

2023 Green Hydrogen COnclave

MHI Group Challenge for the Sustainable Future – Energy Transition / Hydrogen

Rei KIMURA, Managing Director
Mitsubishi Heavy Industries India Pvt. Ltd.

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Mitsubishi Heavy Industries (MHI) Group is one of the world's leading industrial groups, spanning energy, logistics, infrastructure, industrial machinery, aerospace and defense.



REVENUE

4.2

Trillion JPY as MHI Group

**MITSUBISHI
HEAVY
INDUSTRIES
GROUP**

254 Group Companies
(Consolidated)

Foundation

1884

over 130 years history

77,000

Consolidated Employees
worldwide

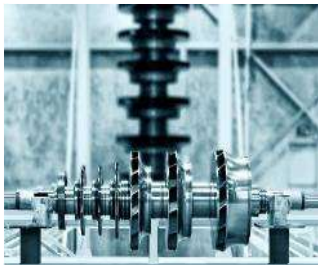


Diverse products

At sea, on land,
in the sky &
space



Gas turbines



Compressors



Aero engines



CO₂ capture plants



Metals machinery



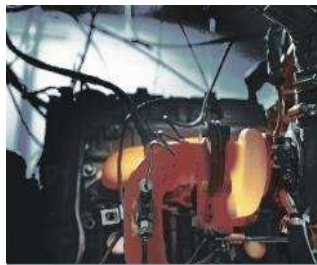
Chemical plants



Transportation



Waste-to-energy



Turbochargers



Aerospace








Rocket engines



Defense

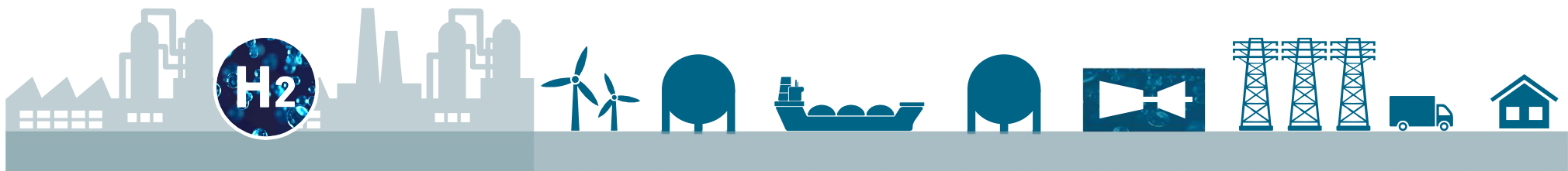
Type of Hydrogen

The type of hydrogen varies depending on the process of its production.

Category	Type	Production process	Technology in MHI Group
Carbon Free	Green	Electrolysis by renewable electricity $H_2O \rightarrow H_2 + \frac{1}{2}O_2$	Electrolyser (Hydrogen Pro) 
	Pink	Electrolysis by nuclear energy $H_2O \rightarrow H_2 + \frac{1}{2}O_2$	Nuclear power - PWR 
	Turquoise	Thermal decomposition of fossil fuel $CH_4 \rightarrow 2H_2 + C$	Methane pyrolysis (Monolith) 
	Blue	Thermal reforming of fossil fuel w. CCS $CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$	Natural gas reforming CO ₂ capture 
Ordinal (emit CO ₂)	Gray	Thermal reforming of fossil fuel $CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$	Natural gas reforming 



Simultaneous (parallel) development of Global Hydrogen Supply Chain, Upstream, Midstream, and Downstream, are essential to realize the Sustainable Future – Energy Transition



Electrolyser

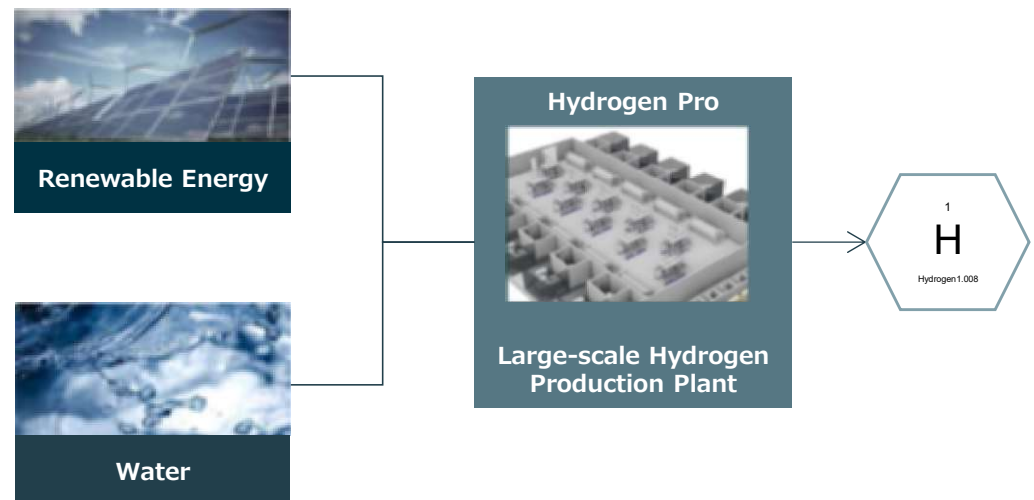
Investment in HydrogenPro (Norway)

- HydrogenPro, established in 2013, aims to be a world leading designer and supplier of alkaline electrolyser technology, that meet the highest standards for safety, reliability and long lifetime.
- MHI Group Undertakes Investment in HydrogenPro of Norway, in October 2020.

