MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

Energy Transition Briefing

May 24, 2023

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Mitsubishi Heavy Industries, Ltd.

MITSUBISHI HEAVY INDUSTRIES

Today's Agenda

1. Introduction

2. Decarbonizing Existing Infrastructure

3. Realizing a Hydrogen Solutions Ecosystem

4. Realizing a CO_2 Solutions Ecosystem

5. Key Takeaways

1. Introduction

Energy Transition accelerating globally

- Energy crisis precipitated by invasion of Ukraine
- IRA accelerating developments in US market
- Increased activity in APAC market as well

Strengthening MHI Energy Transition initiatives

- October 2021 Integrated Mitsubishi Power into MHI
- April 2023 Integrated Mitsubishi Heavy Industries Engineering into MHI

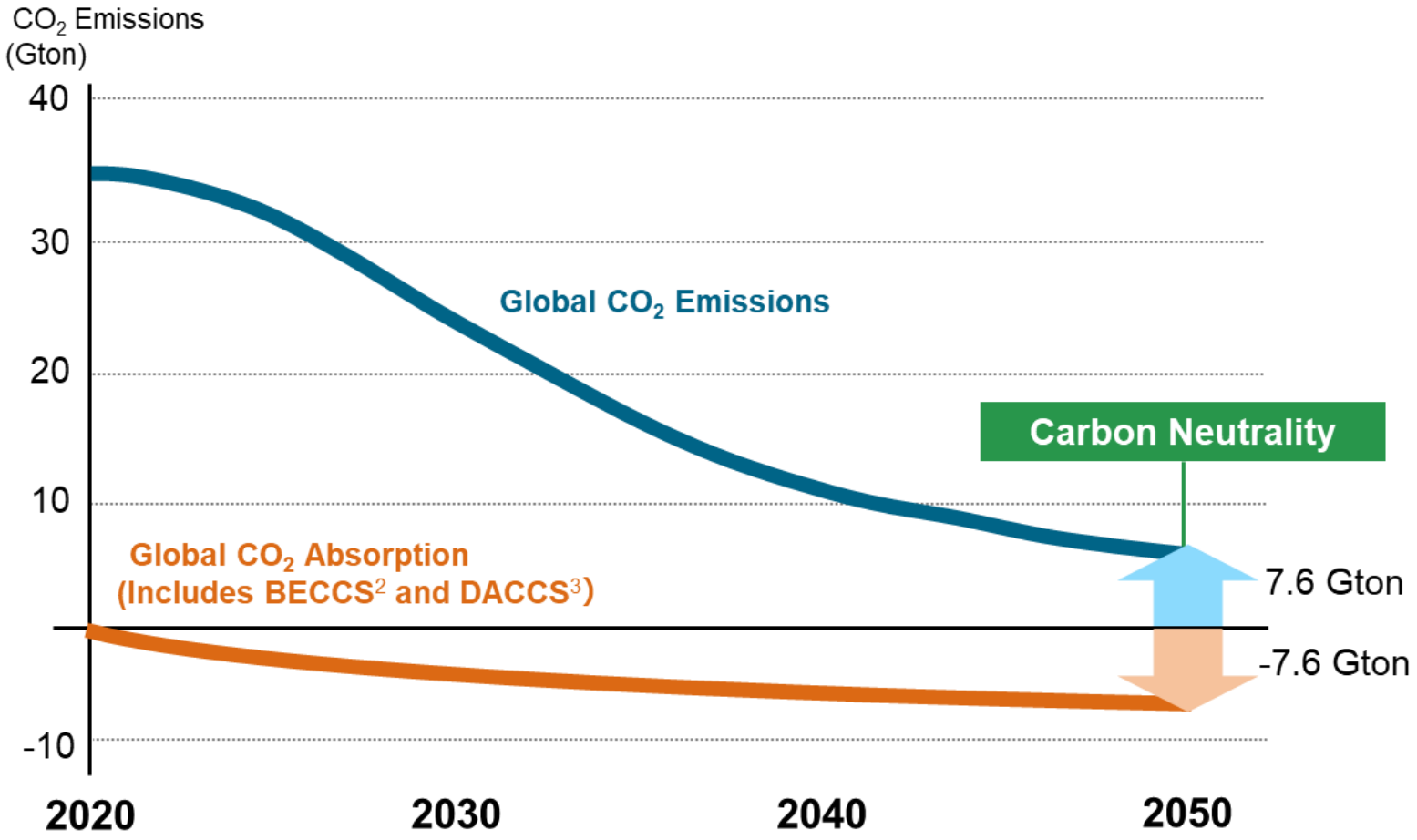
Content of Today's Briefing

- Update on growth area development as discussed at the 2021 Medium-Term Business Plan Progress Briefing on April 5
- Share progress in Energy Transition initiatives seeking to decarbonize energy supply

Excerpt from 2021 Medium-Term Business Plan Progress Briefing (April 5, 2023)

Content of Today's Briefing

MHI Forecast of Global Emissions Based on Major Reports[1]



1 Based on major reports (including McKinsey 1.5C Scenario, IEA NetZero by 2050, IEA SDS, and IPCC)
2 Bio Energy with Carbon Capture and Storage: CO_2 capture and storage from biomass power exhaust gas
3 Direct Air Carbon Capture and Storage: Capture and storage of atmospheric CO_2

Decarbonize existing infrastructure

- Roadmap
- Technology Development
- Initiatives at Takasago and Nagasaki
- Hydrogen and Ammonia Firing Projects

Realize a hydrogen solutions ecosystem

- MHI Initiative Areas
- Hydrogen Production Technology Development
- Advanced Clean Energy Storage Project (US)

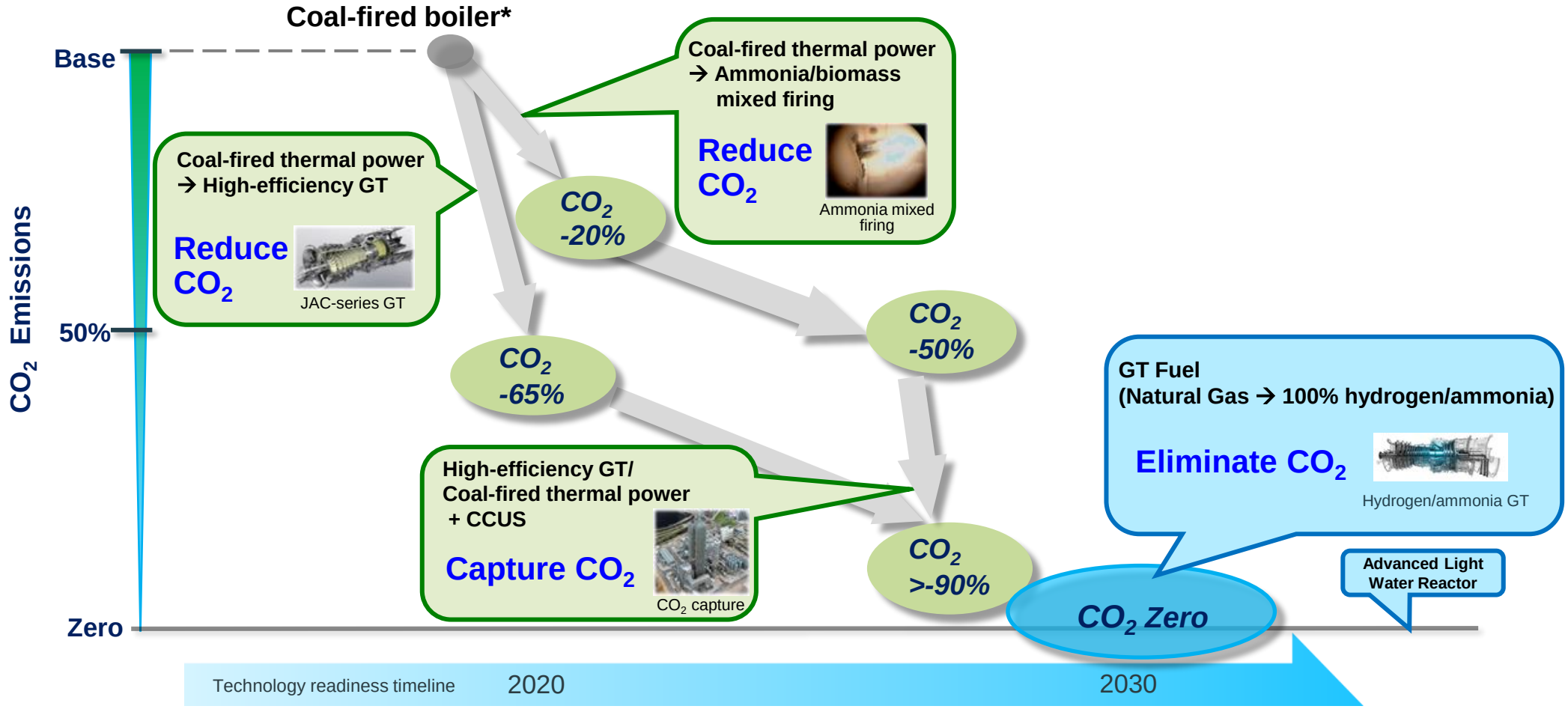
Realize a CO_2 solutions ecosystem

- MHI Initiative Areas
- CO_2 Capture
- CO_2 Transport
- CO_2 Storage
- Carbon Recycling

2. Decarbonizing Existing Infrastructure

Roadmap for Decarbonizing Existing Infrastructure

- **Reducing, capturing, and eliminating CO_2** is one path to decarbonizing thermal power
- Another path is to reduce CO_2 emissions by maximum utilization of nuclear power, a carbon-free energy source



*Based on CO_2 emissions from subcritical pressure coal-fired boilers

Bases of Decarbonization Technology Development

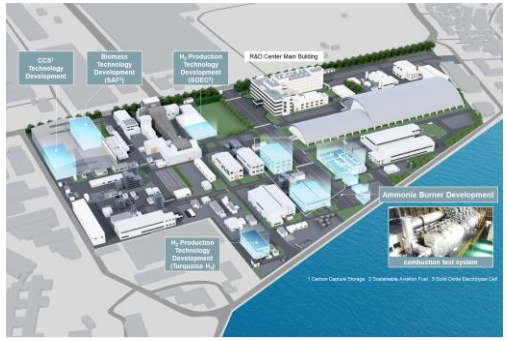
- Developing elemental technologies at Nagasaki and Takasago (Hyogo Prefecture). Planning to commercialize after validation testing at Takasago.

(1) Develop elemental technologies (Nagasaki &Takasago)

Nagasaki Shipyard & Machinery Works

Koyagi Plant, Nagasaki Prefecture

Takasago Machinery Works, Hyogo Prefecture



Nagasaki area facilities

Takasago area facilities

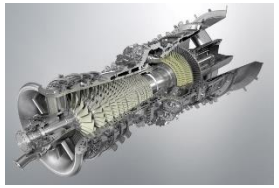
(2) Validate technologies at commercial power generation facility (Takasago)

Validation at Takasago Hydrogen Park

EU CO_2 Emissions Regulations and GT Development Schedule

1. EU Taxonomy-compliant 50% H_2 mixed firing technology
Successful combustion test for large frame GT **(2022)**


GTCC power generation facility

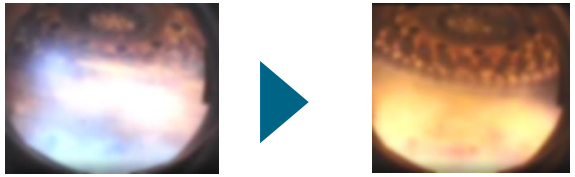

JAC-Series GT (Natural gas/H_2)


