MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

Mitsubishi Heavy Industries (MHI)

Hydrogen/Ammonia Solution Ecosystem

Ammonia Energy Association Conference 2021

November 10. 2021

Ricky Sakai

Mitsubishi Heavy Industries America, Inc.

MITSUBISHI HEAVY INDUSTRIES

Mitsubishi Group Companies

Total Number of Employees	Apx. 570,000	Number of Group Companies	600 +
Total Sales Turnover	Apx. US$580 Bil.	Year of Foundation	1870

Mitsubishi Group

Mitsubishi Corporation

MITSUBISHI HEAVY INDUSTRIES

MUFG

ENEOS

MITSUBISHI ELECTRIC

MRI

MITSUBISHI PAPER MILLS LIMITED

MITSUBISHI CHEMICAL

KIRIN

MGC

MITSUBISHI PLASTICS

Mitsubishi Logistics

Nikon

FUSO

MITSUBISHI MOTORS

MEIJI YASUDA

TOKIO MARINE NICHIDO

Tokio Marine & Nichido Fire Insurance Co.,Ltd.

Yusen Logistics

NYK LINE NIPPON YUSEN KAISHA

MHI Group at a Glance

Technology-focused conglomerate company across industries from Energy, Infrastructure, Transportation, Space and Defense for over a hundred years

COMPANY HIGHLIGHTS

$36.7BN
Annual revenue (*)

54%
Sales outside Japan

83,000
Employees worldwide

Americas	$ 7.7 Bil.
Japan	$ 17.7 Bil.
Asia Pacific	$ 6.6 Bil.
EMEA	$ 4.7 Bil.

More than
24,600
Patents

130+
Years

240+
Global companies

(FY2019 Results @110JPY/$)