Hydrogen pro



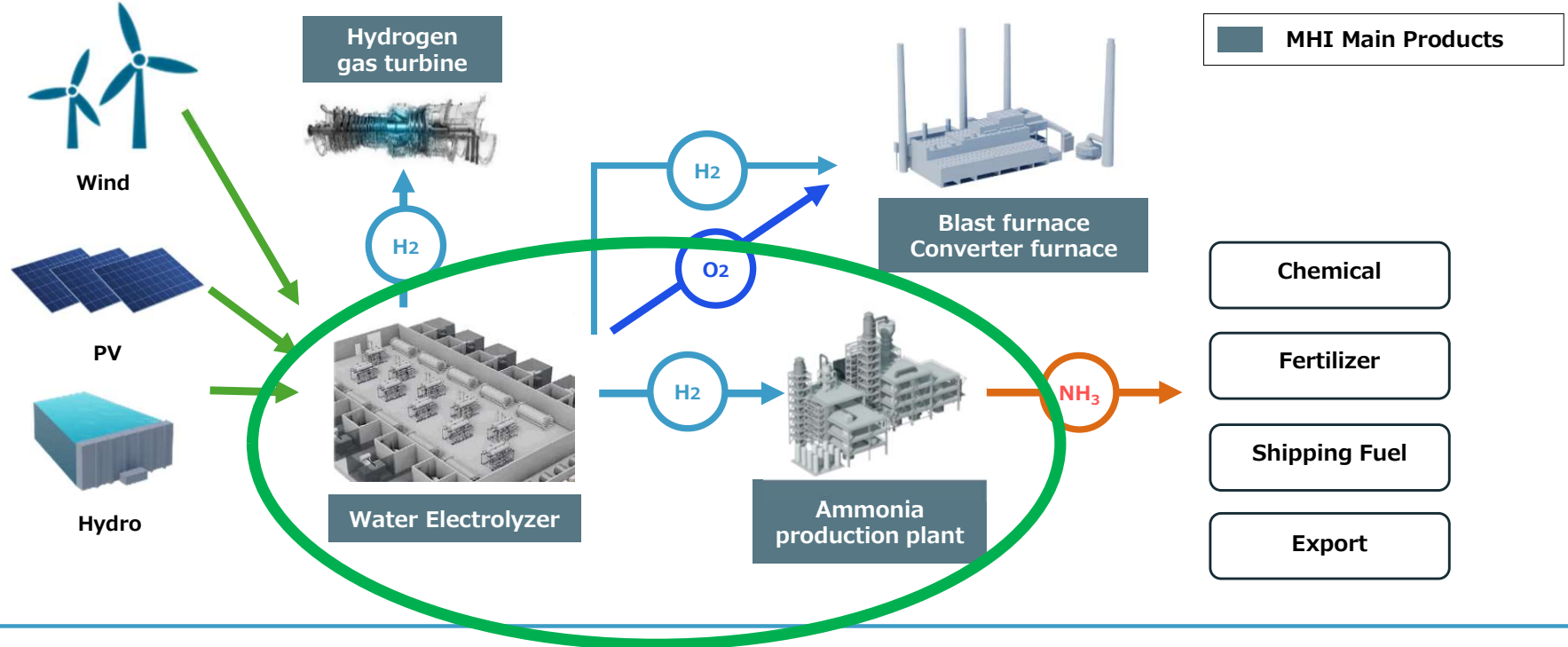
Middle-size Electrolysis
(10-20MW)



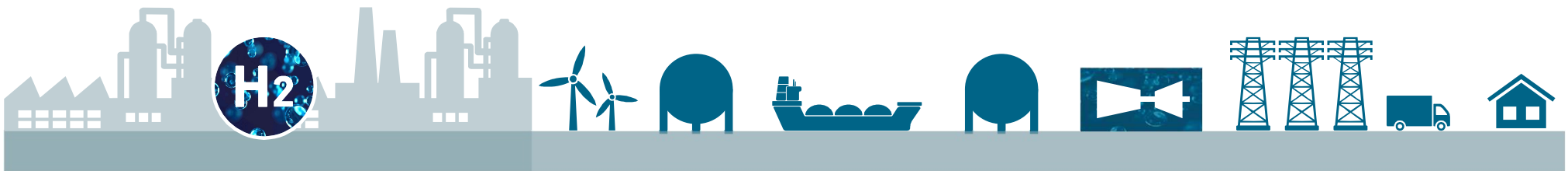
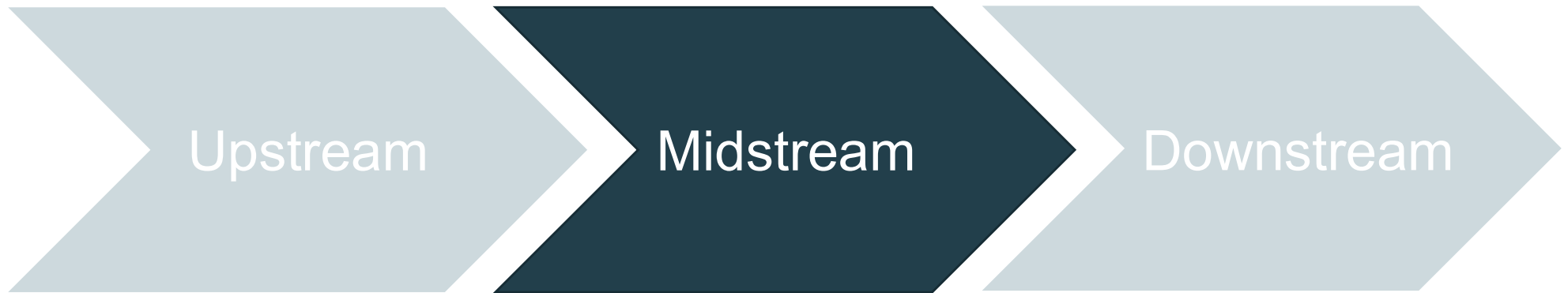
<https://www.mhi.com/news/201014.html>

