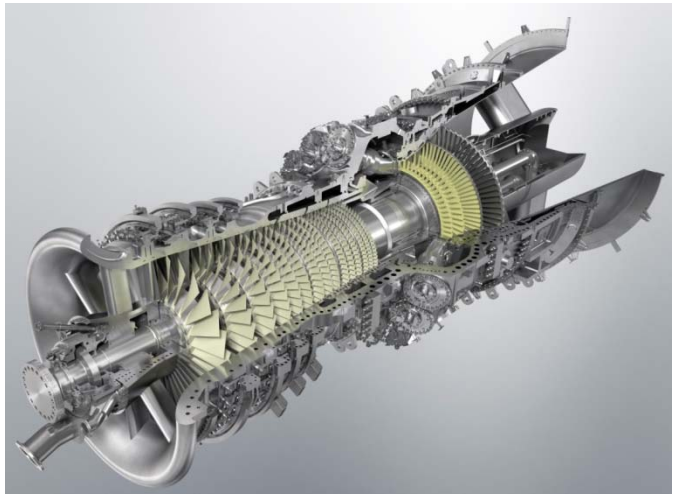
2. MHPS Gas Turbine development
H2 Gas Turbine

Existing Gas Turbine can run with hydrogen
by limited modifications to combustion parts

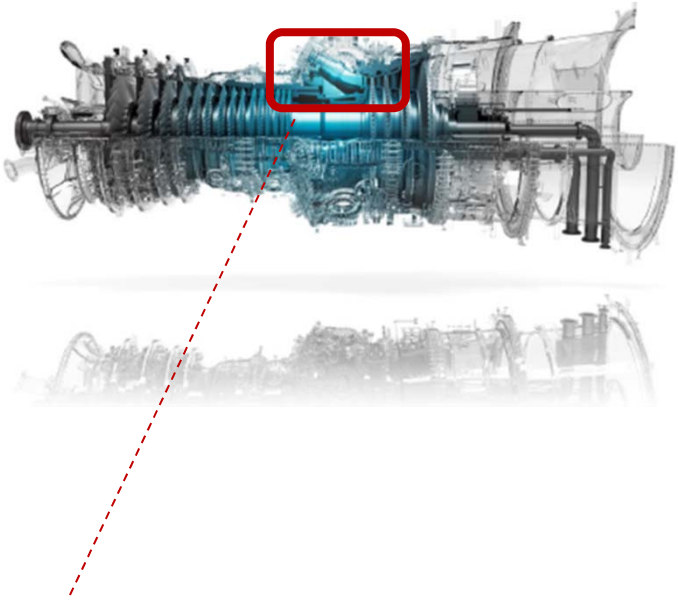
Advanced Technology



MHPS's "JAC"
Super High Efficiency GTCC

Efficiency : ~65%