MHI Group Technologies and Domain

Energy Systems

MITSUBISHI POWER

THERMAL POWER GENERATION SYSTEMS

MITSUBISHI HEAVY INDUSTRIES COMPRESSOR CORPORATION

COMPRESSORS

RENEWABLE ENERGY&STORAGEE

NUCLEAR ENERGY SYSTEMS DIVISION

Aircraft, Defense & Space

COMMERCIAL AIRPLANES

AIRCRAFT DIVISION

MHIRJ

REGIONAL AVIATION MRO

SPACE SYSTEMS DIVISION

Plant & Infrastructure Systems

CHEMICAL PLANTS

MITSUBISHI HEAVY INDUSTRIES ENGINEERING

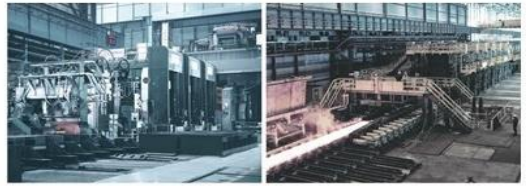
ENVIRONMENTAL PROTECTION SYSTEMS

CO2 CAPTURE SYSTEM

MITSUBISHI SHIPBUILDING

SHIPBUILDING & OCEAN DEVELOPMENT

LAND TRANSPORTATION SYSTEMS

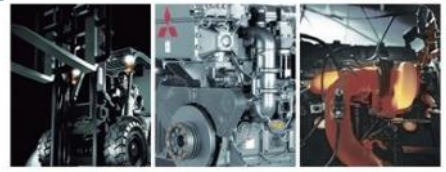


METALS MACHINERY PRIMETALS TECHNOLOGIES

Logistics, Thermal & Drive Systems

Logisnext

MITSUBISHI HEAVY INDUSTRIES ENGINE & TURBOCHARGER



MATERIAL HANDLING EQUIPMENT / ENGINE & ENERGY / TURBOCHARGER

MITSUBISHI HEAVY INDUSTRIES THERMAL SYSTEMS

AIR-CONDITIONING & REFRIGERATION

MHI's strategy to achieve Carbon Neutrality

Build an innovative solutions ecosystem to realize a carbon neutral future

Decarbonize existing infrastructure

Build a hydrogen solutions ecosystem

Build a CO_2 solutions ecosystem

Highly Efficient Turbomachinery

Renewable Energy & Storage

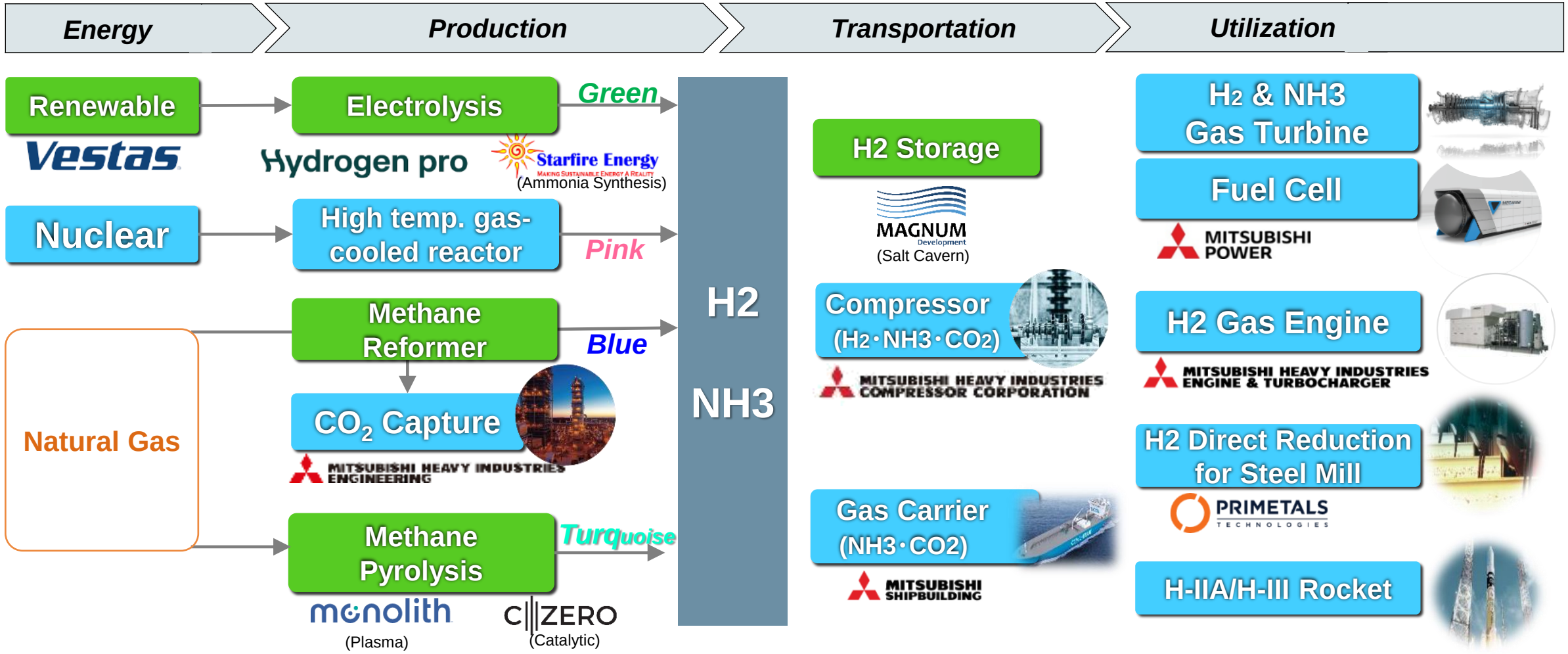
Hydrogen GT

CO2 Carrier

CO2 Capture and Utilization

Build Hydrogen / Ammonia Solution Ecosystem

The MHI Group has a vast range of technologies and end-to-end solutions for hydrogen value chain



- Expanding value chain by R&D activities and Strategic partnership
- Developing flagship projects all over the world

In-House | Partnership

MHI's Global Green & Blue Hydrogen / Ammonia Project : Developing Flagships

Bakken Energy
Clean Hydrogen Hub
Bismarck, North Dakota

Harrison Energy Center
1,200 MW Green Hydrogen Power
Harrison County, Ohio

Vattenfall Magnum
Existing GTCC Conversion to Blue Hydrogen
Eemshaven, Netherlands

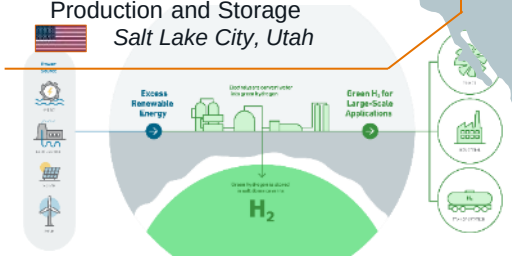
Intermountain Power
840 MW Green Hydrogen Power
Salt Lake City, Utah

