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Development and Verification of MHI Carbon Neutral Solutions (NH₃, H₂ and CO₂)







- Carbon Neutral Technologies
- Hydrogen Verification in Takasago Hydrogen Park



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MHI's Carbon Neutral Power Generation Technologies Roadmap





*1 :Based on Sub-Critical Coal Firing CO₂ Emission



Able to convert a natural gas-fired gas turbine to hydrogen or ammonia firing – and thereby achieve decarbonization – simply by replacing the combustors and adding a fuel supply system

Natural Gas	Type 1 (Diffusion)	100% H ₂	Development complete	Ready to apply
	Type 2	30% H ₂ co-firing	Development complete	to commercial facilities
Hydrogen	(Pre-mix)	50% H ₂ co-firing	2022: Successful combustion test for large frame GT	
NH3 Ammonia gas Ammonia	Type 3 (Multi- cluster)	100% H ₂ firing	Validating in lead up to 2025 commercialization	
	Type 1 (Diffusion)	100% ammonia firing	Validating in lead up to 2025 commercial unit operation and commercialization	
	.A.			
			Combustor Replacement	
Type 1 Type 2 Type 3 Type 1 Type 2 Type 3 Type 1 Type 2 Type 3				

Ammonia : Challenges of Combustor Development

Ammonia is the non-flammable fuel and followings need to be overcome

- ➤ Low LHV
- Low flame temperature
- Low burning velocity
 - \Rightarrow Need to apply diffusion burner for stable combustion



Ammonia : Power Generation Technology



Gas turbine: Working on combustor development, aiming for commercialization after 2025 ➢ Boiler: Working on burner development, targeting commercialization of ≥50% co-firing in early 2030s -2024 > 2025-GT Combustor Validation testing, development commercialization \mathbf{X} Combustion test at low pressure(2022) Ammonia (combustion test) Current hydrocarbon fuel Combustion test at high pressure(2023) 100% firing Low pressure combustion test High pressure combustion facility(Nagasaki) test facility(Katsuta) -2024 -2030 -2035 -2050 **Boiler** 2027-2028 Early 2030s Validation Burner development, ≥50% co-firing Commercialization validation preparation testing (Green Innovation Fund) \times 0.5t/h combustion test(2023) 石炭バー 石炭バーナー 4t/h combustion test (2023-2024) アンモニアバーナー ※矢印はバーナー設置場所と炉内投入方向を示す。

Ammonia : Gas Turbine Combustor Development



- Low pressure combustion tests initiated in 2022. Initial high pressure combustion tests were started in 2023. All emissions satisfied development target.
- Currently conducting feasibility study for engine demonstration. \geq

Low Pressure Combustion Test Facility



Hydrogen : Challenges of Combustor Development



Hydrogen is the flammable fuel and the followings need to be overcome

- > Higher flame temperature \Rightarrow Increase of NOx emission
- > Higher burning velocity \Rightarrow Increase in risk of flash back









Hydrogen : Type-2 50% Co-firing / Type-3 100% Firing



Hydrogen Co-firing~50vol%

30% Development Completed in 201850% Combustion Test Conducted in 2022



Fuel Nozzle (**Type -2**)





Flame Image (LNG+H2)

Hydrogen 100% Firing

Hydrogen 100% high pressure combustor test was conducted with Multi-cluster comb of H-25 on April, 2022.



Fuel Nozzle (**Type-3**)







100 vol.% Hydrogen





High Press Comb Test Facility

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Carbon Dioxide : Carbon Capture Project



Petra Nova Project

The World's Largest Post-Combustion Carbon Capture Plant

EPC full turnkey project

MHI has provided the world's largest carbon capture plant on coal-fired flue gas delivered in December 2016

Project Formation	 Consortium of MHI / The Industrial Company (TIC) (MHI: Engineering and Procurement for Carbon Capture Plant)
Plant location	NRG WA Parish Power Plant (Thompsons, TX)
Project owner	Petra Nova - partnership between NRG Energy and JX Nippon Oil&Gas Since 2022, full ownership under JX Nippon Oil&Gas
Plant scale	240 MW _{eq}
CO ₂ capacity	4,776 t/d (1.4 Mt/y)



Carbon Capture Plant

*Clean Coal Power Initiative

*U.S. Department of Energy "W.A. Parish Post-Combustion CO₂ Capture and Sequestration Project Final Environmental Impact Statement Volume I" (Feb, 2013), DOE/EIS-0473

Source: Press Release by MHI



- Carbon Neutral Technologies
- Hydrogen Verification in Takasago Hydrogen Park

Bases of Carbon Neutral Technology Development



MHI is developing and verifying decarbonization technologies to achieve carbon neutrality. Takasago Machinery Works started the integrated verification of hydrogen production, storage and utilization in 2023.



Takasago Hydrogen park





Takasago Hydrogen Park





Hydrogen 30% Co-firing Power Generation in Takasago Hydrogen Park

[Nov. 20, 2023] Takasago Hydrogen Park M501JAC large frame gas turbine(566MW) with dry low NOx combustor 30vol% H2 co-firing was successfully operated.

- > Achieved 30vol% hydrogen co-firing in 100% load, world's first large high-end gas turbine
- Reduce CO₂ emissions by 10%
- > Integrated system verification of 1 Hydrogen Production $\rightarrow 2$ Storage $\rightarrow 3$ Power generation





November 20, 14:47 achieved 30% hydrogen co-firing (Control room)

*1 compared to natural gas

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SOEC(Solid Oxide Electrolysis Cell) : MHI Technology



- SOEC is reverse reaction of SOFC(Solid Oxide Fuel Cell). So, basic cell technology is common.
- > SOEC (Solid Oxide Electrolysis Cell) produces hydrogen using steam and electricity.
- More than 10% efficiency compared with water electrolyzer.



SOEC Single Cell Stack Test

 \succ Durability test are on-going.

SOEC: 0.1MW Cartridge Test

> July 2023 \sim , cartridge test > Durability test has passed 15,000hrs. was completed.









<COMPLETED>

> March, 2024

≥ 2024 -2025

> March, 2024

- September,2023 : Started operation of Alkaline water Electrolyzer (Hydrogen Pro)
- > November, 2023 : 30% hydrogen co-firing operation with M501JAC Gas Turbine
 - : Started operation SOEC 400kW demonstration system (MHI development)
 - : Hydrogen storage to be increased from 39,000 to 117,000Nm³ (1050 units)
 - : Start verification of H-25(40MW) engine test of 100% hydrogen

<PLAN>

MHI's hydrogen production technologies (SOEC, Methane Pyrolysis) is under development in Nagasaki and will be installed to Takasago Hydrogen Park.

After verification, the products will be delivered to the market in the near future.



"Hydrogen is Not the Future, This is Real."

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