Availability: 99.5%

H2 Gas Turbine



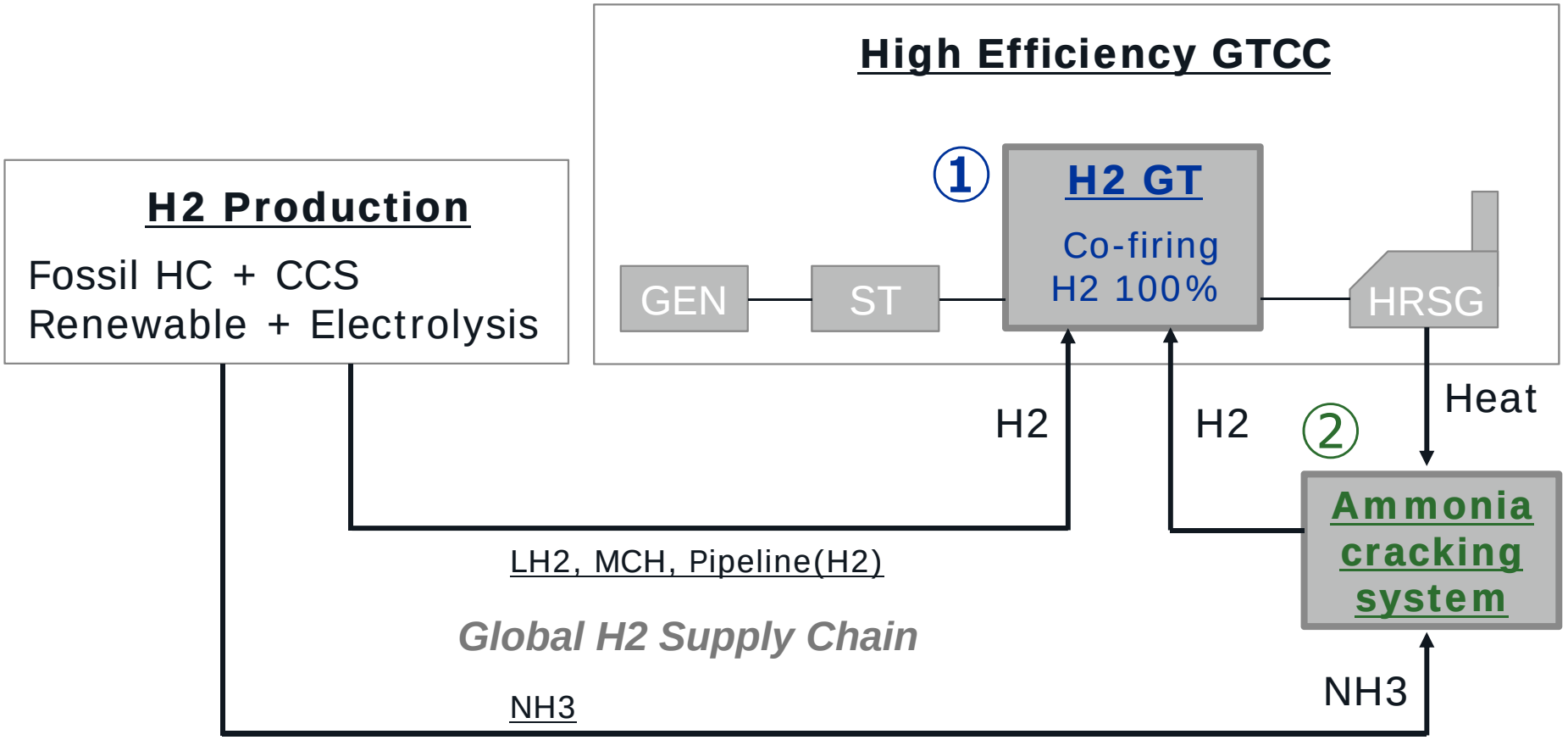
Limited modification to combustion parts

2. MHPS Gas Turbine development
H2 Gas Turbine

R&D for H2 Gas Turbine are on-going in 2 areas;

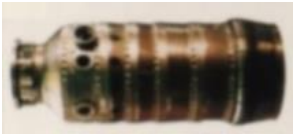
① H2 Gas Turbine combustion technology development