Investment to H2U - Carbon-free Ammonia Production Project (Australia)

- Using abundant renewable energy in Australia to produce hydrogen and ammonia
- Contributing to regional steel industry and exporting carbon-free ammonia.

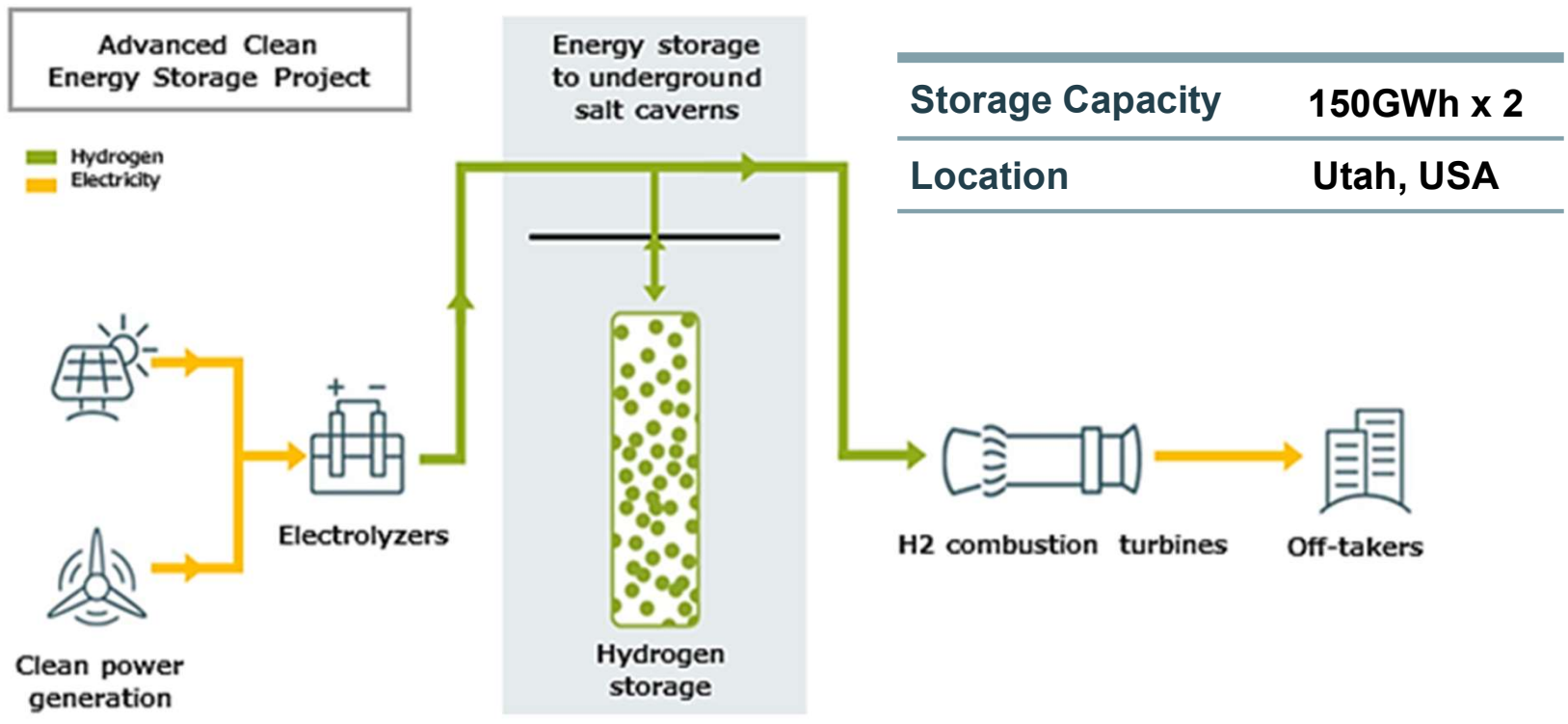


MHI Group in Global Hydrogen Supply Chain



Investment to Advanced Clean Energy Storage (ACES) Project (USA)

- The world's largest renewable energy storage project.



Ammonia (NH₃) is the best hydrogen carrier, because of

- 1) Highest content of hydrogen in volume
- 2) Easy handling

LH₂ require higher energy consumption, because of its lower liquidus temperature.

NH ₃	-33.4°C
LPG	-42°C
LNG	-162°C
LH ₂	-254°C

- Commence development of Large-size Ammonia (NH3) Carrier fueled by NH3, to promote demand for NH3 and increase volume of marine transportation of NH3.

