Mitsubishi Heavy Industries Group at a Glance

1884 Foundation
over 130 years history

78,486 Employees
(Consolidated)

256 Group Companies
(Consolidated)

¥4.2TN ($31.1BN*) Revenue
(FY2022, consolidated)

Note: The U.S. dollar revenue figure was converted from Japanese yen using the FY2022 average exchange rate, JPY 134.9/USD.

Diverse products
On land, at sea, in the sky, in space

Gas turbines
Compressors
Aero engines
CO₂ capture plants
Metals machinery
Chemical plants
Transportation
Waste-to-energy
Turbochargers
Aerospace
Rocket engines
Defense

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MISSION NET ZERO

2040 Carbon Neutrality Declaration

Through our group products, technologies, and services that help reduce CO₂ emissions, as well as new solutions and innovations to be developed with partners around the world, Mitsubishi Heavy Industries Group will contribute to realizing “Net Zero” emissions for the world as a whole.

To this end, each and every one of our employees is embracing and internalizing “Mission Net Zero” and will act to implement a “Net Zero” future.

Path to achieving Carbon Neutrality

Build an innovative solutions ecosystem to realize a carbon neutral future

<table>
<thead>
<tr>
<th>Target Year</th>
<th>Reduce CO₂ emissions across MHI Group Scope 1&amp;2</th>
<th>Reduce CO₂ emissions across MHI's value chain Scope 3 + reductions from CCUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>-50% (compared to 2014)</td>
<td>-50% (compared to 2019)</td>
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<tr>
<td>2040</td>
<td>Net Zero</td>
<td>Net Zero</td>
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</table>

Scope 1&2: The calculation standard is based on the GHG Protocol.
Scope 3: The calculation standard is based on the GHG Protocol. However, we also account for reductions achieved by CCUS as an MHI original index.

GHG: Greenhouse Gas  CCUS: Carbon dioxide Capture, Utilization and Storage
JAC Series Gas Turbine (50Hz)

- **Power Output**: 840 MW
- **C/C Efficiency**: > 64%
- **Reliability**: 99.5%
CO2 Zero power generation technology Roadmap

Reduce CO2 by High Efficiency Gas Turbine ➔ ZERO CO2 by Hydrogen Gas Turbine

1. High Efficiency Natural Gas-fired Gas Turbine
   - JAC series

2.1 Ammonia Biomass Co-firing Boiler
   - Ammonia co-firing

2.2 Gas Turbine Combined Cycle plant + CCUS

2. Ammonia Biomass co-firing
   - Toward CO2 Zero

3. CO2Zero
   - Hydrogen Gas turbine
   - Ammonia Gas Turbine Development
   - Hydrogen Production
     - water electrolyser
     - SOEC
     - Turquoise H2

CO2Emission (%)

0%  50%  Base

Technology Road Map
2020

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*1 :Based on Sub-C CO2 Emission
Ammonia Power Technology Roadmap

- **Gas turbine:** Working on combustor development, aiming for commercial unit operation and commercialization in 2025
- **Boiler:** Working on burner development, targeting commercialization of ≥50% mixed firing in early 2030s

**GT**

- 100% firing

**Boiler**

- 20% mixed firing
- ≥50% mixed firing (Green Innovation Fund)

**MHI**

- 20% mixed firing
- Burner development
- Validation testing

**MHI/ JERA**

- ≥50% mixed firing (Green Innovation Fund)
- Burner development, validation preparation

- 2027-2028 Validation testing
- Early 2030s Commercialization
Ammonia Fueled Gas Turbine

Cover large power output / high efficiency areas
⇒ Expand range of use
⇒ Achieve carbon neutrality of Ammonia fueled power generation

- Cracking GTCC
  - GTCC Large size
  - GTCC Small size
- Co-generator (GT) (direct firing)
- Marine diesel
- Boiler + Turbine (Co-firing)

MHI’s target
TRL7-8 (GTCC Large size)
TRL5-6 (GTCC Small size)
TRL3-4 (Boiler + Turbine)
TRL6-7 (Co-generator)
TRL6-7 (Marine diesel)
Ammonia Fueled Gas Turbine

Ammonia (NH3)

- Good H2 Carrier
- Fuel use available (No CO2)
- Combustion emit high N0x (Fuel N0x)

High efficiency large frame GT

Ammonia cracking cycle gas turbine system

NH3 → H2 + N2

Ammonia cracking system

H2

Combusstor

HRSG

Exhaust flow

High Exhaust temp. (>600°C) is good for NH3 cracking.