Danskammer Energy Center
600 MW Green Hydrogen Power
Newburgh,NY

Green Energy Hub
100MW Green Hydrogen Production
Hamburg, Germany

Chickahominy
1,500 MW Green Hydrogen Power
Charles City,VA

ACES
World's Largest Green Hydrogen Production and Storage
Salt Lake City, Utah



Keppel Data Centers
Tri-generation from Blue Hydrogen
Singapore

HySTRA
CO_2-free Hydrogen Usage
Japan

Entergy Decarbonization
Multiple Green H2 Project
Across Four Utilities
TX, LA, MS, AK

H2@Scale Texas
Renewable Hydrogen network

Global Hydrogen Experiences

H2U
Green Ammonia Project
South Australia

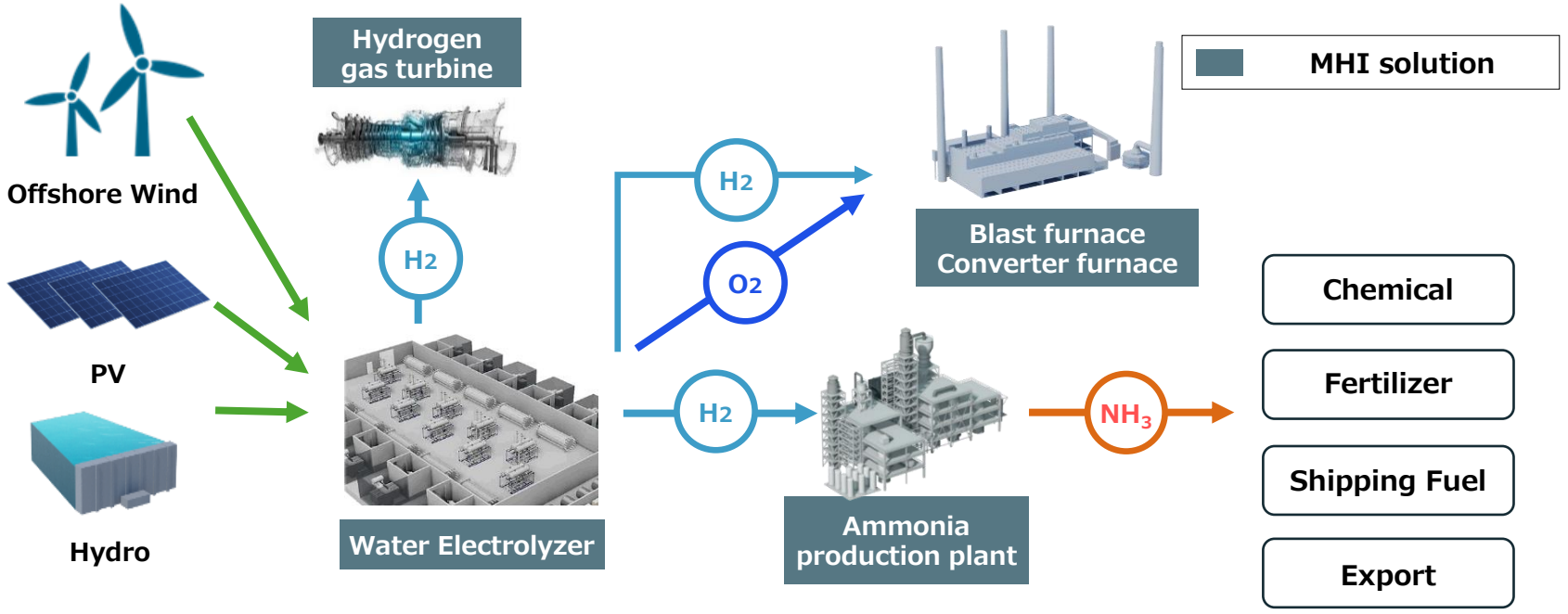
HySTRA
CO_2-free Hydrogen from Coal
Latrobe, Australia

Establishing Hydrogen Energy Value Chain

Partnership / Project　Carbon-free Ammonia Production Project

Green

- Capital participation in H2U Investments conducting carbon-free ammonia production project in South Australia
- Making use of abundant renewable energy in the area, producing hydrogen and ammonia. Contributing to the region's industries such as nearby steel mills, and export carbon-free ammonia



Ammonia as Fuel: CO2 Free Ammonia Value Chain

CO2 Free Production

Renewable Power

Water

Electrolysis

N2

Green H2

Ammonia Plant

Green

Blue

Ammonia

fertilizer

Blue H2

EOR /CCS

CH4

Hydrogen (Reformer)