Achieved 20% H_2 mixed firing at US commercial plant

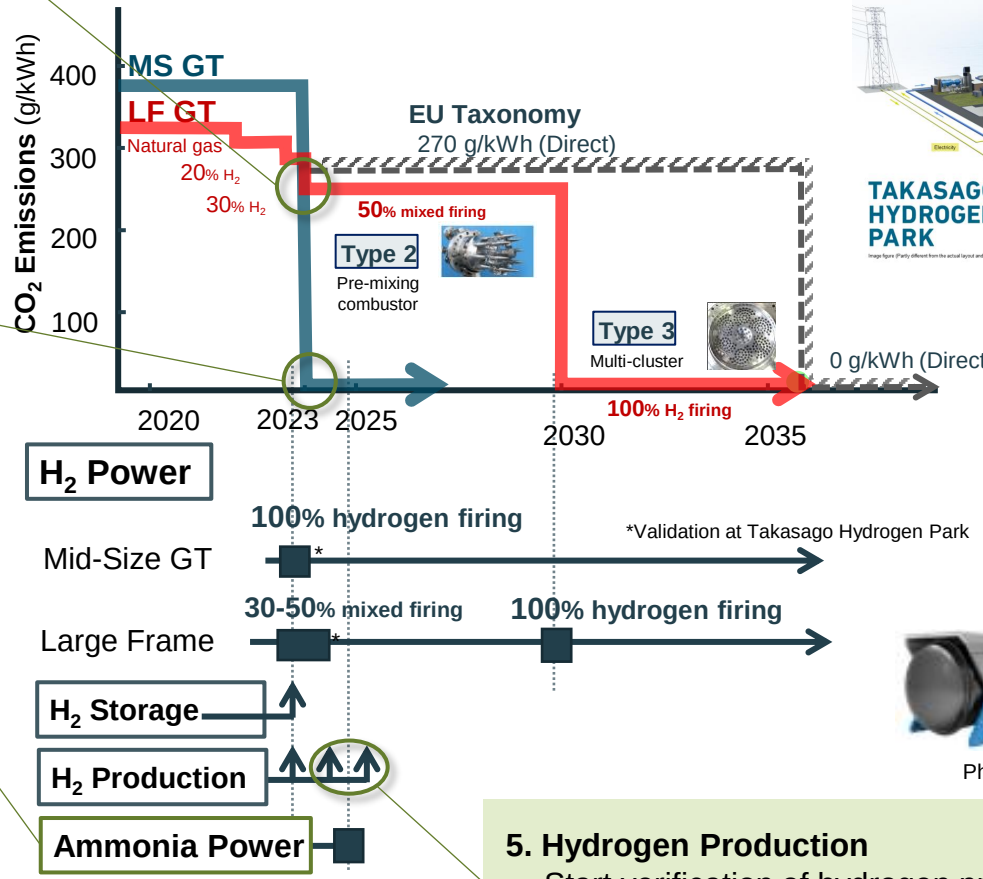
2. Zero-carbon 100% H_2 firing technology
Successful combustion test for small- and mid-size GTs **(2022)**


H-25 gas turbine

3. Zero-carbon 100% ammonia firing technology
Successful combustion test for small and mid-size GTs **(2022)**


Current hydrocarbon fuel

Ammonia (combustion test)



4. Validation at utility-scale power plant
Begin Takasago Hydrogen Park operation **(2023)**

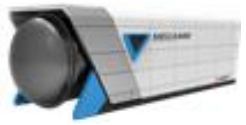
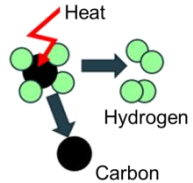


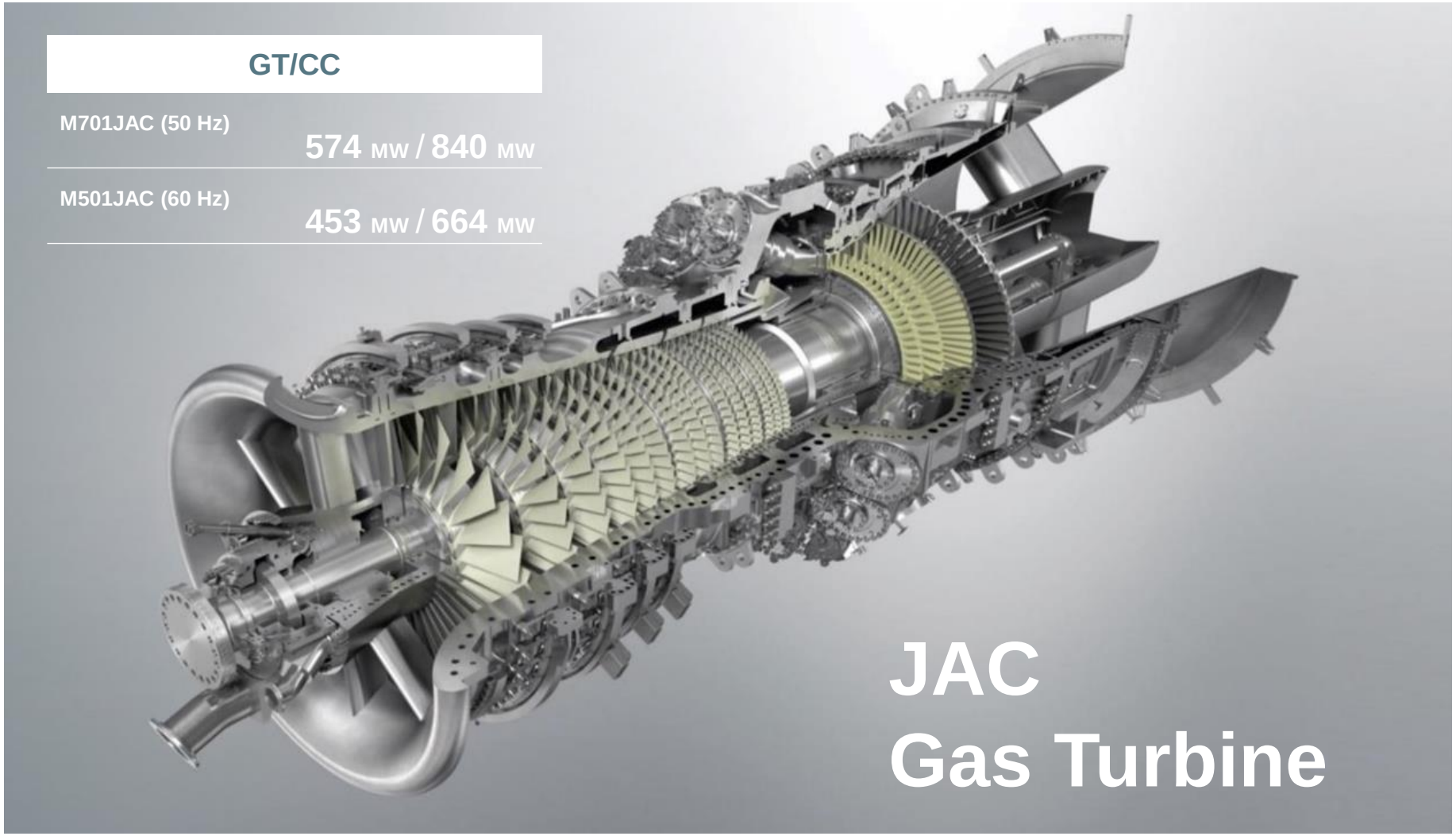
Photo: SOFC



5. Hydrogen Production
Start verification of hydrogen production using water electrolysis, SOEC, and Turquoise H_2 **(2023-)**

Coal-Fired Thermal Power → High-Efficiency GT

- 65% reduction in CO_2 emissions is possible by simply replacing coal-fired thermal power with a Natural Gas-fired Gas Turbine Combined Cycle (GTCC) plant



High Efficiency

64% CC efficiency

- High pressure ratio compressor (25:1)
- Enhanced air-cooled combustors
- Advanced TBC*

Reliability

99.5% reliability

- Cumulative operation hours: >2 million
- Booked units: 108
  (J-Series as of end April 2023)

Fuel Flexibility

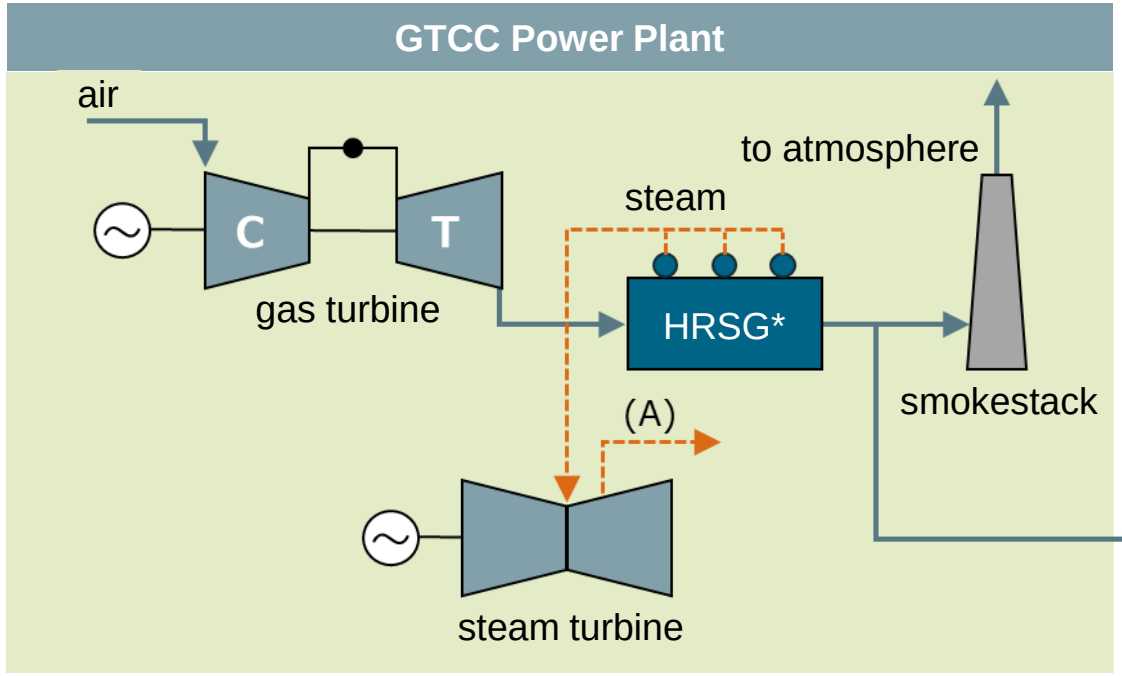
Compatible with variety of fuels

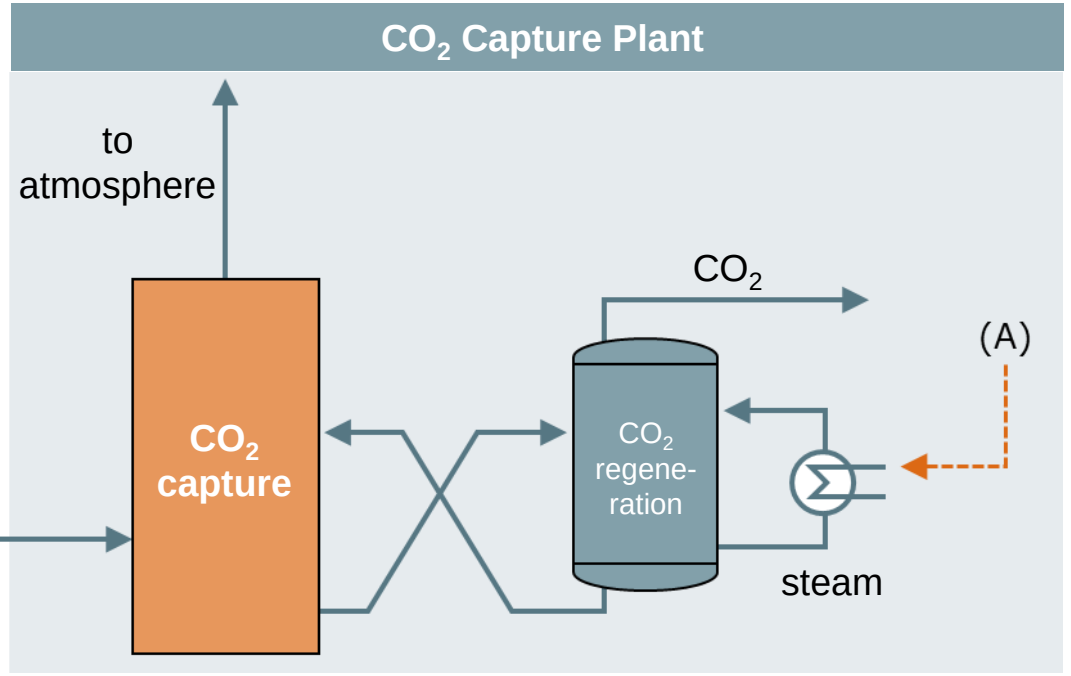
- Fossil fuels (natural gas, oil)
- Clean fuels (hydrogen)

*TBC: Thermal Barrier Coating

High-Efficiency GTCC + CO_2 Capture

- By applying a CO_2 capture system to a GTCC plant, it is possible to capture over 90% of CO_2