Mitsubishi Shipbuilding to Commence Development of Large-size Ammonia Carrier Fueled by Ammonia -- Collaboration with Mitsui O.S.K. Lines and Namura Shipbuilding Targets Decarbonization of Maritime Industry --

2021-11-04

[f](#) [t](#) [in](#)

- Aims set on achieving operation of vessels fueled by ammonia – a clean energy – and increasing volume of marine transportation of ammonia
- Basic design concept to be developed among those three partners.



Image of the Vessel's Operation

Tokyo, November 4, 2021 – Mitsubishi Shipbuilding Co., Ltd., a part of Mitsubishi Heavy Industries, Ltd. (MHI) Group, has reached an agreement with Mitsui O.S.K. Lines, Ltd. and Namura Shipbuilding Co., Ltd. on joint development of large-size ammonia carrier fueled by ammonia.

Ammonia is mainly used as a raw component of fertilizers, and is expected to be a high-quality, reliable and clean energy. The development aim to increase the volume of marine transportation of ammonia by large-size ammonia carrier which are fueled by ammonia. The three companies will jointly proceed with the development of basic design of large-size ammonia carrier where Mitsubishi Shipbuilding will take charge of the optimal design of cargo tank and deck tank used for ammonia fuel, organizing engine and related machinery systems including the fuel supply system, and development and design of cargo handling equipment, special equipment for ammonia transportation and safety equipment onboard.

Mitsubishi Shipbuilding Completes Conceptual Design of VLGC Enabling Conversion of Main Fuel from LPG to Ammonia

-- AIP Acquired from ClassNK in Preparation for Future Viability of Ammonia-Fueled Carriers --

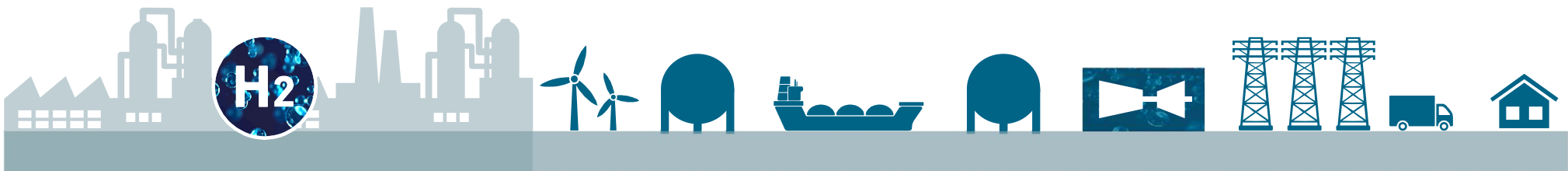
2022-06-09

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- New design will enable small-scale retrofitting when ammonia fuel goes into practical application
- Ammonia-carrying VLGCs now powered by LPG are highly suited to future use of ammonia fuel