Air

CO2

CCS Plant

CO2

LCO2

CO2 Free Transportation

IMO GHG reduction target 2050
△ 70% by Efficiency , △ 50% GHG Emission

Ammonia powered Ammonia Carrier

Ammonia expected as Hydrogen carrier

Ammonia powered Bulk carrier

CO2 free "Coal" transport

Ammonia powered LCO2 carrier

LCO2

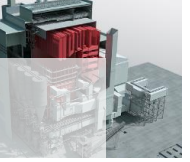
CCS Plant CO2 liq.

CO2

CO2 Free or Reducing utilization

Hydrogen Power plant

City Use hydrogen power



Ammonia Power plant

Coal ammonia Co-firing power plant

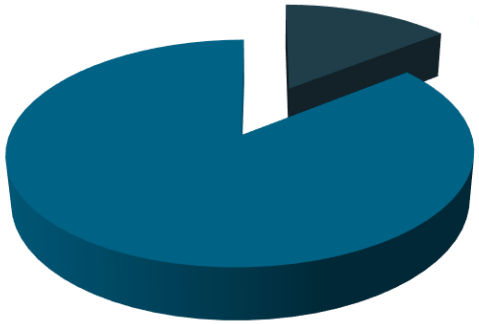
The **use of ammonia fuel for ships** reduces CO2 emissions throughout the Supply chain.

Ammonia Production EPC + CO2 Capture = Blue

Blue Ammonia

MHI group is a leading EPC contractor for Ammonia, and CCS plant
Business development of Blue / Green Ammonia undergoing

Contractors Share for Ammonia Plant (2008 – 2018 / Capacity-Based)



MITSUBISHI HEAVY INDUSTRIES ENGINEERING

(14.3%)

***15** Ammonia plants*
with HTAS technology
built Globally

Mitsubishi Heavy Industries Engineering, Ltd. is a authorized licensee of Haldor Topsoe Ammonia Technology

Plant location	NRG WA Parish Power Plant (Thompsons, TX)
Project owner	Petra Nova – partnership between NRG Energy and JX Nippon Oil & Gas
Plant scale	240 MW_{eq}
CO_2 capacity	4,776 TPD (1.4 MMtonne/year)
CO_2 conc.	11.5 mol%-wet
CO_2 removal	90%

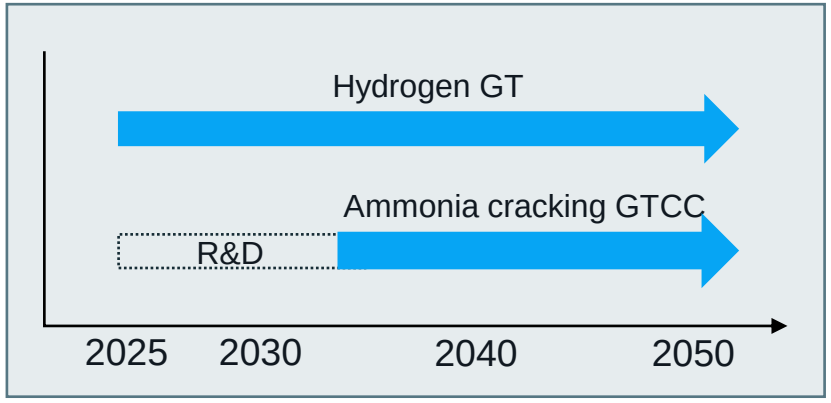
CO_2 Used for CO_2-EOR	
Pipeline	12 in diameter, ~ 81 miles
Injection Site	West Ranch Oil Field

Ammonia as Fuel- Technology Development

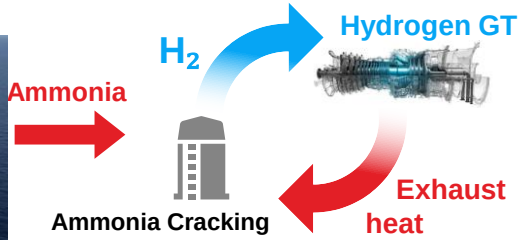
Utilization of ammonia is a path to H_2 society mitigating economical impact

Hydrogen Carrier

- Utilize ammonia as a carrier of voluminous hydrogen
- Exhaust heat from GT used for ammonia cracking