② Ammonia cracking system by using Gas Turbine exhaust heat



2. MHPS Gas Turbine development
H2 Gas Turbine

① H2 Gas Turbine combustion technology development

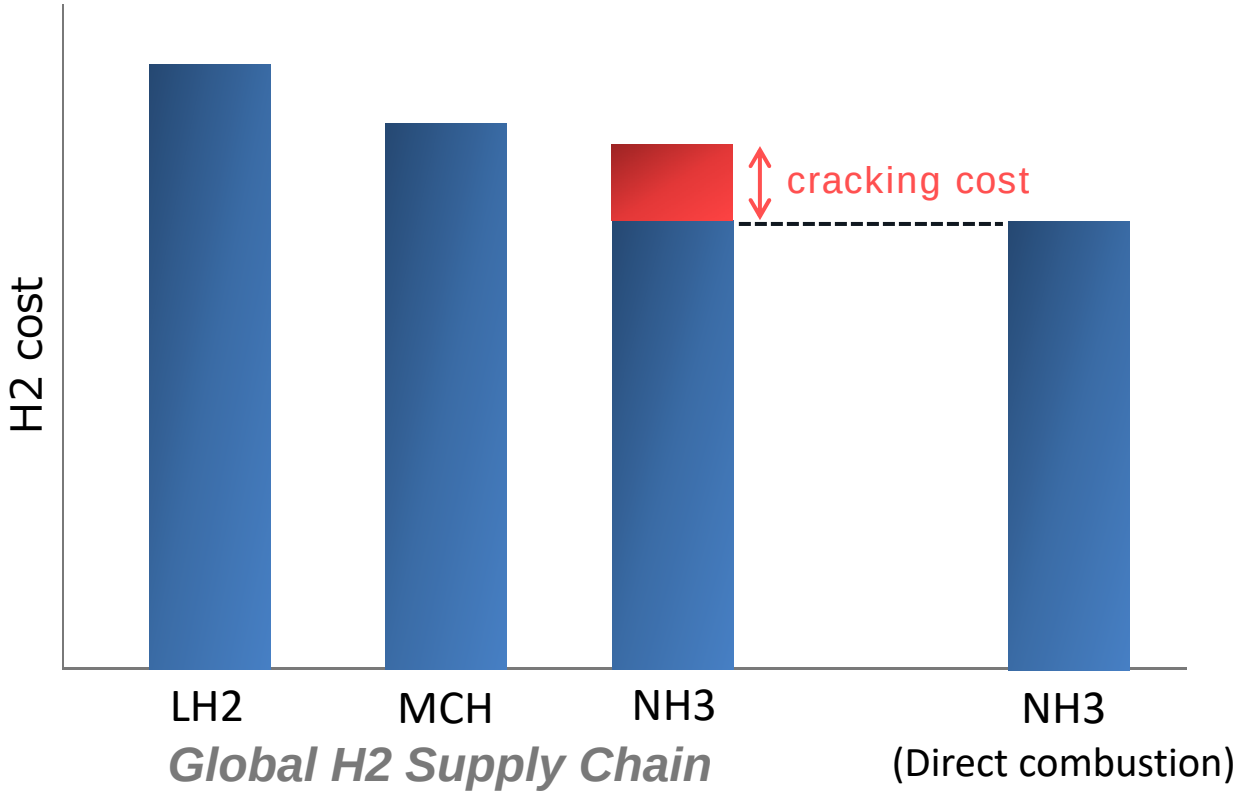
	Type	Low NOx tech.	Turbine Inlet Temp.	H2 density	Schedule
Ready	Diffusion 	N2 dilution, Water/Steam injection	1200 ~ 1400℃	~ 100%	1970 ▼ Cogen/IGCC (31 units, > 3 mil hours experience) → 2025 ▼ Nuon Magnum H2 conversion
Ready	Pre-mix 	Dry	1600℃	~ 30%	▼ DLN → ▼ 30% co-firing test completed (*NEDO PJ)
Under development	Multi-Cluster 	Dry	1650℃	~ 100% (target)	target ~2024 ▼ Under development (*NEDO PJ)

*Developed under Hydrogen Value Chain National Project in Japan by NEDO (New Energy and Industrial Technology Development Organization)

2. MHPS Gas Turbine development
Ammonia Cracking Gas Turbine

② Ammonia cracking system by using Gas Turbine exhaust heat

- NH3 has advantage in cost and technical maturity
- Efficiency improvement of cracking system is the key for NH3 use



H2 cost:
- Target H2 cost in Japan at 2030
- Blue H2 basis (Natural Gas + CCS)
- Incl. dehydrogenation/cracking cost
- Transport distance 10,000km (≒Australia to Japan)