Standalone Verification Test: 2025～

GTCC Combination

Middle & Small Frame GT

Ammonia direct combustion gas turbine system

NH3 (gas)

Evaporator

Low combustion temp. allow N0x control by two stage burner system. SCR is mandatory for N0x reduction.

SCR

Exhaust flow

Small Frame

Combustor Test: 2023～

Engine Verification: 2025～

Large Frame GT combusstor development

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Mitsubishi H-25 Gas Turbine

Our Advanced Class Gas Turbines are designed for deep decarbonization.

Mitsubishi Heavy Industries
“H-25” Gas Turbine

High Efficiency
- More than 80% Co-generation Overall Efficiency
  - Simple cycle: 36.2%
  - Combined Cycle: 54.0%
  - Cogeneration: Over 80.0%
    79 ton/h (Heat Output)

High Reliability
- Cumulative total operating time exceeds 11.0 million hours
  - Over 11.0 million operation hours
  - Ordered: 193 GT units
    (H-25 as of 2023)

Fuel Flexibility
- Gas Turbine can be fueled by
  - Fossil fuel (Natural Gas, Oil)
  - Clean fuel (Hydrogen, Ammonia)
Ammonia Direct Combustion Gas Turbine

Key challenges of Ammonia combustion
- Flame is unstable
- Higher NOx (Fuel NOx)

Solution
- Rich/Lean 2-stage combustion

H25 gas turbine
- 41MW (Output)
- 36.2% (SC efficiency)
- 80%+ (Cogeneration)
- ~191 units orders

Combustor (Schematic)
- Secondary Air injection
- Primary Air
- Fuel NH₃
- Rapid mixing

Solution
- Rich/Lean 2-stage combustion

High efficiency SCR (Selective Catalytic Reduction) Required

HRSG
- N.Gas for Start up
- GT(H-25)
- Rich-Lean combuster swap
- NH₃(gas)
- Evaporator
- (liquid)
- NH₃

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Ammonia Firing Combustor Development Status

Rich-lean combustion technology based on the matured standard diffusion combustor is applied. Combustion tests are on going.

Schedule

<table>
<thead>
<tr>
<th>CY</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
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</thead>
<tbody>
<tr>
<td>Design</td>
<td>Rig test (Low Pressure)</td>
<td>Rig test (High Pressure)</td>
<td>Manufacture</td>
<td>Demonstration (plan)</td>
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<td></td>
<td>Nagasaki</td>
<td>Katsuta</td>
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<td>2022.7</td>
<td>2023</td>
<td>2023</td>
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<tr>
<td>Test facility construction</td>
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</tbody>
</table>
Ammonia GTCC Plant System

Conceptual Scope of Each Island (Fuel Handling Island/ Power Island) shown below
MHI Ammonia / Hydrogen Gas Turbine Combined Cycle projects

Zero Carbon Humber (H2 Saltend) Hull, Humber, UK
M701F, 1200MW (3 GTCC), 30vol% H2 co-firing, FS

H2M (Magnum) Eemshaven, the Netherlands
M701F, 440MW (1 GTCC out of 3 GTCC), FS

Intermountain Power Delta, Utah, USA
M501JAC, 840MW (2 GTCC)
30vol% H2 co-firing, Same time in 2025, 100vol% H2 firing, Ready

M701JAC, 600 MW (1 GTCC), 30vol% H2 co-firing, Ready

Advanced Clean Energy Storage Delta, Utah, USA
Green Hydrogen Production and Storage in 2025