Image of an LPG-powered VLGC convertible to ammonia fuel



Hydrogen Gas Turbine for Power Generation

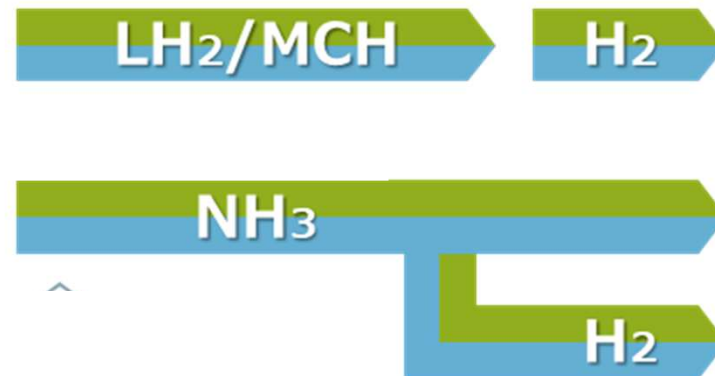
■ Saving Investment Costs

Can be applied to existing power plant facilities with minimum modifications

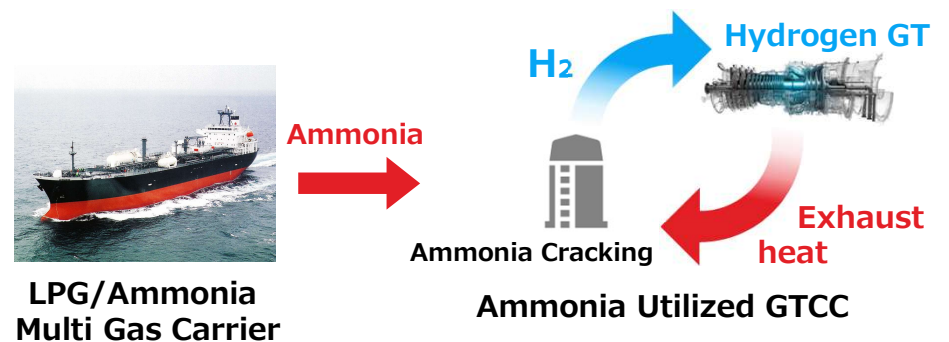


■ Carrier Flexibility

Low purity hydrogen is usable and can be transported with any carrier

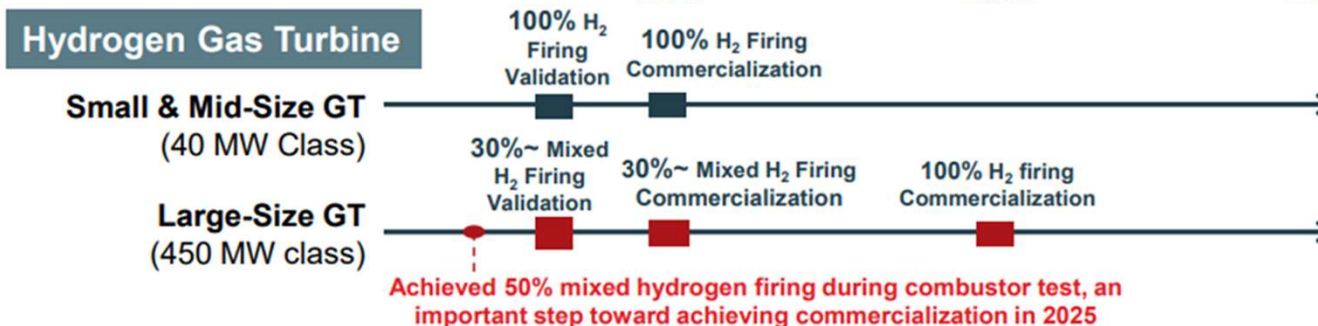
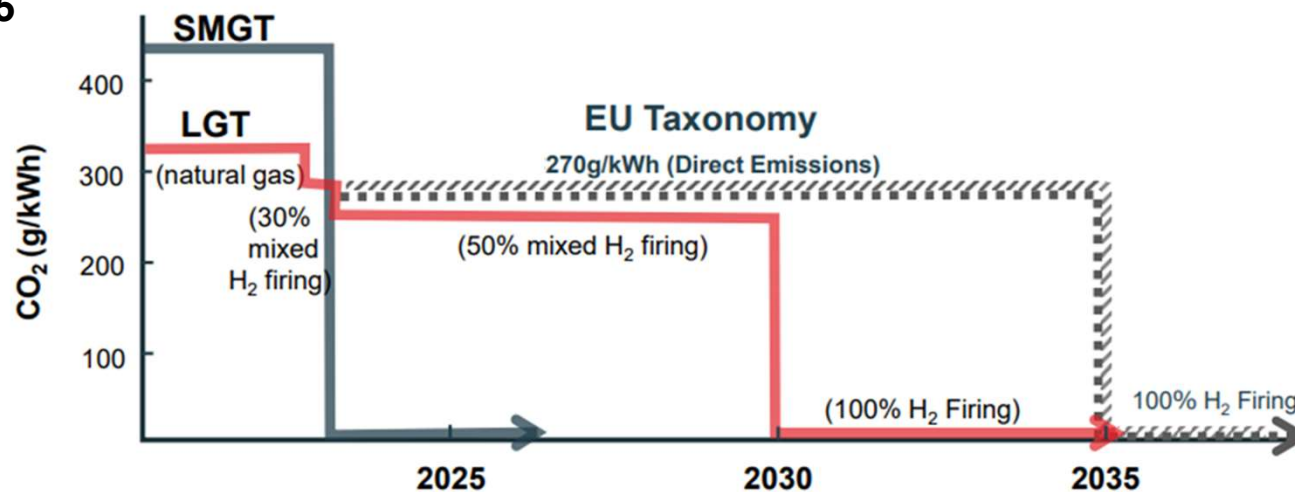


Hydrogen combustion :
A) Faster combustion speed
B) Lower calorific value



EU Taxonomy and MHI development schedule

- Progressing with validation testing with the goal of commercializing carbon-free power generation using Hydrogen
- Achieved 50% mixed hydrogen firing during combustor test, an important step toward achieving commercialization in 2025