- Awarded Front End Engineering Design (FEED) contract for CO_2 capture plant to be applied to a natural gas-fired GTCC power generation facility in Alberta, Canada
- Supporting customers' decarbonization efforts with both GTCC and CO_2 capture systems

https://www.mhi.com/news/220711.html

- Awarded FEED contract for GTCC power generation facility and CO_2 capture plant in Scotland
- Supporting commercial-scale CCS implementation, contributing to UK's achievement of Net Zero by 2050

https://www.mhi.com/news/22083001.html

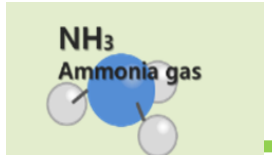
*Heat Recovery Steam Generator

Hydrogen- and Ammonia-Fired Gas Turbines

- 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

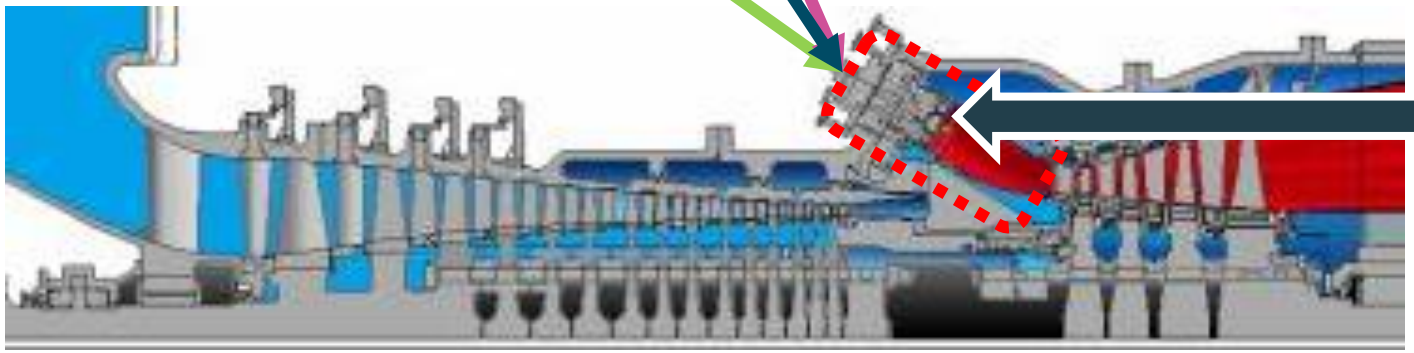
Hydrogen



Ammonia

Type 1 (Diffusion)	**100% H_2**	**Development complete**
Type 2 (Pre-mix)	**30% H_2 mixed firing**	**Development complete**
	50% H_2 mixed firing	2022: Successful combustion test for large frame GT
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

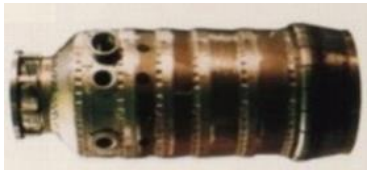
Ready to apply to commercial facilities



Combustor Replacement

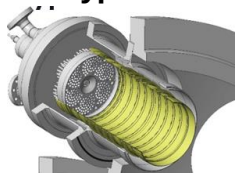
Convert to H_2/ammonia firing by replacing combustors and adding fuel supply system

Type 1



Type 2

Type 3



Ammonia Power Technology Roadmap

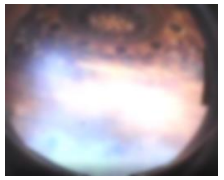
- Gas turbine: Working on combustor development, aiming for commercial unit operation and commercialization in 2025
- Boiler: Working on burner development, targeting commercialization of ≥50% mixed firing in early 2030s

GT

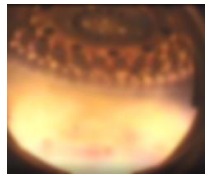
-2024 → 2025-

100% firing

Combustor development → Validation testing, commercialization



Current hydrocarbon fuel

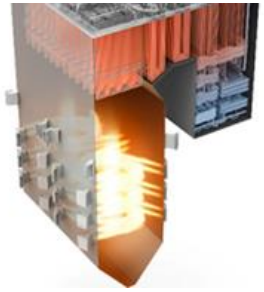


Ammonia (combustion test)

Boiler

-2024 → -2030 → -2035 → -2050

		-2024	-2030	-2035	-2050
MHI	20% mixed firing	Burner development → Validation preparation → Validation testing			
MHI/ JERA	≥50% mixed firing (Green Innovation Fund)	Burner development, validation preparation	2027-2028: Validation testing	Early 2030s: Commercialization	

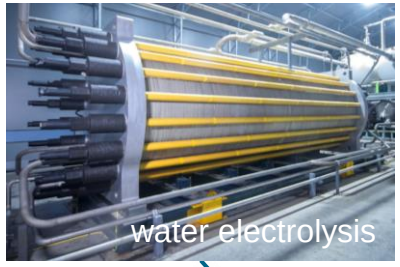


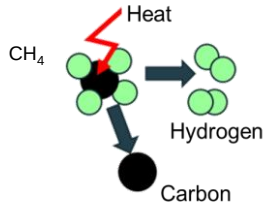
Takasago Hydrogen Park

- Integrated validation of hydrogen production, storage, and utilization began at Takasago Machinery Works in 2023

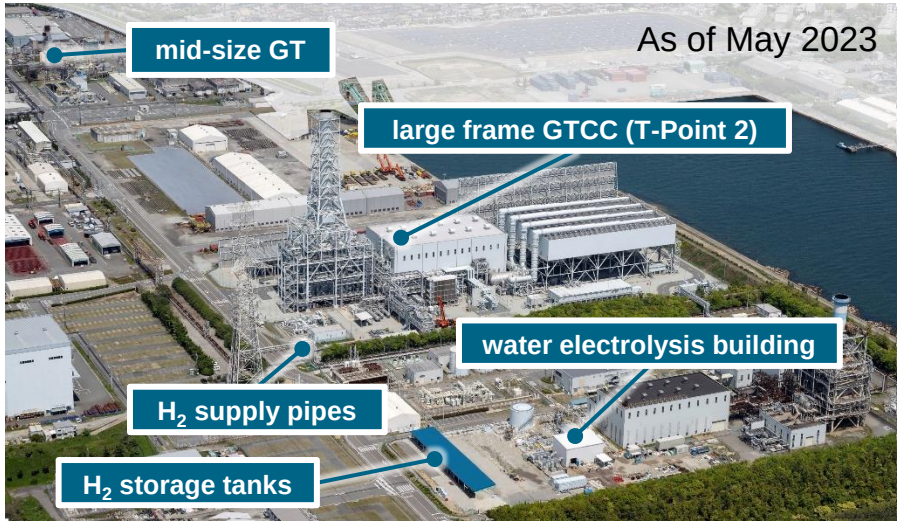
Hydrogen Utilization (Power Generation)