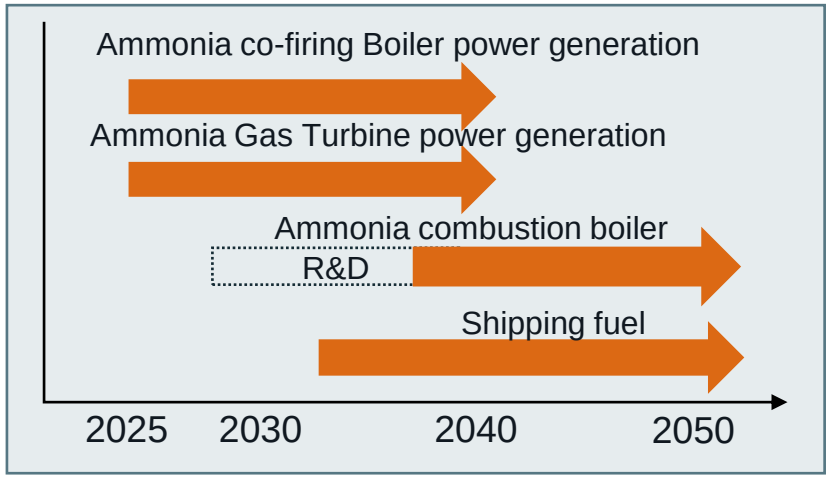
Ammonia Powered Ammonia Carrier

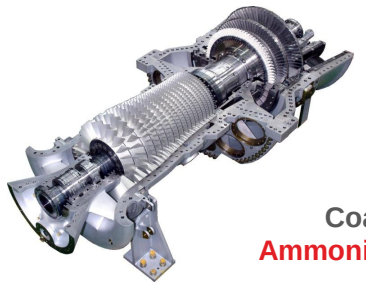


Ammonia Cracking GTCC

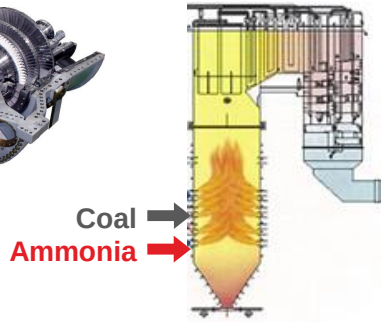
As Fuel

- Use ammonia as low CO_2 emission or carbon-free fuel





Ammonia Gas Turbine



Ammonia Co-Firing Boiler

Shipping Fuel

Participate in Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

Ammonia Fuel Gas Turbine

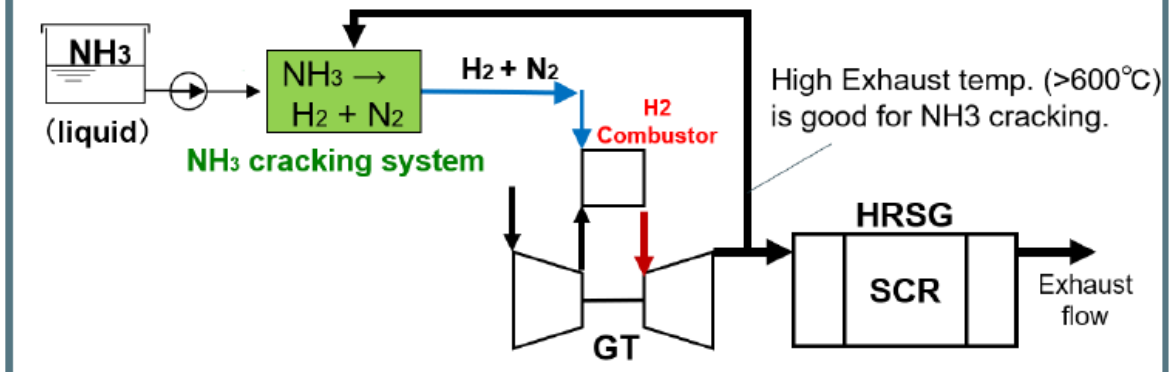
Ammonia Cracking GTCC

Apply to large frame GTs with high combustion temp. and high efficiency operation.