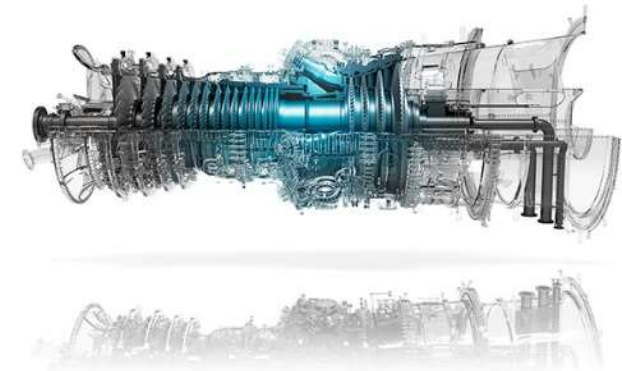
Intermountain Power Plant



Source: LADWP Los Angeles Times

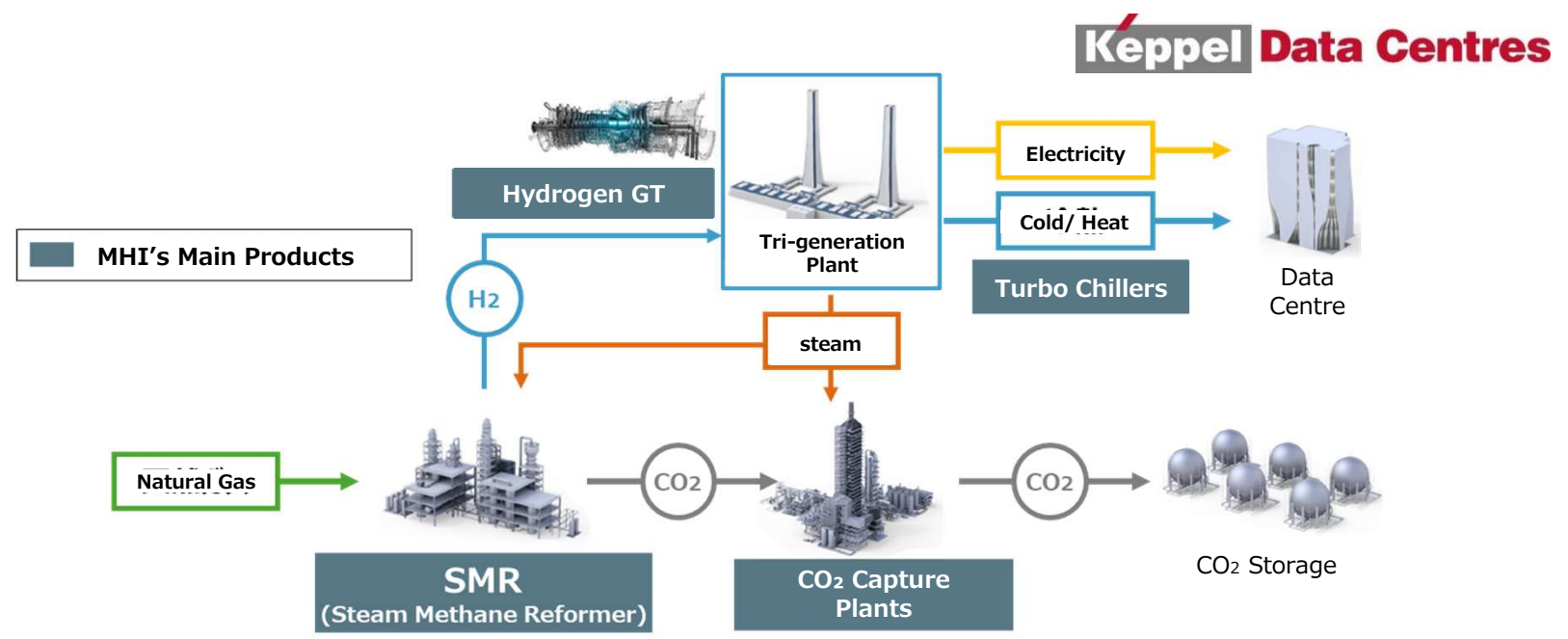
Gas Turbine Model	M501JAC
Power Output	840 MW (by 2 CCGT)
Location	Utah, USA

- 30% renewable hydrogen by 2025.
- 100% renewable hydrogen by 2045



Joint Development of Tri-generation for Data Centres (Singapore)

- Supplying clean electricity, cooling/heat, and steam derived from carbon-free hydrogen for carbon neutrality of data centres



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 (NH₃). The project

H-25 Gas turbine

- Output: 41.0MW
- Efficiency: (SC) 36.2% (SC)
(Cogen) more than 80%
- Deliveries : about 200 units

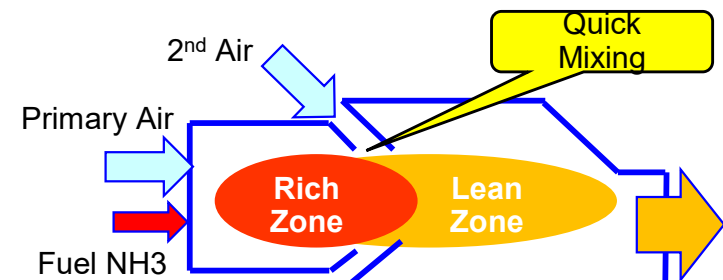


Ammonia combustion :

- 1) Slower combustion speed,
- 2) Lower calorific value,
- 3) Lower combustion temperature
- 4) Nox generation

Solution

Rich-Lean Two Stage Combustor



Fuel Cell (SOFC)

- Multi-fuel capability (hydrogen, natural gas biogas, etc.)
- Rated Output : 200kW~2MW
- Power Generation Efficiency: 53%
Overall Efficiency: 73% (when supplying hot water)
- First overseas project delivered in 2022
- Can be applied to SOEC (hydrogen production)