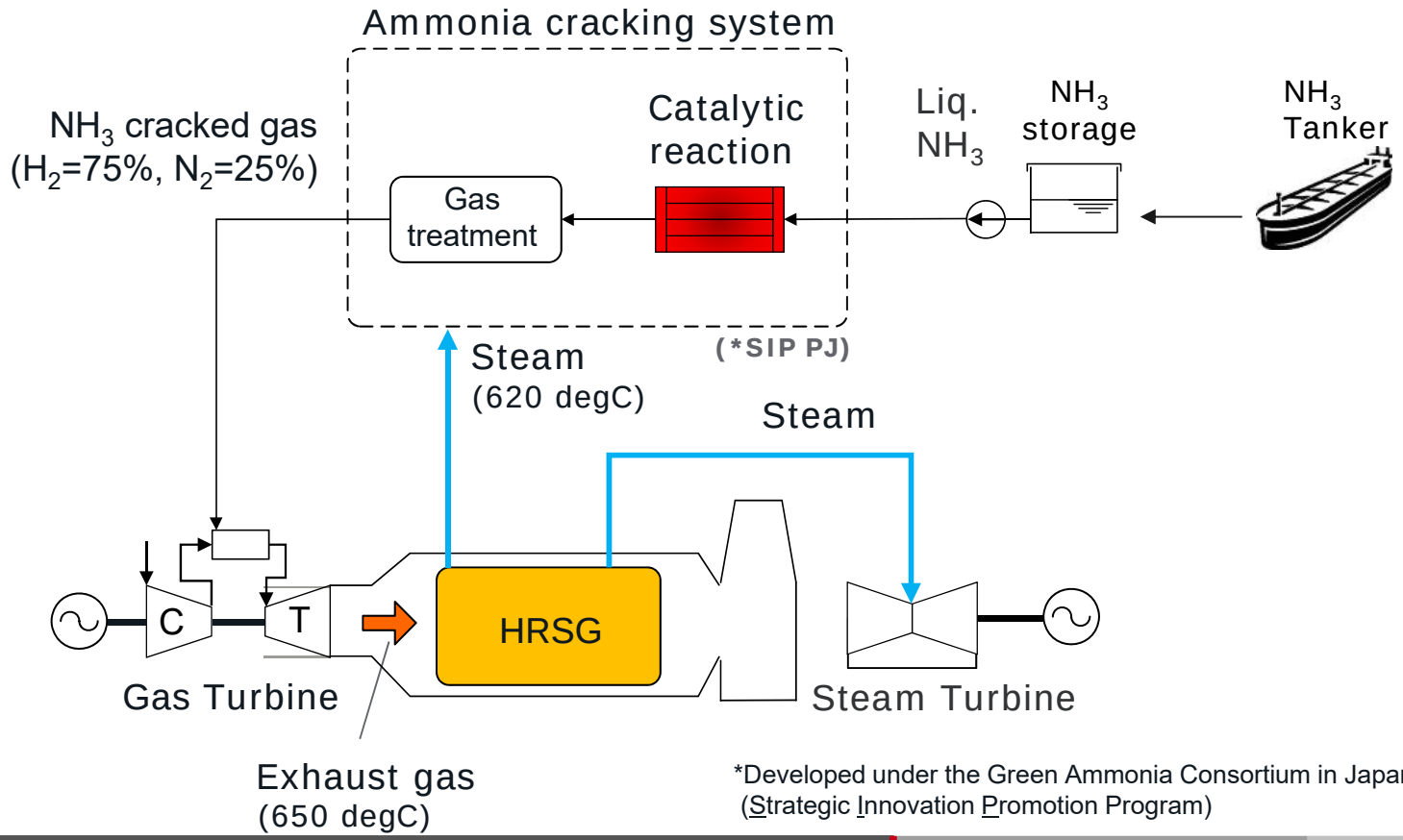
Reference:
The Institute of Associated Energy (Japan)
http://www.iae.or.jp/wp/wp-content/uploads/2018/02/metanation_20180221.pdf

2. MHPS Gas Turbine development
Ammonia Cracking Gas Turbine

② Ammonia cracking system by using Gas Turbine exhaust heat

- Ammonia is cracked to H2 and N2 by utilizing exhaust heat of GT
- The cracked H2 and N2 can burn by H2 Gas Turbine

[System configuration example]



*Developed under the Green Ammonia Consortium in Japan by SIP (Strategic Innovation Promotion Program)