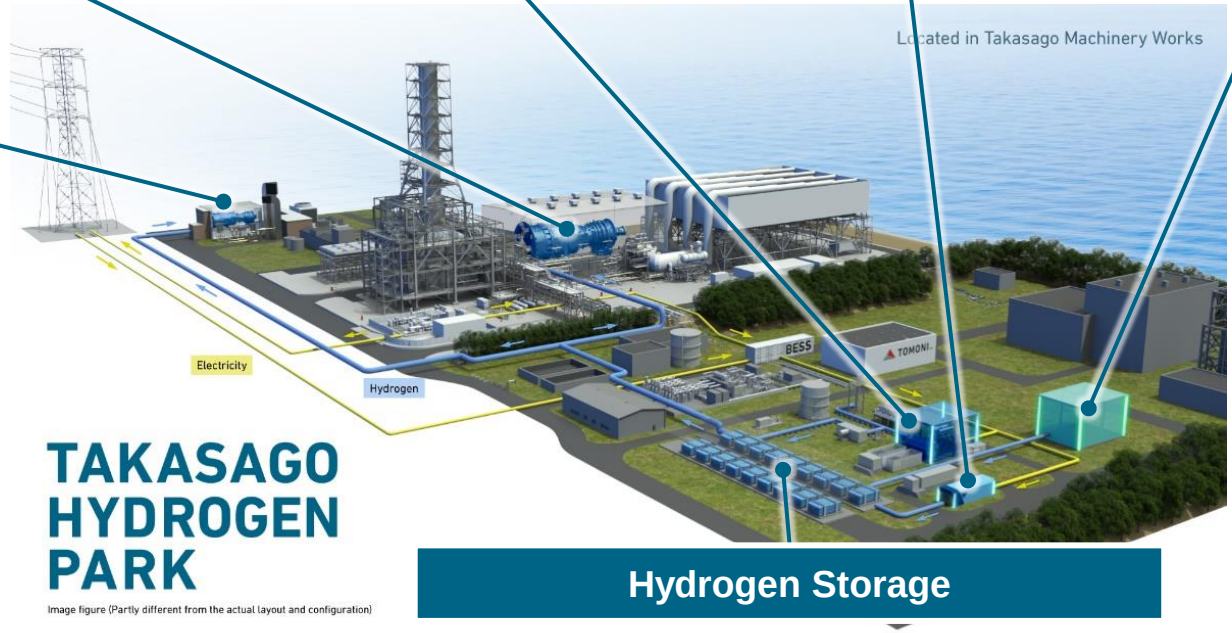
Hydrogen Production





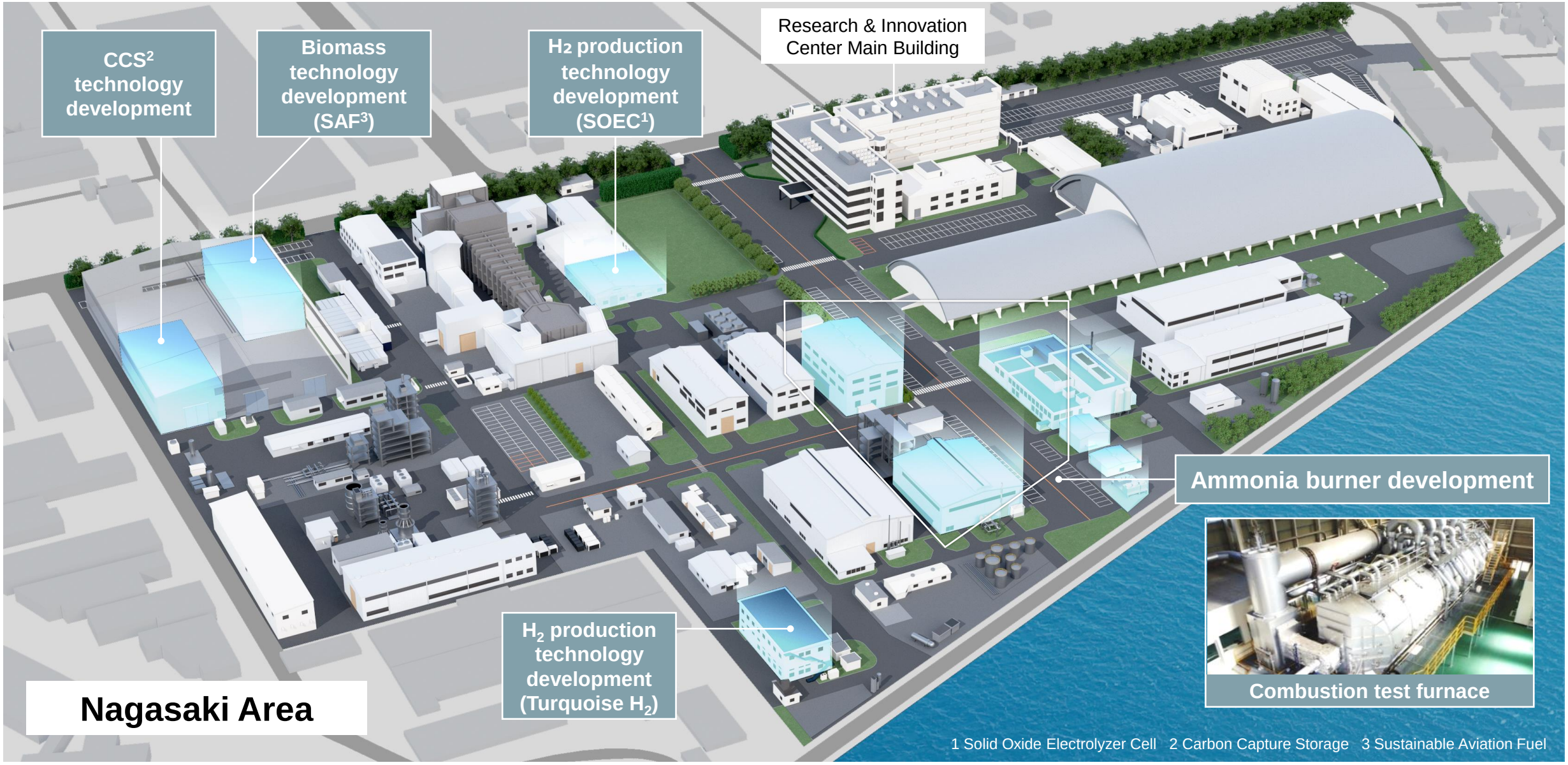
Turquoise H_2



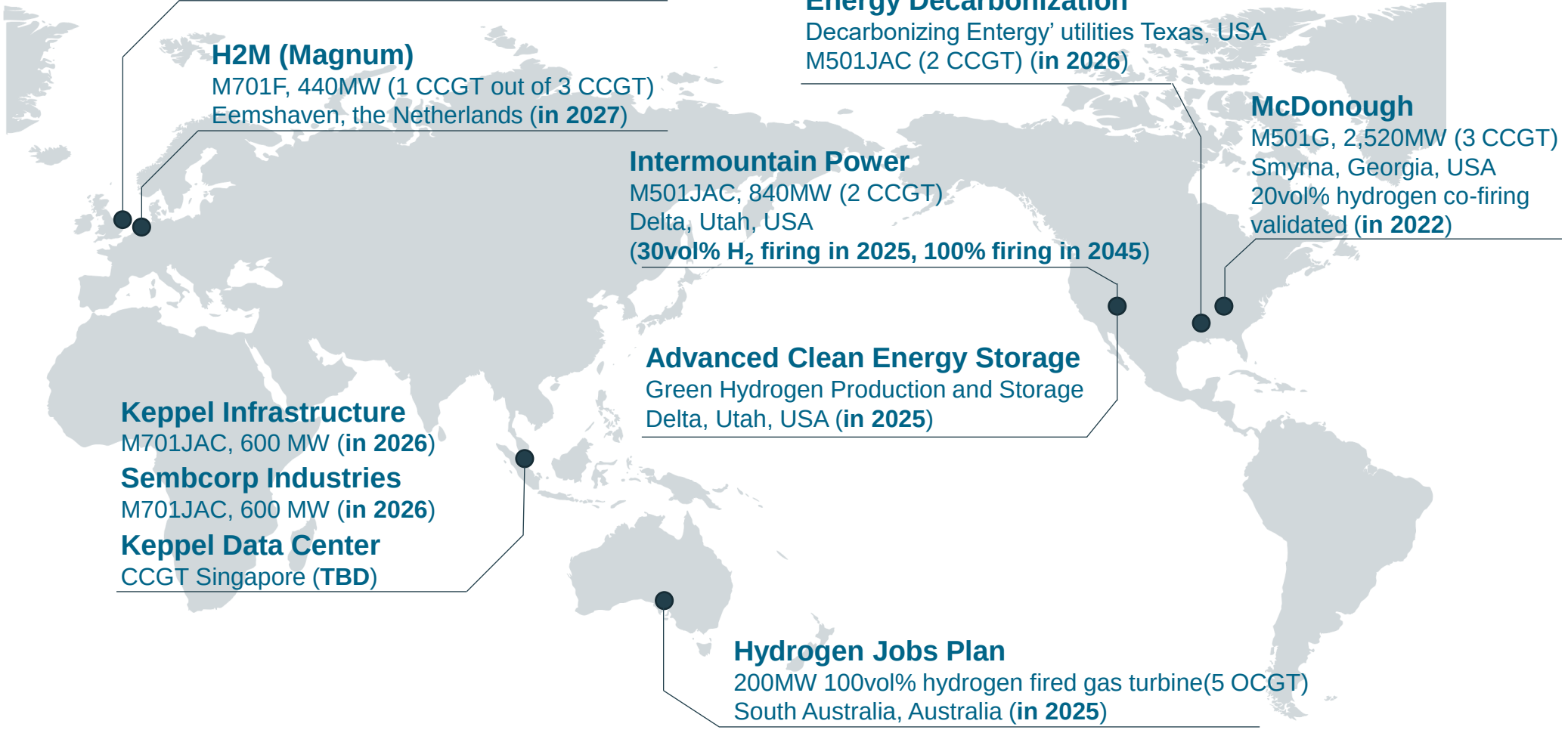


Hydrogen Storage

Development of Carbon Neutrality-Focused Technologies



MHI Hydrogen-Fired GTCC Projects



Zero Carbon Humber (H2H Saltend)
M701F, 1,200MW (3 CCGT)
Hull, Humber, UK (**after 2026**)

H2M (Magnum)
M701F, 440MW (1 CCGT out of 3 CCGT)
Eemshaven, the Netherlands (**in 2027**)

Energy Decarbonization
Decarbonizing Entergy' utilities Texas, USA
M501JAC (2 CCGT) (**in 2026**)

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

Intermountain Power
M501JAC, 840MW (2 CCGT)
Delta, Utah, USA
(**30vol% H_2 firing in 2025, 100% firing in 2045**)

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

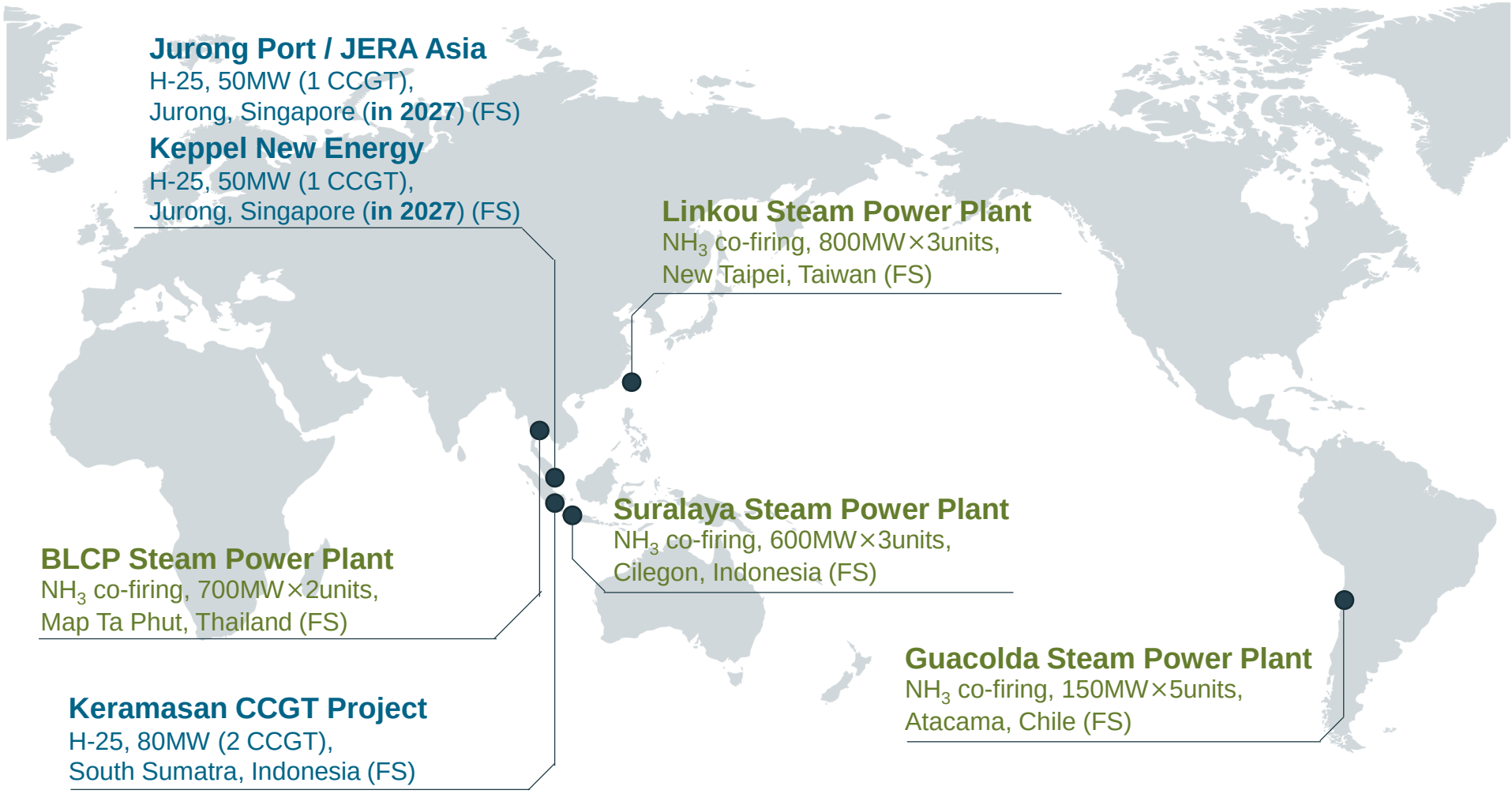
Keppel Infrastructure
M701JAC, 600 MW (**in 2026**)

Sembcorp Industries
M701JAC, 600 MW (**in 2026**)

Keppel Data Center
CCGT Singapore (**TBD**)

Hydrogen Jobs Plan
200MW 100vol% hydrogen fired gas turbine(5 OCGT)
South Australia, Australia (**in 2025**)

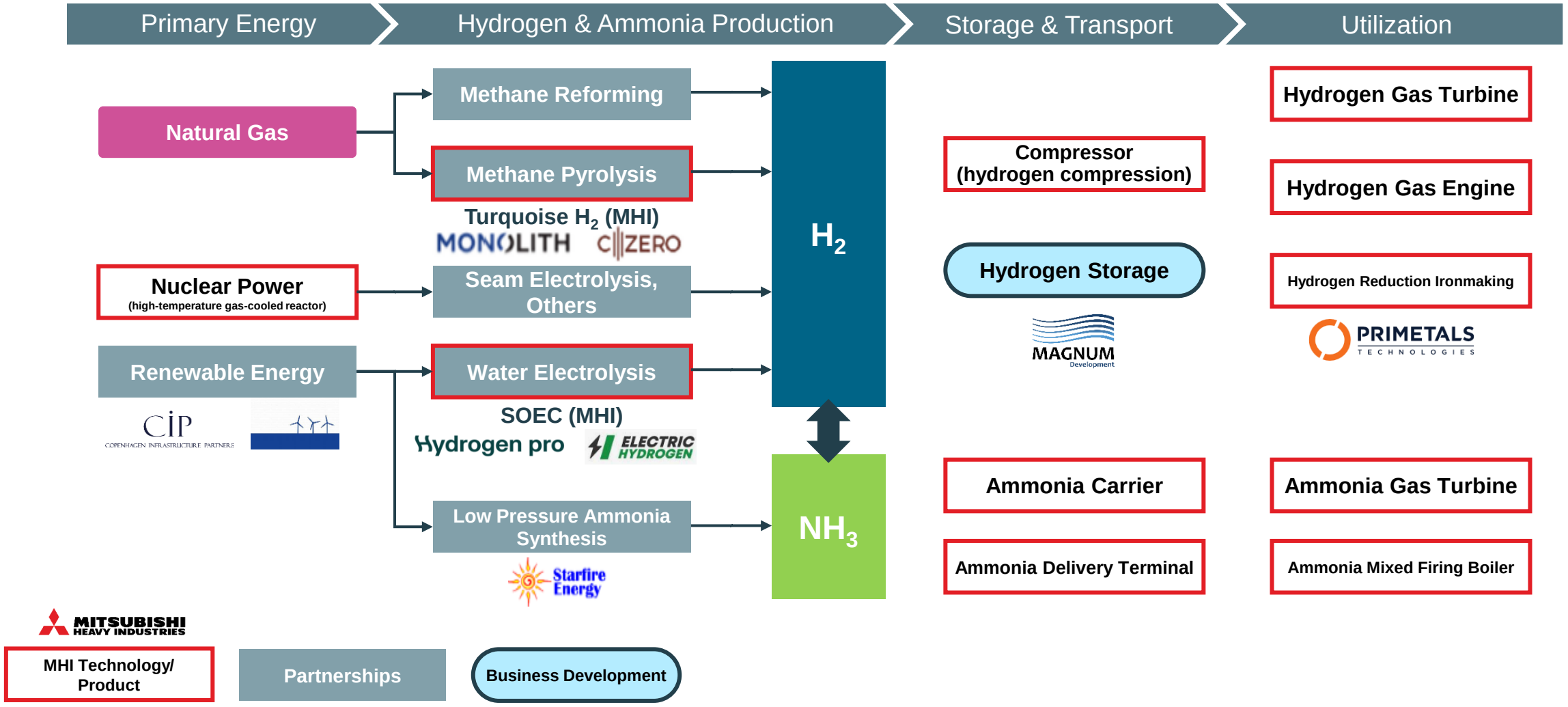
MHI Ammonia-Fired GTCC and Boiler Projects