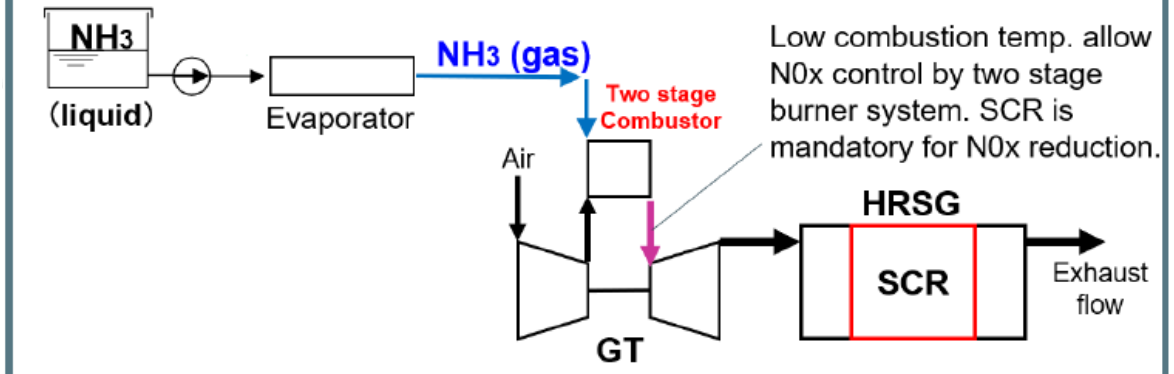
Ammonia Direct Combustion GT

Ideal for small frame GT due to low combustion temperature operation

High efficiency large frame GT



Small Frame GT



Ammonia Direct Combustion GT Development

- Commenced development of gas turbine fueled by 100% ammonia. (30- 40MW, H-25)
- Utilizing combustion technology to reduce NOx emissions generated from nitrogen in fuel
- Expanding lineup of carbon-free power generation options.

PRESS RELEASE

Mitsubishi Power Commences Development of World's First Ammonia-fired 40MW Class Gas Turbine System -- Targets to Expand Lineup of Carbon-free Power Generation Options, with Commercialization around 2025 --

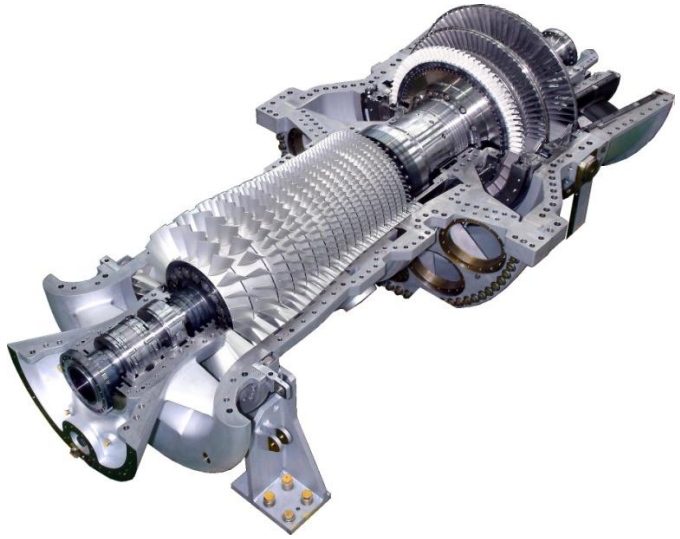
2021-03-01

• Utilizing technology that enables 100% direct combustion of ammonia will contribute to formation of ammonia fuel supply chain
• Commercialization will also support decarbonization systems for small to medium-scale power plants in industrial applications, on remote islands, etc.

YOKOHAMA, JAPAN (March 1, 2021) - Mitsubishi Power, a subsidiary of Mitsubishi Heavy Industries (MHI) Group, has commenced development of a 40-megawatt (MW) class gas turbine that is fueled by 100% ammonia (NH_3). The project

H-25 Gas turbine

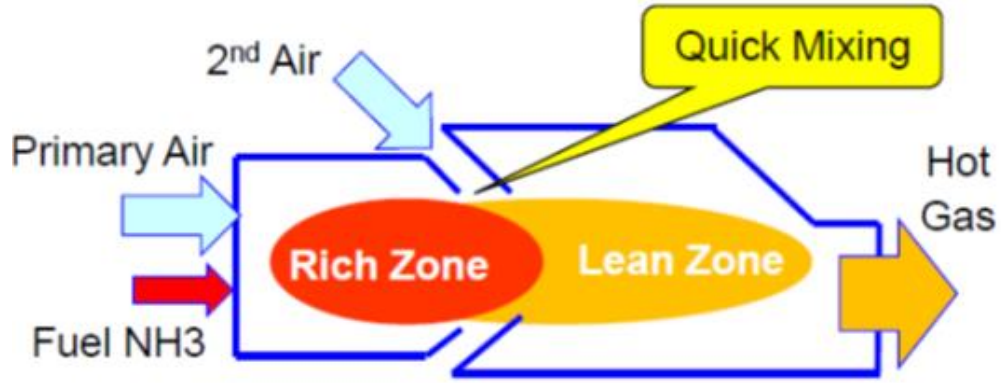
- Output : 41.0MW
- Efficiency : 36.2% (SC)
- 80% + (Cogen)
- Delivered fleet : 189 units