McDonough Smyrna, Georgia, USA
M501G, 2,520MW (3 GTCC)
20vol% H2 co-firing validated in 2022

Jurong Port / JERA Asia Jurong, Singapore
H-25, 50MW (1 GTCC), FS

Keppel New Energy Jurong, Singapore
H-25, 50MW (1 GTCC), FS

Keppel Infrastructure Jurong, Singapore
M701JAC, 600 MW (1 GTCC), 30vol% H2 co-firing

Sembcorp Industries (Banyan) Jurong, Singapore
M701JAC, 600 MW (1 GTCC), 30vol% H2 co-firing, Ready

Keramasan GTCC Project South Sumatra, Indonesia
H-25, 80MW (2 GTCC), FS

Port of Newcastle
Under discussion to establish H2 HUB and clean energy economy

Hydrogen Jobs Plan South Australia, Australia
100vol% H2 firing

Hydrogen related Projects
Ammonia related Projects
Keppel, MHI and DNV Sign Agreement to Explore Adoption of Ammonia-fired Gas Turbine on Jurong Island

2021-09-27

Mitsubishi Heavy Industries, Ltd.
DNV

Tokyo, September 27, 2022 – In a Memorandum of Understanding (MoU) signed yesterday, Keppel New Energy Pte Ltd, a wholly owned subsidiary of Keppel Infrastructure, Mitsubishi Heavy Industries, Ltd. (MHI), and DNV, a global independent energy expert and assurance provider, announced a strategic collaboration to explore the feasibility and implementation of an ammonia-fired gas turbine on Jurong Island, Singapore.

The MoU will see the three companies work together to implement a joint venture between Mitsubishi Heavy Industries, Keppel Ventures, and Keppel Infrastructure to pursue the development of an Ammonia Power Plant in Singapore.

Under the MoU, Keppel will study the feasibility of an ammonia-fired gas turbine and related solutions brand, Mitsubishi Power, will develop an ammonia gas turbine to be used in the plant. DNV will provide its project management expertise to prepare and present a QRA analysis of the project.

Takao Tsukui, General Manager, International Sales and Technologies at DNV, explained, “Ammonia is a potential key component to building a hydrogen and hydrogen fuel combustion technologies for power. This MoU is a dedication to pursue cutting-edge solutions that can support the development of more sustainable energy systems in Asia Pacific region.

“DNV is proud to use our well-established advisory and risk assessment tools to support this impactful project. We believe that ammonia is critical in the move towards a more sustainable energy future. This MoU offers us an exciting opportunity to share our extensive industry experience to support this important contribution to Singapore’s net zero and energy transition goals,” said Brice Le Gall, Vice President and Regional Director, Asia Pacific Energy Systems, DNV.


Port of Newcastle and MHI Announce Clean Energy Partnerships Enabling Port of The Future in Newcastle

2023-07-12

Port of Newcastle
Mitsubishi Heavy Industries, Ltd.

Port of Newcastle and Mitsubishi Heavy Industries, Ltd. have unveiled, during a visit by Mr. Chris Bowen, Minister for Climate Change and Energy, to the Port today, an MoU setting out a pathway towards the enabling of a world-class clean energy economy in the Hunter Region through the Port’s Clean Energy Precinct, which secured a $100-million Commonwealth funding grant in the 2022 Federal Budget.

Port of Newcastle CEO Craig Carmody said the once in a generation diversification strategy.