3. Realizing a Hydrogen Solutions Ecosystem

Hydrogen Solutions Ecosystem Initiatives

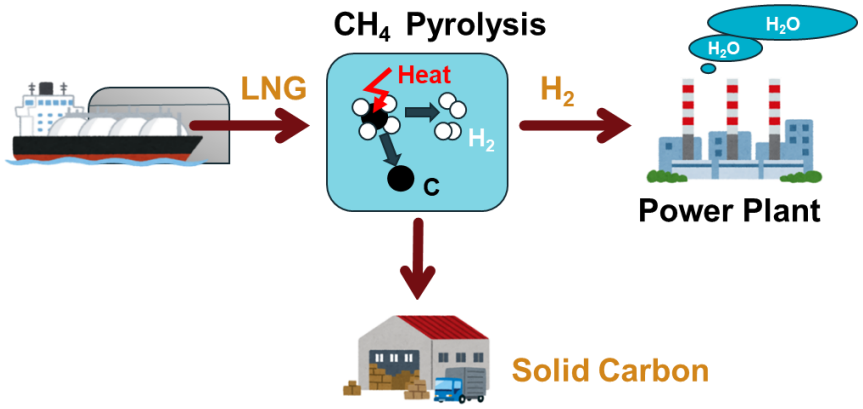
- In addition to in-house development, MHI is working to strengthen cooperation with partners and pursue business development to cover the entire value chain



Status of Hydrogen Production Technology Development

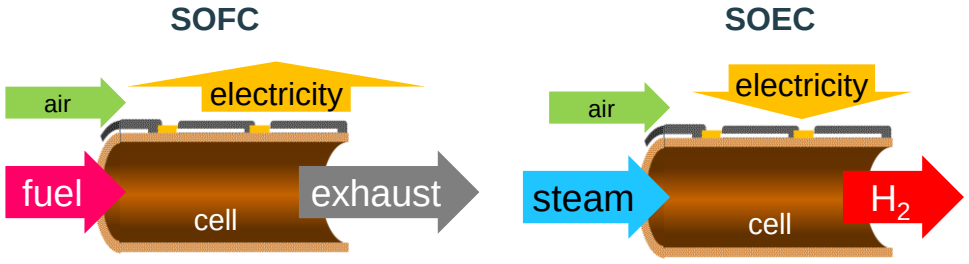
Turquoise Hydrogen

- Produce hydrogen by methane pyrolysis with catalyst. Recover carbon as a solid.
- Low-cost supply of carbon-free H_2 at scale utilizing existing LNG infrastructure



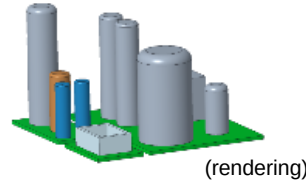
SOEC

- SOEC (Solid Oxide Electrolysis Cell) produces hydrogen using steam and electricity
- Able to apply cell technology by reversing SOFC (Solid Oxide Fuel Cell) reaction



- Planning to start validation of MHI-developed SOEC during FY2023
- Executing development and validation aiming for commercialization in FY2026 or thereafter

	2023	2024	2025	2026-
Turquoise H_2				
Elemental testing				
Development & validation				
Commercialization				
SOEC				
Elemental testing				
Development & validation				
Commercialization				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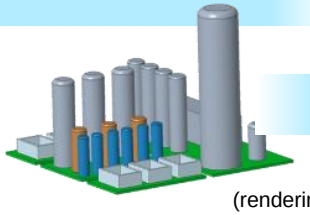
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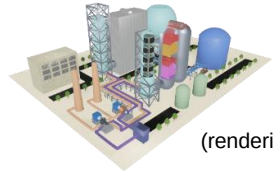
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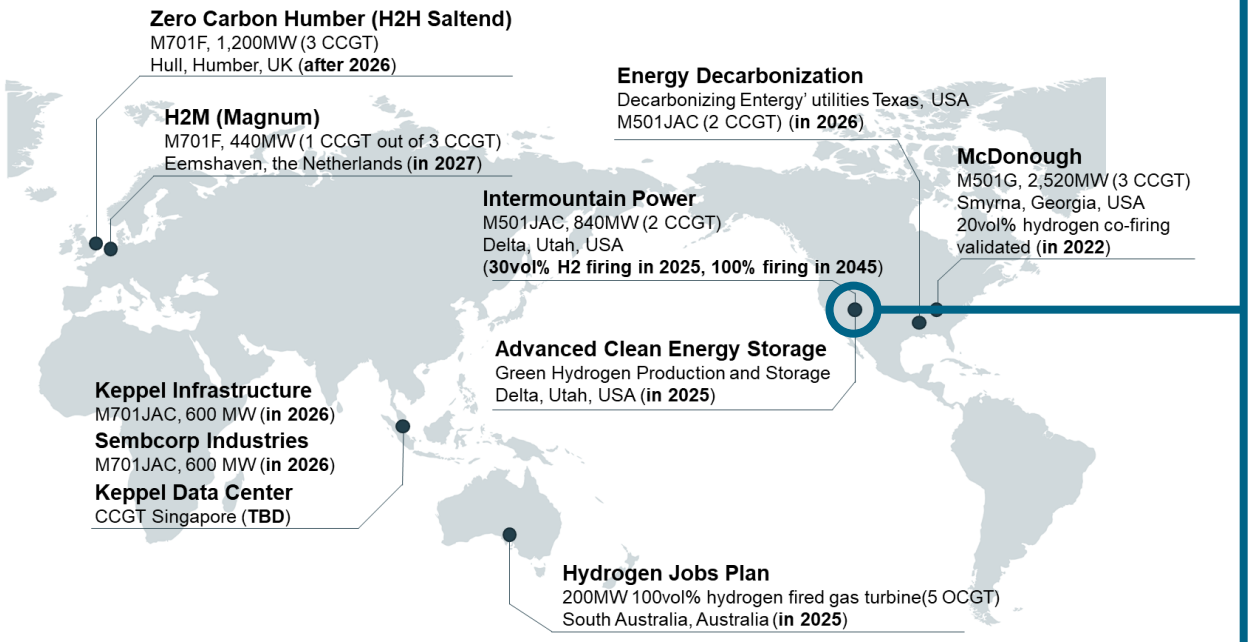
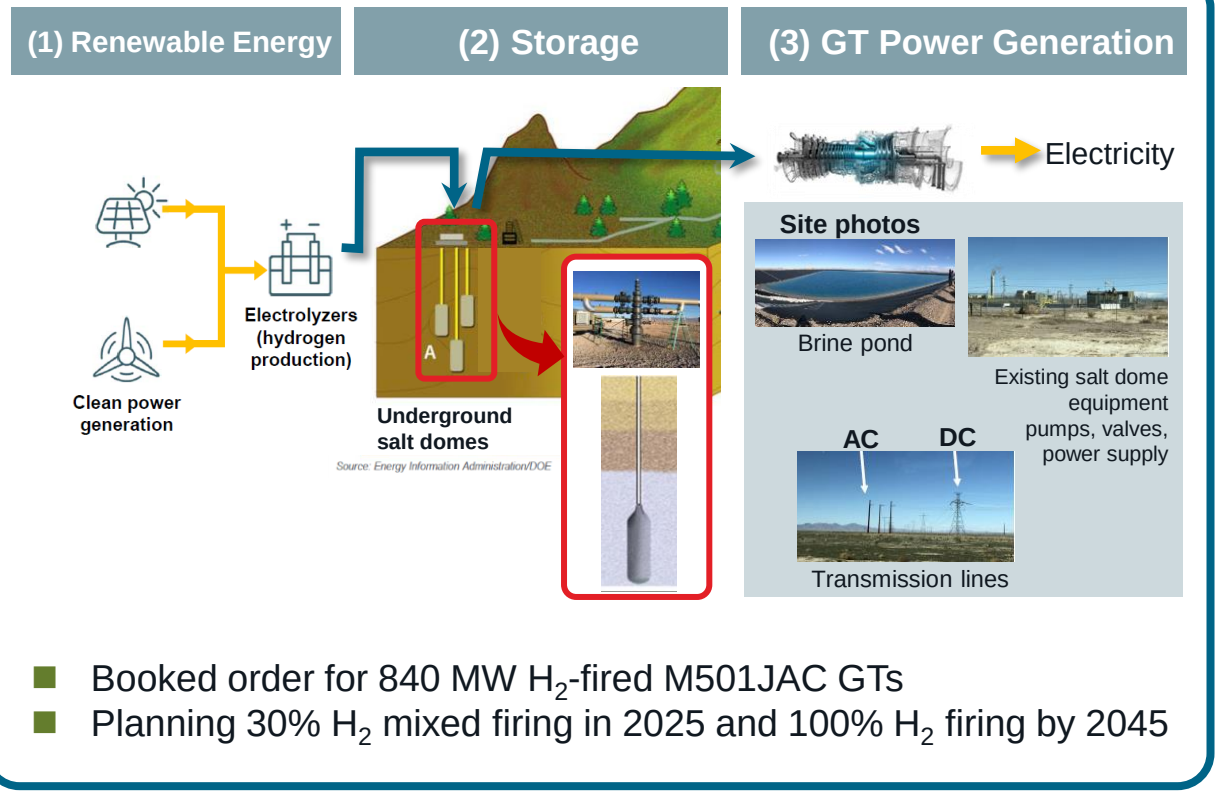
Example of Hydrogen Storage + GT Project in US

Advanced Clean Energy Storage Project (Utah, US)

- Produce green hydrogen with abundant renewable energy from West Coast. Store green hydrogen in underground salt domes.
- When electricity is required, draw on green hydrogen to produce electricity with gas turbine, thereby stabilizing the power supply/demand balance in the medium to long term
- Final investment decision reached in June 2022. Start of 30% hydrogen mixed firing planned in 2025.



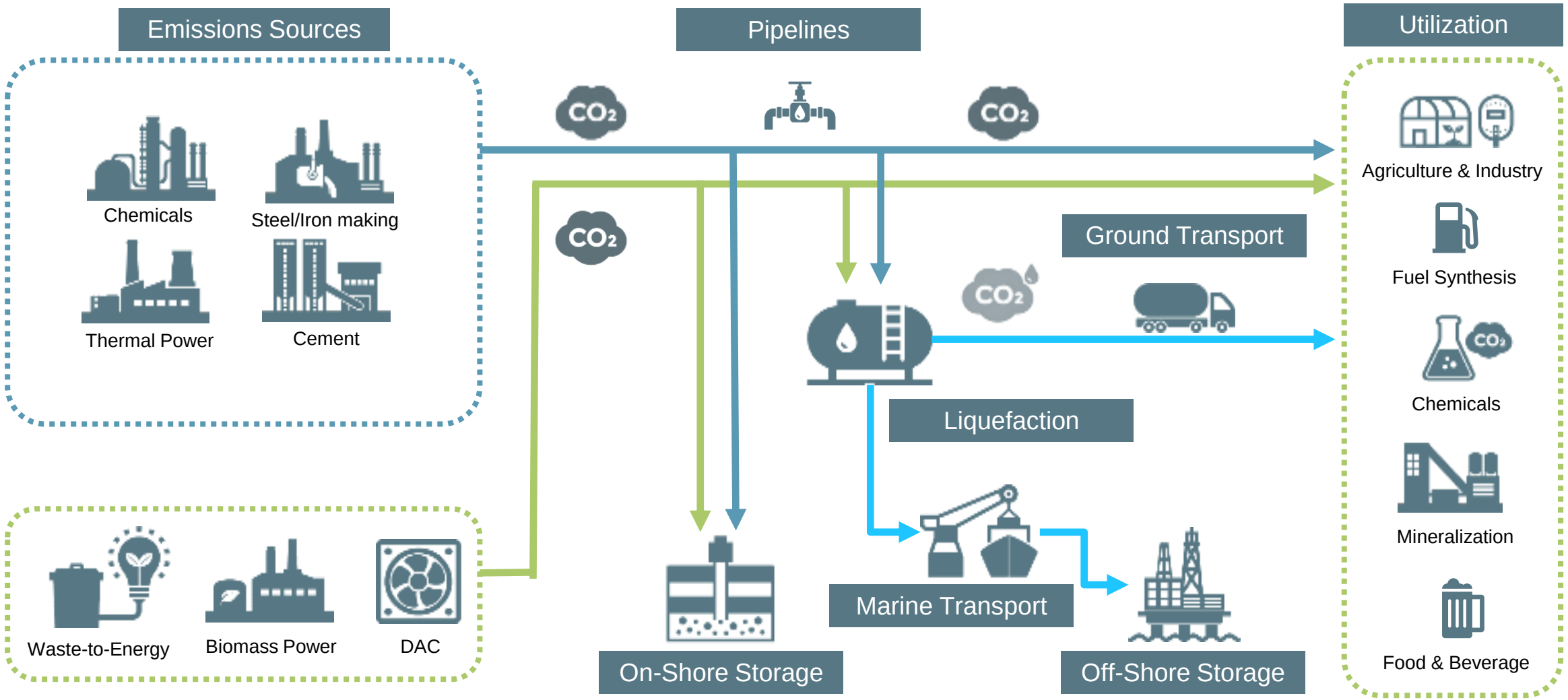


- Booked order for 840 MW H_2-fired M501JAC GTs
- Planning 30% H_2 mixed firing in 2025 and 100% H_2 firing by 2045