Ammonia Direct Combustion GT Development

- Combustion stability is maintained by using “Diffusion Combustion Method”.
- Fuel-NOx formation is controlled by using “Two-stage Combustion Technology”;
- Rapid mixing of lean air enables switching from Fuel rich zone(1) to Fuel lean zone(2) without passing through the Fuel-NOx formation zone.

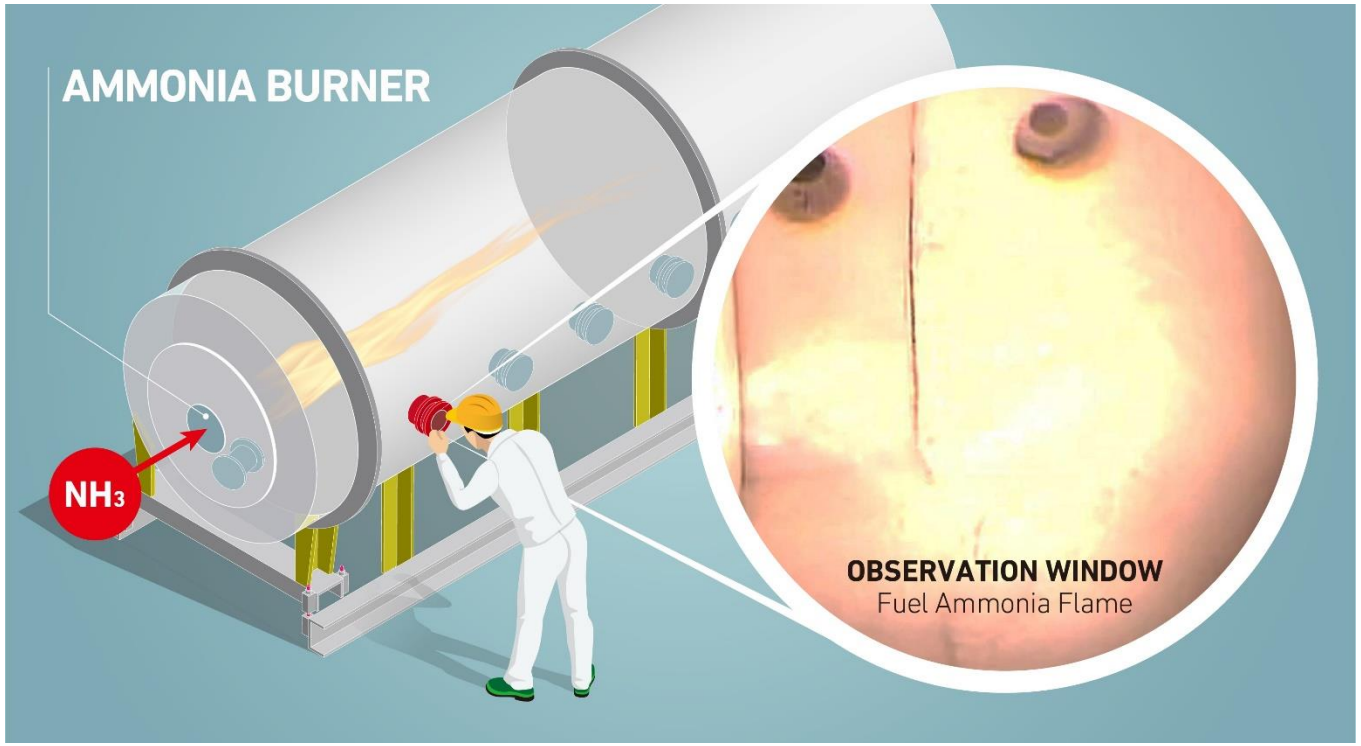
Solution
Rich-Lean
Two Stage Combustor



Model	Fuel	GT modification	Other modifications	Performance	Remarks
Standard H-25 (Base spec.)	LNG / NG	Base spec.	Base spec.	Base spec.	Existing
Ammonia Direct Combustion GT	100% Ammonia	Combustor only	Fuel Gas System Add./Improve. of De-NOx system	Same level as base spec.	New

Ammonia Co-Firing Boiler Development

- NOx emission minimized with appropriate firing system (including burners)
- Modification scope is limited to fuel supply and burner since the combustion speed of ammonia and pulverized coal is almost same. (Modification/addition of DeNOx system may be required, depending on NOx restriction/regulation.)
- Power generation can be maintained by coal even if ammonia supply is unstable.