Biogas SOFC at Asahi Breweries Ibaraki Brewery

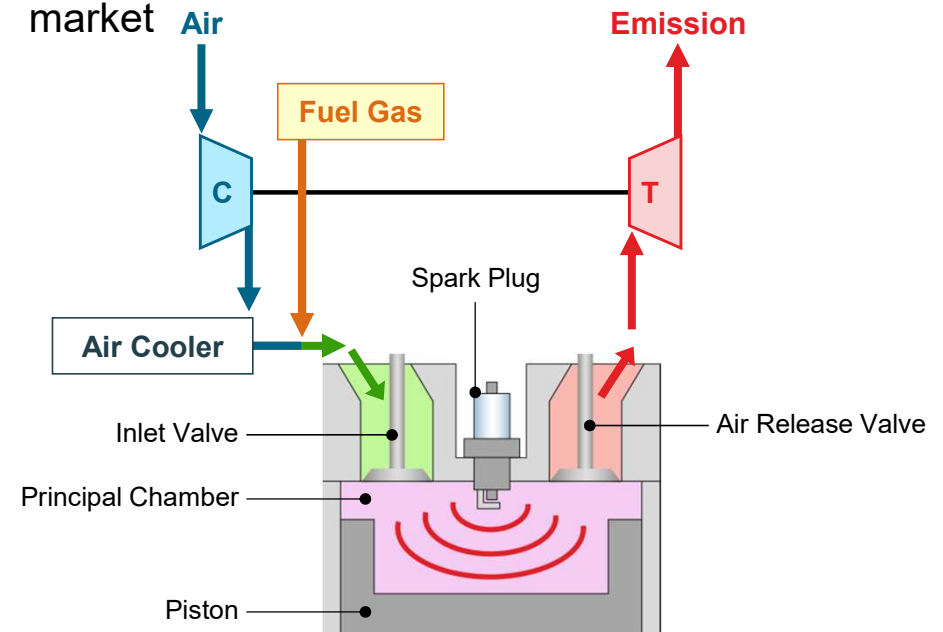
SOFC : Solid Oxide Fuel Cell

SOEC : Solid Oxide Electrolysis Cell

H₂ Gas Engine

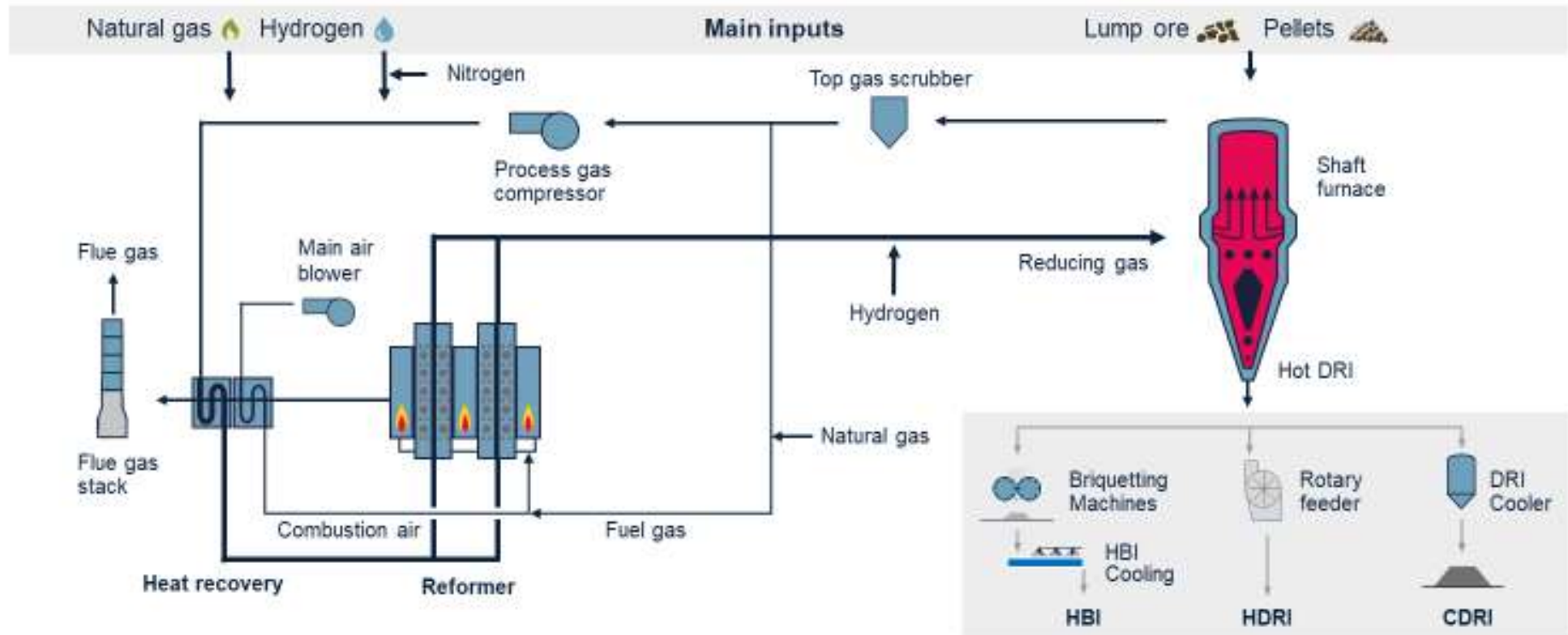


- Development started in 2019. 30% Co-firing combustion test was successfully done. Further development in progress
- Rated Output : 300kW~ 1 MW
- Market release by 2030s supporting hydrogen market





MIDREX Flex



Green Steel



Break-Through Innovations HYFOR - Pilot Plant

Main input

- Direct use of iron ore fines <0.50 mm
- Reducing gas: Hydrogen

Main benefits

- No pelletizing required
- Highest yield (Dry dedusting, WHR)
- CO₂-free ironmaking
- Highest metallization, low temp./pressure operation