4. Realizing a CO_2 Solutions Ecosystem

Overview of CO_2 Solutions Ecosystem Initiatives

- MHI's Energy Transition initiatives will address these areas within the CCUS value chain, which comprises the CO_2 solutions ecosystem



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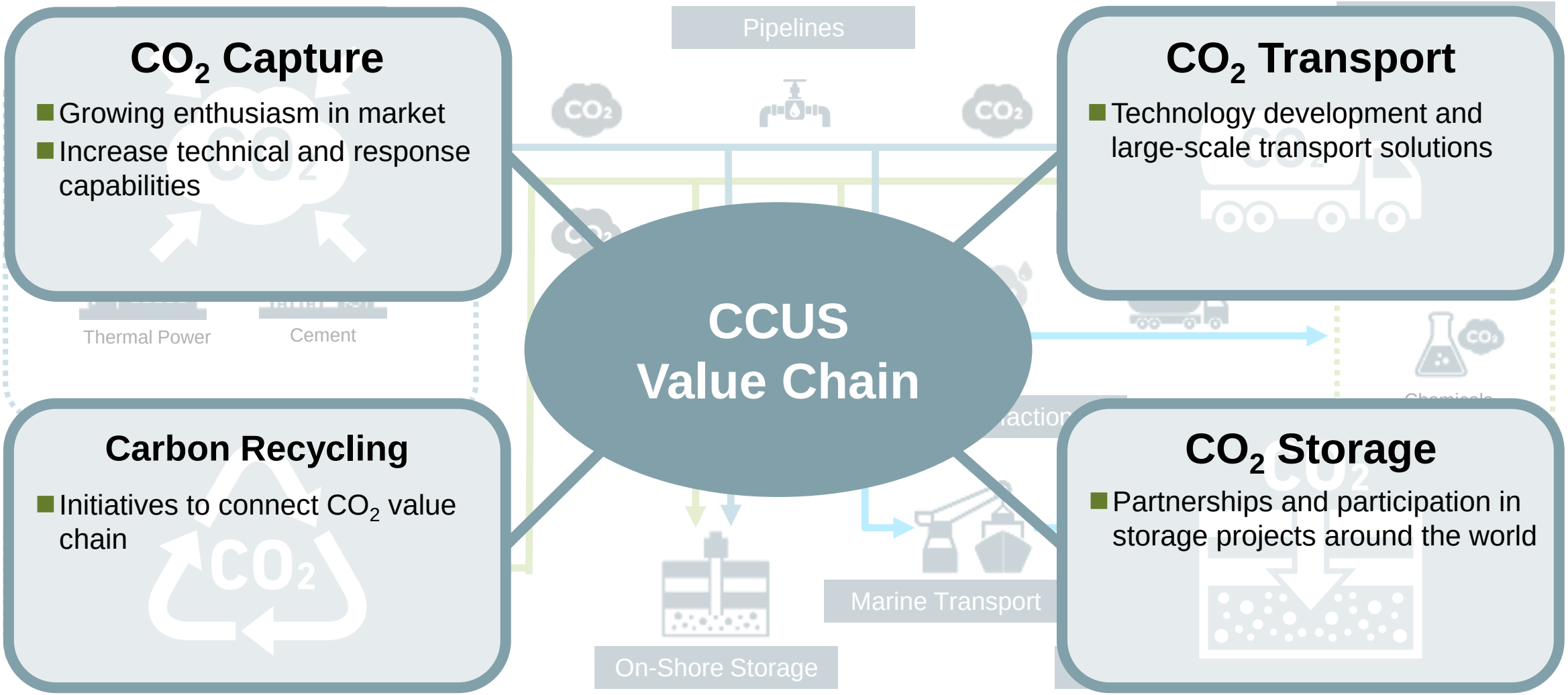


CO_2 Capture

- Growing enthusiasm in market
- Increase technical and response capabilities

CO_2 Transport

- Technology development and large-scale transport solutions

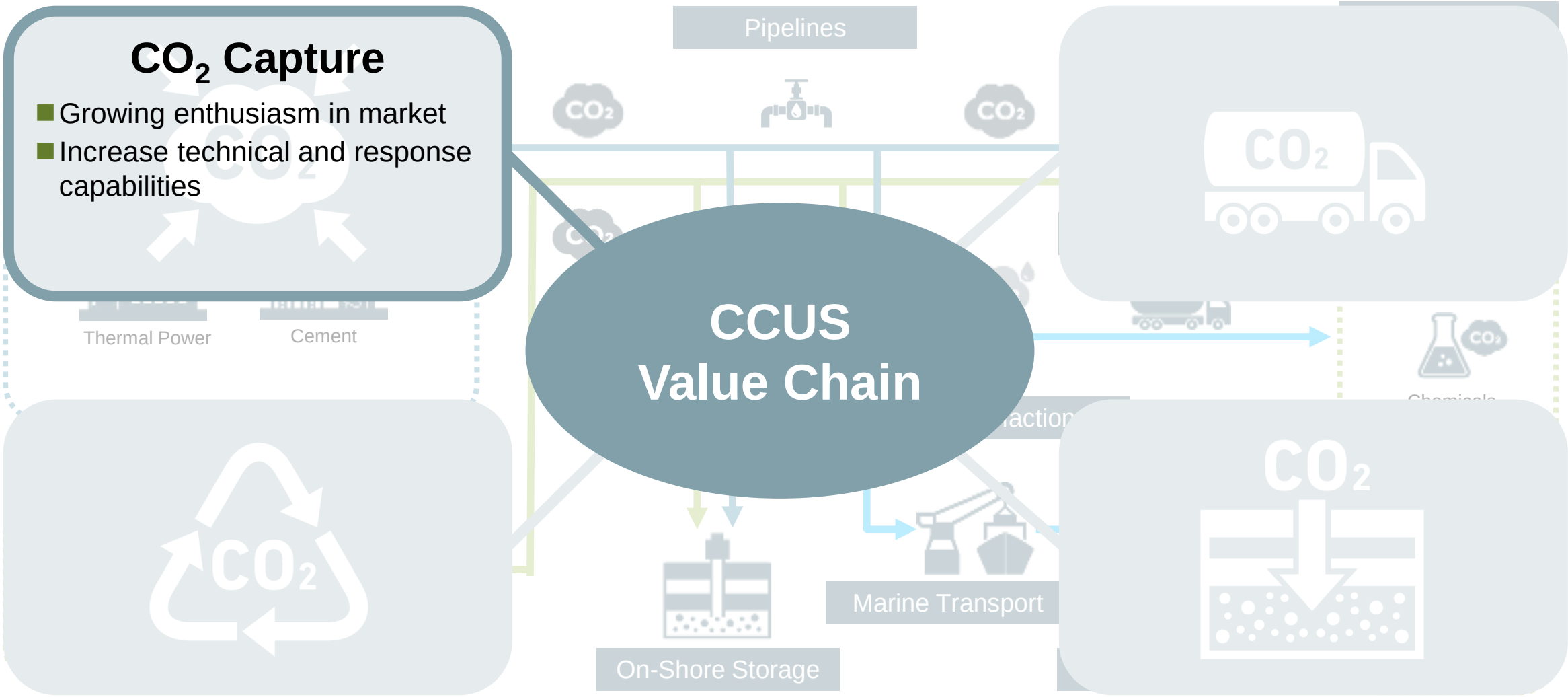
Carbon Recycling

- Initiatives to connect CO_2 value chain

CO_2 Storage

- Partnerships and participation in storage projects around the world

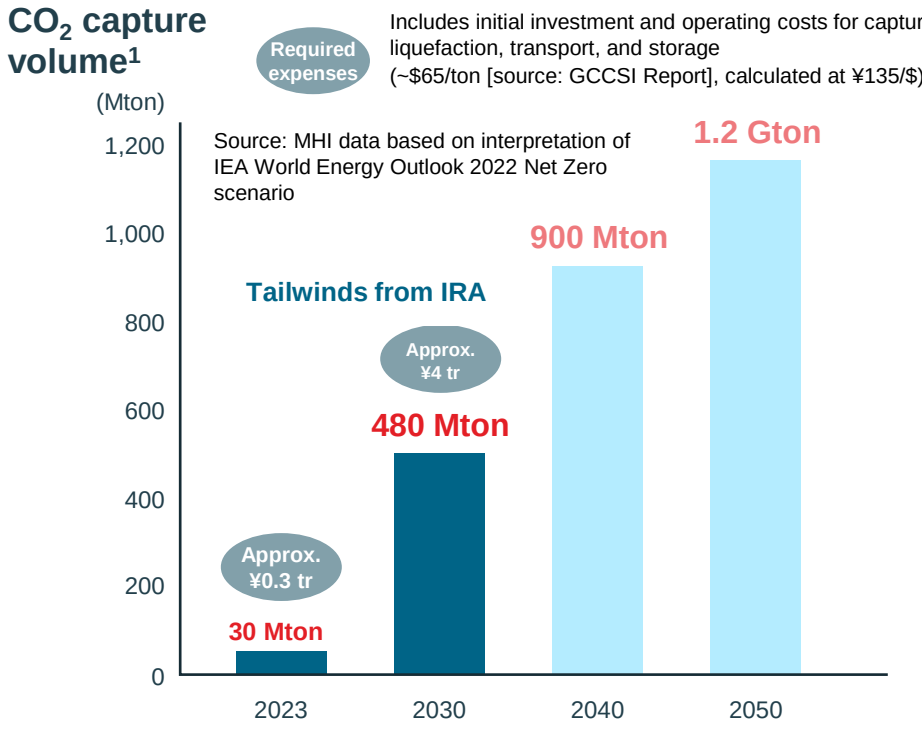
- MHI's Energy Transition initiatives will address these areas within the CCUS value chain, which comprises the CO_2 solutions ecosystem



CO_2 Storage: Growing Enthusiasm in Capture Market

- Inquiries strong especially in Europe and US on back of IRA passing. Respond to further growth in CO_2 capture demand in US, aiming to expand business and maintain market share.
- In May 2023, US Department of Energy (DOE) Office of Clean Energy Demonstrations (OCED) announced 8 new grant recipient projects which will progress to FEED stage. Due to high customer rating of our technology, 3 of these projects plan to use MHI CO_2 capture systems.

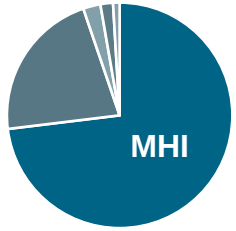
CO_2 Capture Required for Net Zero Scenario (US)



1 MHI calculation of yearly CO_2 capture volumes assuming 300 days of operation/year

No.	Selected Contractor	Site Location
1	Duke Energy Indiana, LLC	Indiana
2	Entergy Services, LLC	Louisiana
3	Lehigh Hanson, Inc	Indiana
4	Navajo Transitional Energy Company, LLC	New Mexico
5	Southern States Energy Board	Arkansas
6	Taft Carbon Capture, LLC	Louisiana
7	Tampa Electric Company	Florida
8	University of Illinois at Urbana-Champaign	Illinois

Planning to use MHI CO_2 capture technology



MHI global market share of CO_2 capture from exhaust gas is over 70%[2]

DOE Carbon Capture Demonstration Projects Program

Sep 2022: Announcement of total $189M in funding for CCS FEED projects

2 Based on MHI study of CO_2 capture volume from installed commercial systems

CO_2 Capture: Increase Technical and Response Capabilities

- Pursuing further evolution of our world-leading CO_2 capture process. Performing validation testing with ArcelorMittal and other partners from diverse industries aiming to expand application of our process.
- Executing license partnerships with key players in the supply chain in order to respond to growing global business opportunities, strengthening, for example, regional and customer relationship-related capabilities

Improving Technical Capabilities

- With Kansai Electric Power Co., Inc, commercialized Advanced KM CDR Process™ which utilizes newly developed KS-21™ absorbent
- Confirmed superiority of KS-21™ absorbent during validation tests at the CO_2 Technology Centre Mongstad in Norway, one of the world's largest CO_2 capture testing facilities (Aug 2021)
- KS-21T™ characteristics (comparison with previous KS-1™ absorbent)
  - Low volatility and high resistance to decomposition
  - Decreased amine emission levels through oxidation suppression
  - Decreased CO_2 compressor power requirements by increasing regeneration tower pressure