“Our dedicated 220-hectare Clean Energy Precinct will offer a green, zero-emission and low-risk home port which will be supported by common user, open access, share facilities servicing production from the Precinct itself. Dr Hitoshi Kageuchi, Senior Executive Vice President at MHI, said the project for the Port of Newcastle, a promising hydrogen hub, has been considered necessary for the realization of a hydrogen hub for power generation and CO2 capture technologies, ammonia and

CO2 Zero power generation technology Roadmap

Reduce CO₂ by High Efficiency Gas Turbine ➔ ZERO CO₂ by Hydrogen Gas Turbine

1. High Efficiency Natural Gas-fired Gas Turbine
   - JAC series

2. Co-firing
   2-1. Ammonia Biomass Co-firing Boiler
   2-2. Gas Turbine Combined Cycle plant + CCUS

3. CO₂ Zero
   3. Hydrogen Gas turbine Development
   - Ammonia Gas Turbine Development
   3. Hydrogen Production
      - Water electrolyser
      - SOEC
      - Turquoise H₂

CO₂ Reduction -65%

CO₂ Emission (%)

50%

0%

Toward CO₂ Zero

64% High Efficiency Gas Turbine Combined Cycle Power Plant (Commercial Operation in 2020)

-65% down (2020-)

-90%

Technology Road Map

2020

2030

*1 : Based on Sub-C CO₂ Emission
# Development status of Hydrogen Gas turbines

<table>
<thead>
<tr>
<th>Combustor type</th>
<th>Low NOx technology</th>
<th>Turbine inlet temperature</th>
<th>H₂ density (volume %)</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type1</strong> Diffusion</td>
<td>Nitrogen dilution, Water/Steam injection</td>
<td>1200~1400°C</td>
<td>100%</td>
<td>1970</td>
</tr>
<tr>
<td><strong>Type2</strong> Pre-mix(DLN)</td>
<td>Dry</td>
<td>1650°C</td>
<td>30~50%</td>
<td>2018</td>
</tr>
<tr>
<td><strong>Type3</strong> Multi-cluster(DLN)</td>
<td>Dry</td>
<td>1650°C</td>
<td>100%</td>
<td>2025</td>
</tr>
</tbody>
</table>

### Schedule

- **1970**: Nitrogen dilution, Water/Steam injection for Hydrogen firing test completed.
- **2018**: Type1 100% H₂ firing test completed.
- **2022**: Natural gas DLN 30~50% H₂ co-firing test completed.
- **2025**: Type2 30% H₂ co-firing test completed.
- **2025**: Type3 100% H₂ firing test completed.
- **2025**: H₂ co-firing operation in Osaki Cool Gen test completed.
- **2025**: MHI has over 50 years (3.5 million hours) experience in Hydrogen firing.

### Key Points

- **Type1**: 100% H₂ firing, Ready/Development completed.
- **Type2**: 30% H₂ co-firing, Ready/Development completed.
- **Type3**: 50% H₂ co-firing, To be verified in actual engine.
- **Type3**: 100% H₂ firing, Ready by 2025.

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**Note:**

- *This presentation is based on results obtained from a project commissioned by NEDO that is a government organization in Japan.*
- *(NEDO: New Energy and Industrial Technology Development Organization)*
- **DLN**: Dry Low NOx
Hydrogen / Ammonia Gas Turbine Development schedule

1 Production
2 Storage
3 Utilize

Integrated demonstration from hydrogen production to hydrogen power generation from 2023

In combustion test, EU Taxonomy has already been achieved in our Type -2 combustor with 50% hydrogen co-firing. Engine verification starts at Takasago Hydrogen park in 2023.
MHI Hydrogen-Fired GTCC Projects

Advanced Clean Energy Storage Project (USA)

1. Green hydrogen production by electrolyzers using renewable energy from the West Coast.
2. Storage in salt caverns in North America.
4. DOE Loan application submitted for up to $595 million

Renewable energy

- Green hydrogen production by electrolyzers using renewable energy from the West Coast.

Storage

- Storage in salt caverns in North America.

Power generation

- Mitsubishi Power to supply two hydrogen-capable M501JAC gas turbine power trains (1X1) to Intermountain Power Agency. Plans to co-fire 30% Hydrogen in 2025 and operate on 100% Hydrogen no later than 2045.

Mitsubishi Power to supply two hydrogen-capable M501JAC gas turbine power trains (1X1) to Intermountain Power Agency. Plans to co-fire 30% Hydrogen in 2025 and operate on 100% Hydrogen no later than 2045.