Status

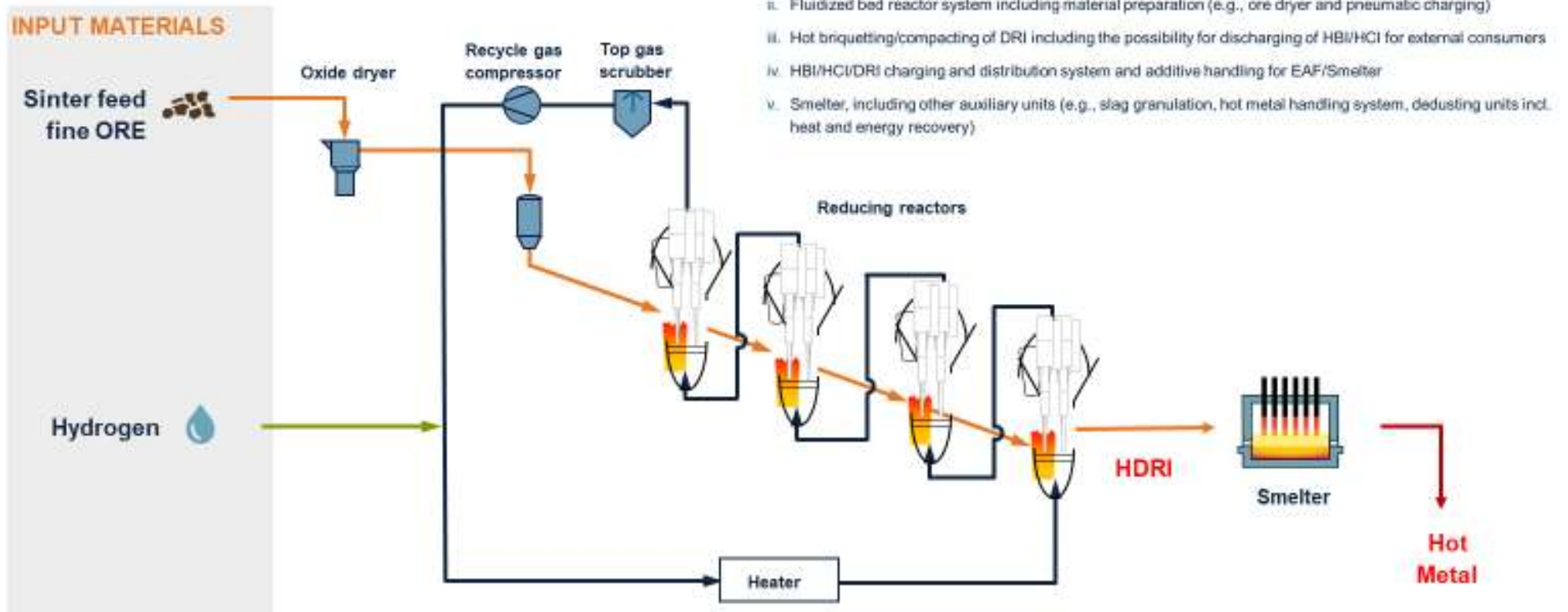
- Digital Showcase (Digital Twin, VR, QR, MAT, m.doc,...)
- Significant number of campaigns successfully executed
- Continue tests with various ores from around the globe
- Industrial Prototype Plant installation in combination with a Smelter planned



HyREX



HyREX - Simplified flowsheet



Traditional (blast furnace)
(84% hot metal and 16% scrap in BOF)



Blast furnace



BOF Converter

Direct reduction + EAF
(80% hot DRI and 20% scrap in EAF)



MIDREX

DRI

Recycled scrap
(100% scrap in EAF)



Scrap

Scrap

EAF

Green steel (H₂DRI-EAF)
(80% hot DRI and 20% scrap in EAF)



MIDREX



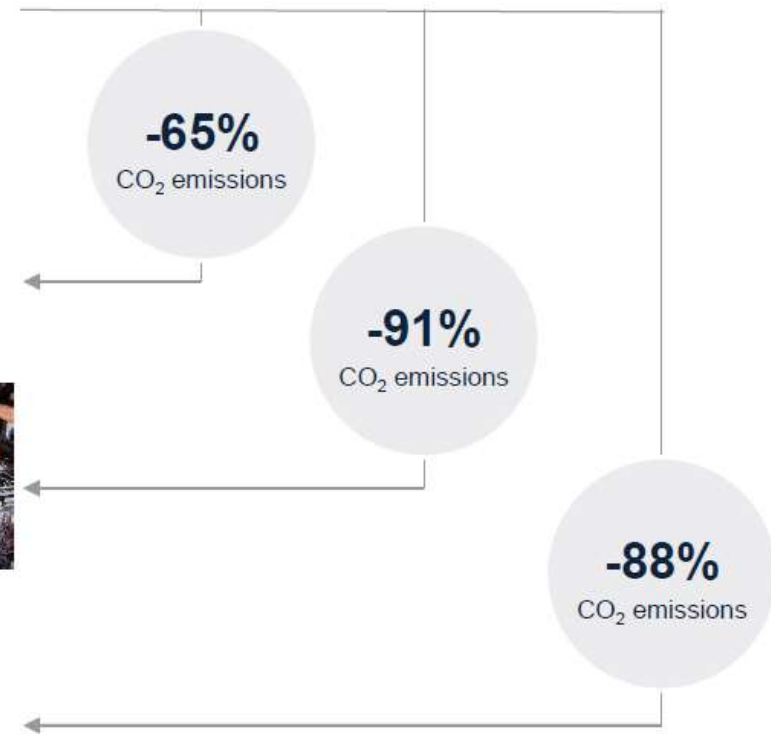
HyREX



HYFOR



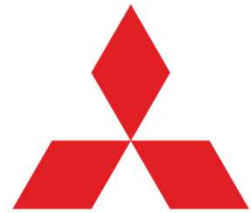
H₂DRI



Hydrogen E-book



<https://oilandgas.mhi.com/ebooks/hydrogen-powering-a-net-zero-future/>



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