	KS-1™	KS-21™ *
Volatility	100	**50-60**
Thermal Decomposition Rate	100	**30-50**
Oxidation Rate	100	**70**
Heat Absorption	100	**85**

*Dependent on exhaust gas parameters

License Partnerships

- Beginning in April 2023, working with leading Italian engineering company, Saipem, as a project cooperation partner to expand sales of CO_2 capture plants, mainly in Europe and the Middle East

SAIPEM

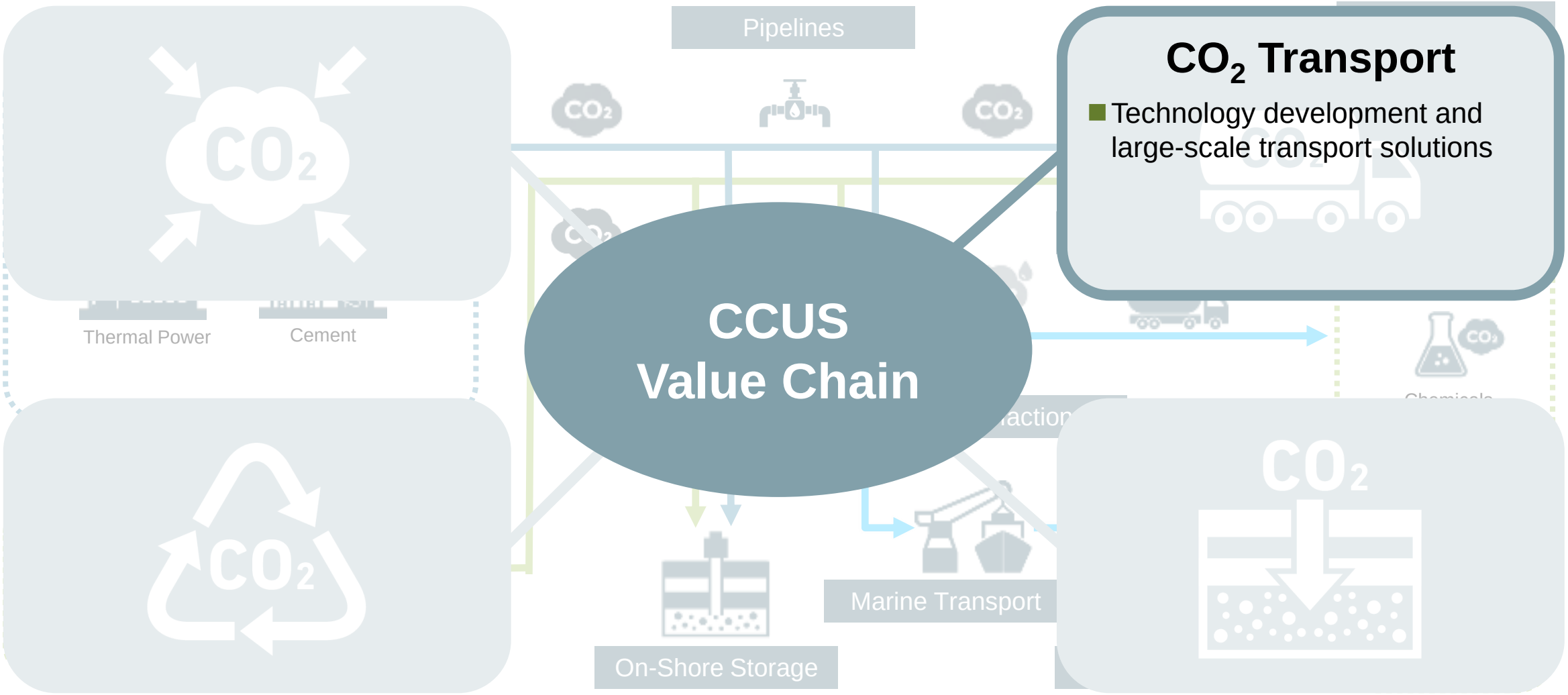
About Saipem

- An Italian engineering company performing engineering, procurement, construction, and project management mainly in the oil and gas sector
- With bases in more than 70 countries, the company possesses advanced, innovative technologies and has a solid track record in completed deliveries
- MHI has had a cooperative relationship with Saipem for many years relating to the latter's urea technology, and we have built fertilizer plants together around the world

Validation Partnerships

Steel/Iron making	**ArcelorMittal and Others** Executed collaboration agreement (Oct 2022)
Cement	**Tokuyama** end Jun 2022 – end May 2023
Waste-to-Energy	**Yokohama City** Jan 2023 – Mar 2024
Gas Engines	**MHI** end Jul 2022 – end May 2023

■ MHI's Energy Transition initiatives will address these areas within the CCUS value chain, which comprises the CO_2 solutions ecosystem



CO_2 Transport: Technology Development and Large-Scale Transport Solutions

- As CCS market takes off, large-scale transport of CO_2 will become essential. MHI will contribute with marine transport vessel technologies.
- Held launch ceremony in March 2023 for liquified CO_2 (LCO_2) carrier demonstration test ship at Shimonoseki Shipyard & Machinery Works
- Executing feasibility studies (FS) (cumulative total projects: 20) on CO_2 transport and pursuing partnerships

After completion at end 2023, planning to transport CO_2 from Maizuru to Tomakomai starting in 2024

Launch ceremony (Mar 2023)

Flag	Japan	Class	ClassNK
Length o.a.	72.0 m	Breadth	12.5 m
Tank capacity	1,450 m^3	Draught	4.55 m

Partnerships on FS and Conceptual Design AIP[1]

Category	Partnership Candidates
CCS Providers	Including Equinor, INPEX, ITOCHU, and TotalEnergies
Marine Shipping Companies	Including Kawasaki Kisen Kaisha, Mitsui O.S.K. Lines, Nippon Gas Line, Nippon Yusen, and Sanyu Kisen
Classification Society	Including Bureau Veritas[2], ClassNK[3], and Det Norske Veritas[4]
Construction Partner	Including Nihon Shipyard

(Organization names presented in alphabetical order)

1 AIP: Approval in Principle 2 A French ship classification society 3 A Japanese ship classification society 4 A Norwegian classification society

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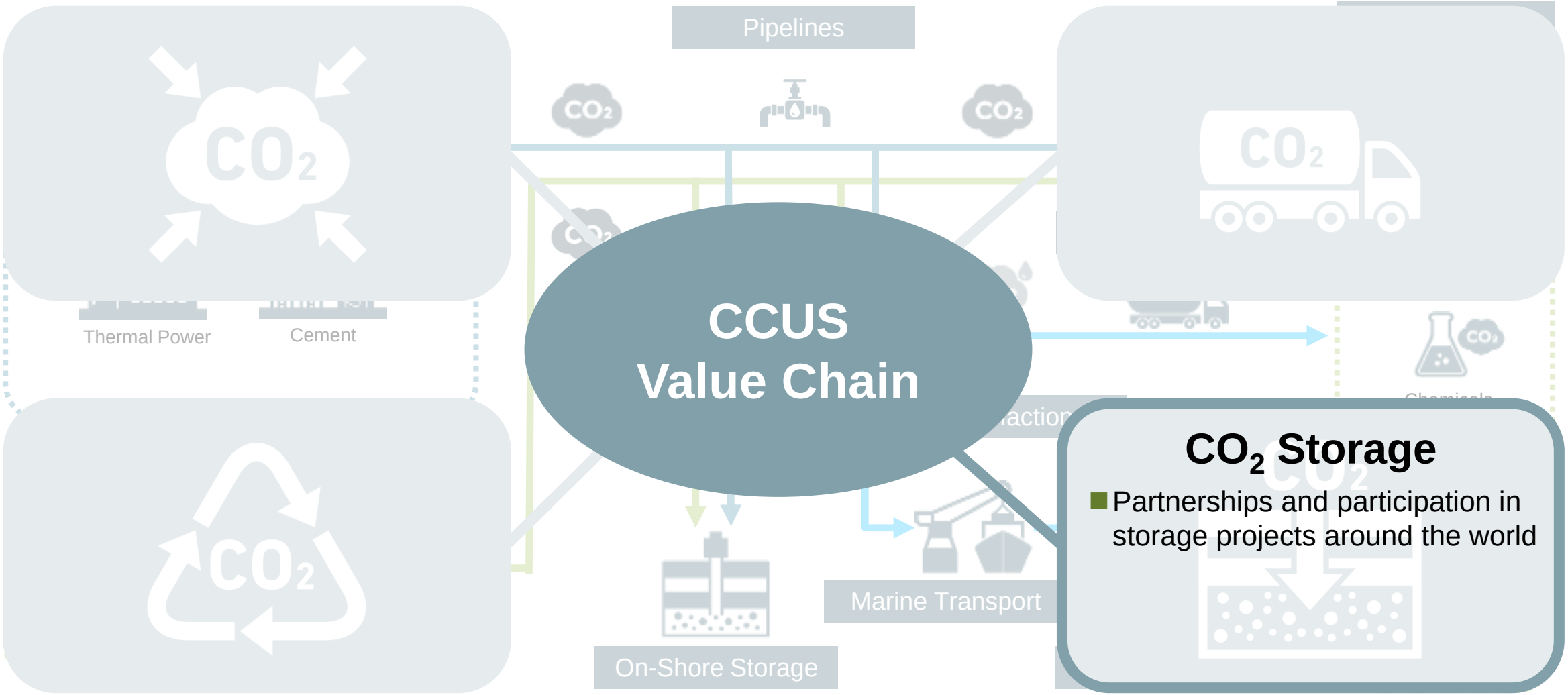
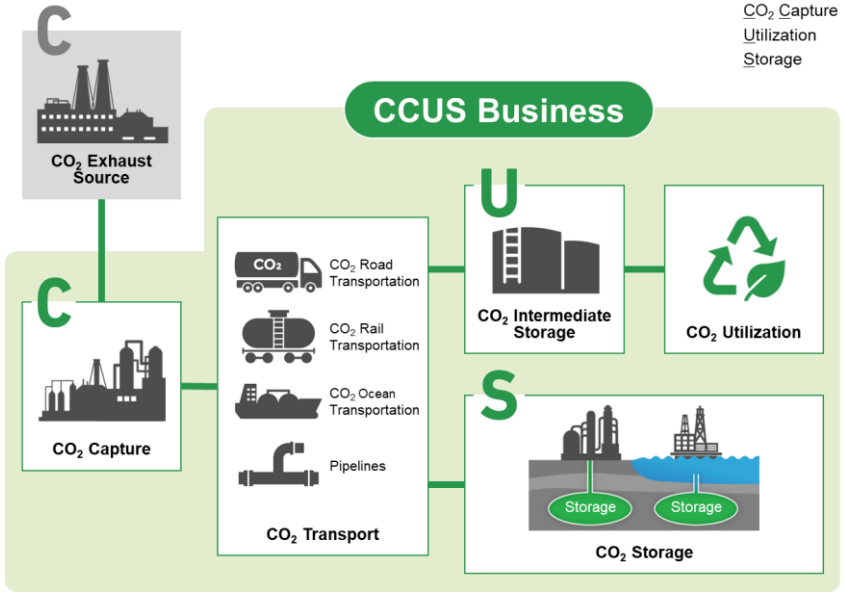


CO_2 Storage: Partnerships and Participation in Storage Projects Around the World

- Formed alliance with ExxonMobil in 2022. Working to establish organization to provide solutions for entire value chain and to accelerate development of projects around globe.
- This alliance will allow MHI to contribute to the creation of an end-to-end CO_2 solutions ecosystem linking emissions sources with storage and utilization providers

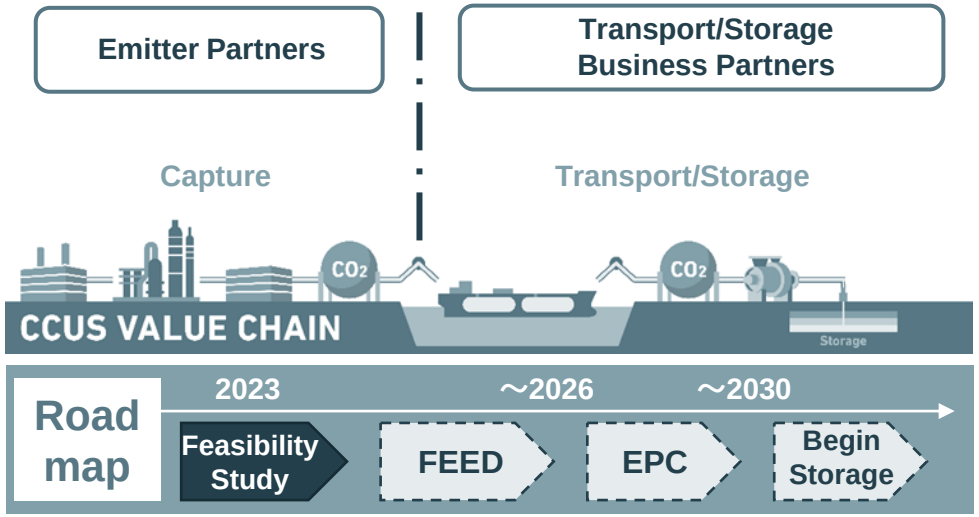
Global: Partnership with ExxonMobil (Expansion of CCS Projects)