Ammonia combustion test

Target : 20～50cal% Ammonia co-firing ratio
Modification scope : Burner and fuel/ammonia supply system.

MHI's strategy to achieve Carbon Neutrality

Build an innovative solutions ecosystem to realize a carbon neutral future

Decarbonize existing infrastructure

Build a hydrogen solutions ecosystem

Build a CO_2 solutions ecosystem

Highly Efficient Turbomachinery

Renewable Energy & Storage

Hydrogen GT

CO2 Carrier

CO2 Capture and Utilization

Build CO_2 Solution Ecosystem

- Expanding our advantage in CO_2 recovery through further technology development
- Enter into the value chain of CO_2 conversion and utilization

CO_2NTAIN

- Power plants (GTCC, Coal-fired, or biomass)
- SMR furnace exhaust
- LNG liquefaction Plant
- Cement and Steel plants
- Commercial facilities

→ CO_2 Recovery

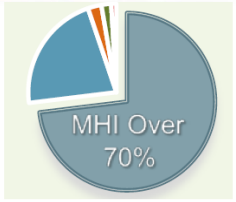
CO_2NNECT

+ Distribution

CO_2NVERT

CO_2 Conversion Utilization →

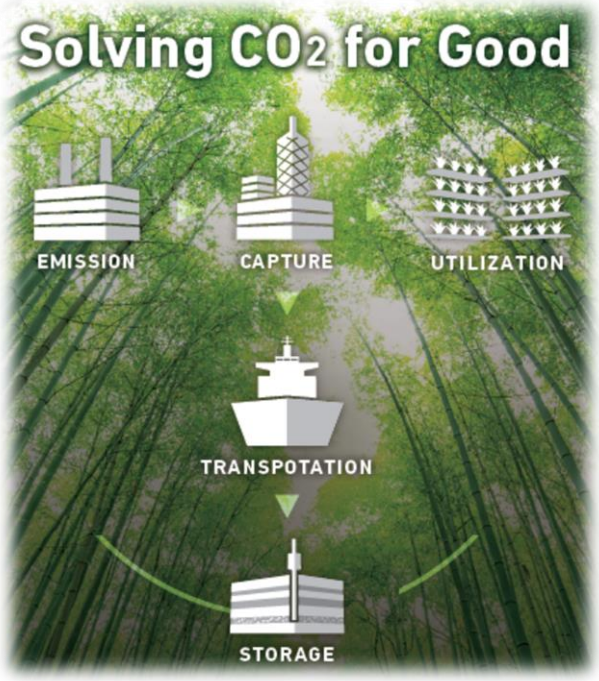
- Storage in earth layer：EOR、CCS
- Fuel synthesis: carbon recycled methanol, Jet Fuel
- Valuable products synthesis: carbon recycled Chemicals
- Industrial use: food and welding



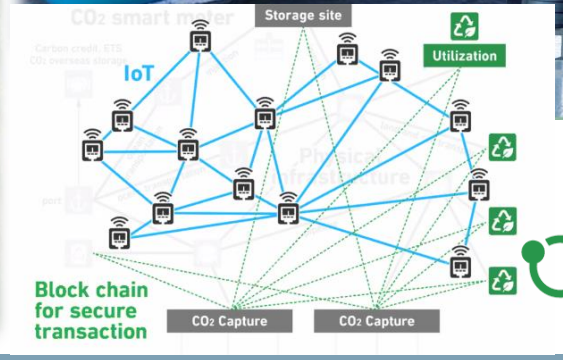
Biomass Power In UK

On-Board

CO_2 Capture



LCO2 carrier (CO_2L-Blue)



CO_2 to X

CO_2NNEX

CCS：Carbon Capture Storage

MITSUBISHI HEAVY INDUSTRIES

MOVE THE WORLD FORWARD

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