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3. Summary（1/2）

(1) MHPS H2 Gas Turbine will contribute to Low Carbon Society

H2 Gas Turbine

Reduce CO2 at large scale

- 1.3 M tons/year CO2 reduction by 440MW CCGT

Fuels H2 infrastructure development

- Large H2 demand for power generation

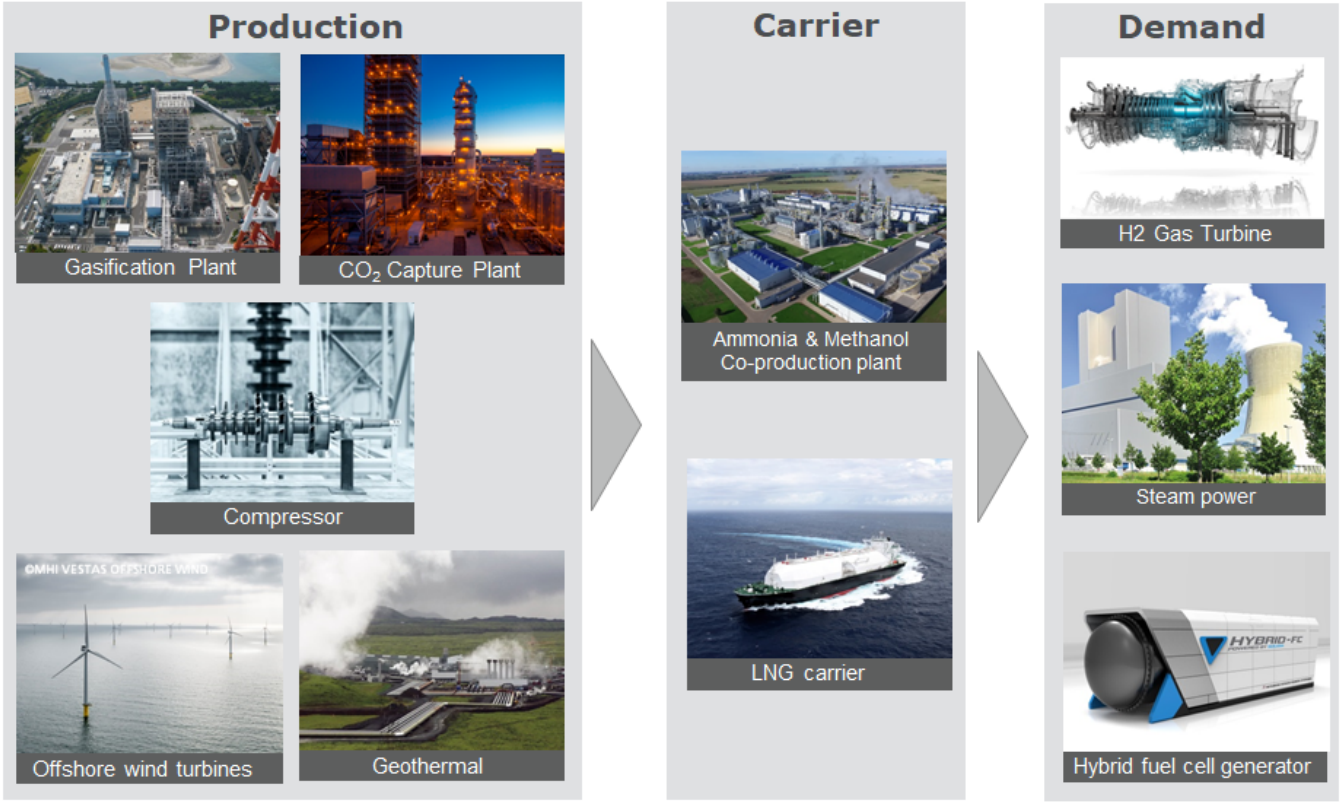
Ammonia cracking at best efficiency

- Utilize exhaust heat from Gas Turbine

Low Carbon Society

3. Summary（2/2）

(2) MHI group can contribute to realize global H2 supply chain



(3) Public-Private Partnerships are essential to realize the technology roll-out

Power for a Brighter* Future