- ExxonMobil has over 30 years of experience in CO_2 capture, transport, and safe injection into geological formations
- Enables end-to-end CCS solutions from capture to storage for industrial customers by combining MHI's CO_2 capture technology with ExxonMobil's transport and underground storage technologies
- Strengthening cooperation on CCS projects around the world, especially in US



Japan: Joint Study on Value Chain Businesses

- Japanese government promoting long-term CCS roadmap including CAPEX and OPEX subsidies
- Plan for domestic CCS efforts to develop rapidly with 3-5 projects representing different combinations of CO_2 emissions source, transport method, and CO_2 storage region selected.
- MHI plans to execute joint study as CCS provider with INPEX and others in FY23



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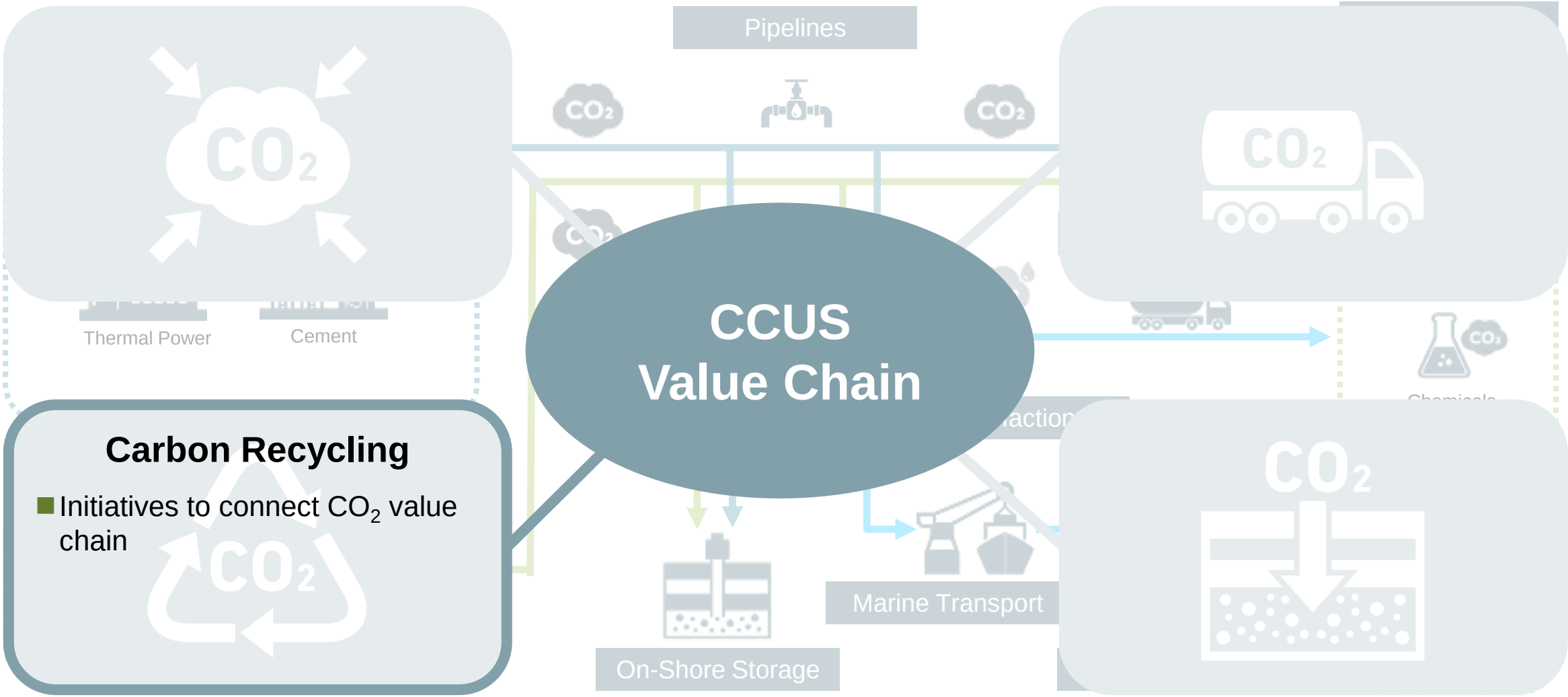
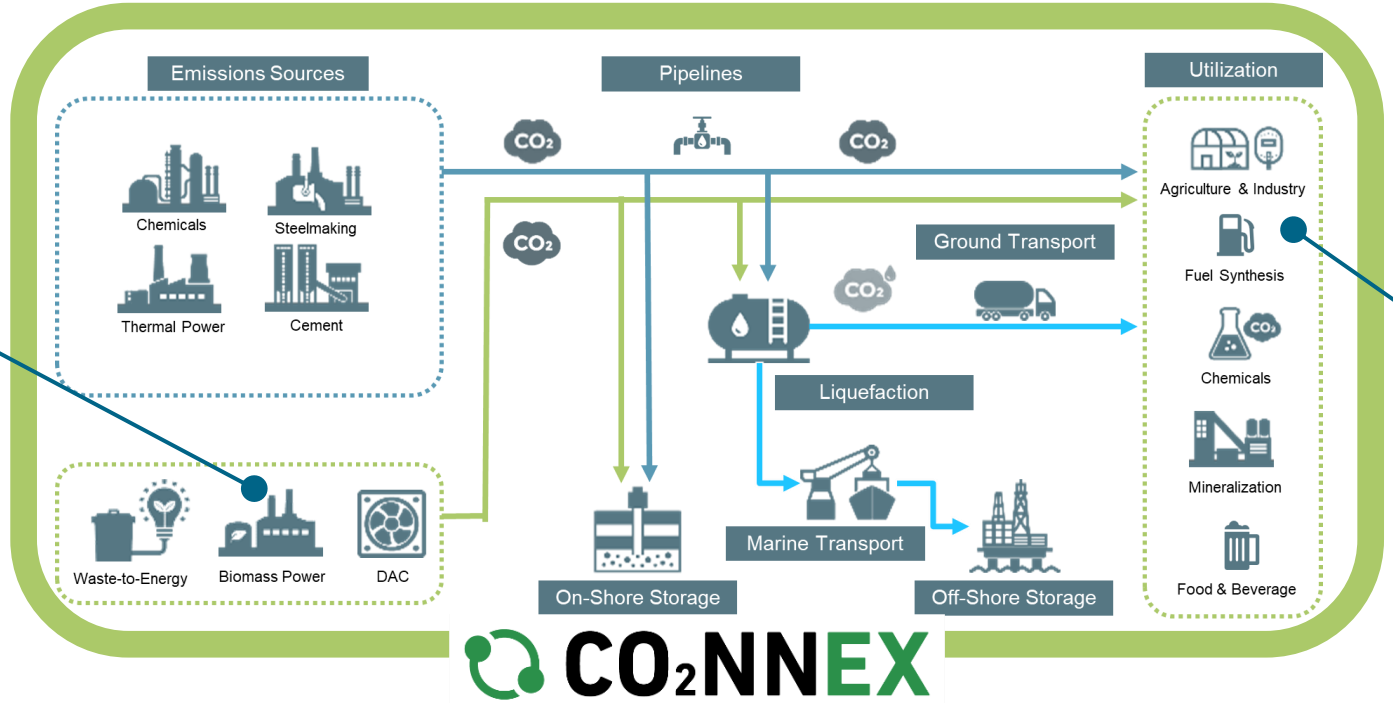


Carbon Recycling: Initiatives to Connect Value of CO_2

- Accurately measure, grasp, and visualize value of CO_2 within CCUS value chain, and support circulation and transactions of this value
- Contribute to carbon recycling market expansion with experience in such areas as fertilizer and methanol manufacturing, as well as through investments in start-ups in a wide variety of industries utilizing CO_2

Appropriately circulate CO_2 with high CN contribution value, such as that obtained from DAC or biomass

- CO_2 capture and utilization at biomass power plant in Hiroshima
- DAC technology development



Contribute to market expansion including through start-up investments in the areas of:

- Synthetic fuels (e-fuels)
- Biotechnologies
- Chemical synthesis
- Mineralization

and more

CO_2NNEX is a digital platform which will connect all participants and CO_2 in the CCUS value chain.
CO_2NNEX will accelerate carbon recycle ecosystem growth. (Jointly developing with IBM)

- Executing several proofs of concept within Japan
- Together with partners including Osaka Gas, working to apply CO_2NNEX for e-methane, a sustainable fuel currently in development

5. Key Takeaways

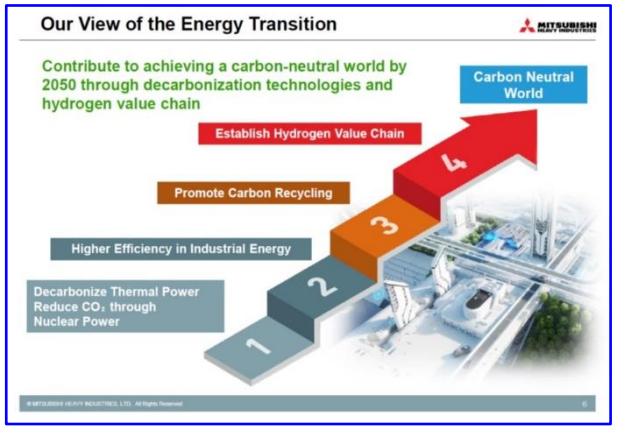
Key Takeaways

- **Multiple MHI technology development projects showing progress in each region**
- **Holding wide discussions with partners in a variety of industries with goal of realizing hydrogen and CO_2 ecosystems**
- **Poised to seize many opportunities presented by the Energy Transition**

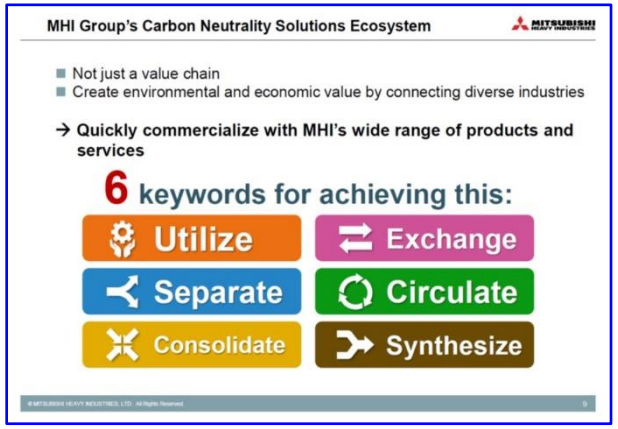

MITSUBISHI
HEAVY INDUSTRIES

Past Briefings on the Energy Transition

Past Briefings on Business Strategy



[Energy Transition Strategy Briefing: Energy Transition – New Frontier for MHI Group (November 26, 2020)]

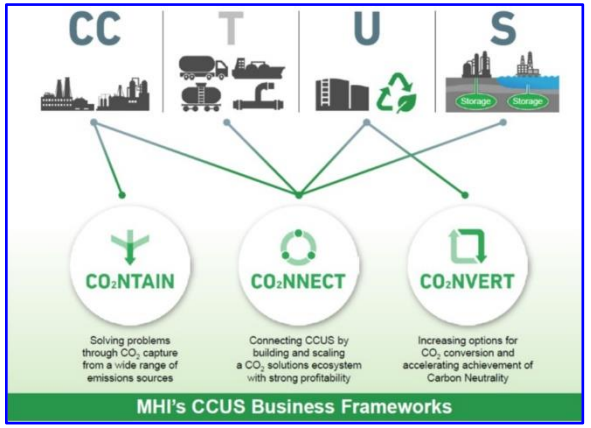


[Carbon Neutrality Briefing (March 18, 2022)]

[2021 Medium-Term Business Plan Progress Briefing (April 4, 2023)]

Past Briefings on Individual Topics

[Hydrogen Technology Virtual Tour (June 14, 2021)]



[CCUS Briefing (October 12, 2021)]