MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

The Potential of CCUS

2021.10.12

Mitsubishi Heavy Industries

MITSUBISHI HEAVY INDUSTRIES

SECTION 1 | Expectations for CCUS

- Annual CO_2 Capture Required to Achieve Carbon Neutrality by 2050
- CCUS Challenges
- Status of CCUS CO_2 storage

SECTION 2 | MHI's Contributions to CCUS

- Three CCUS Frameworks:（CO_2NTAIN / CO_2NNECT / CO_2NVERT）
- Timeline

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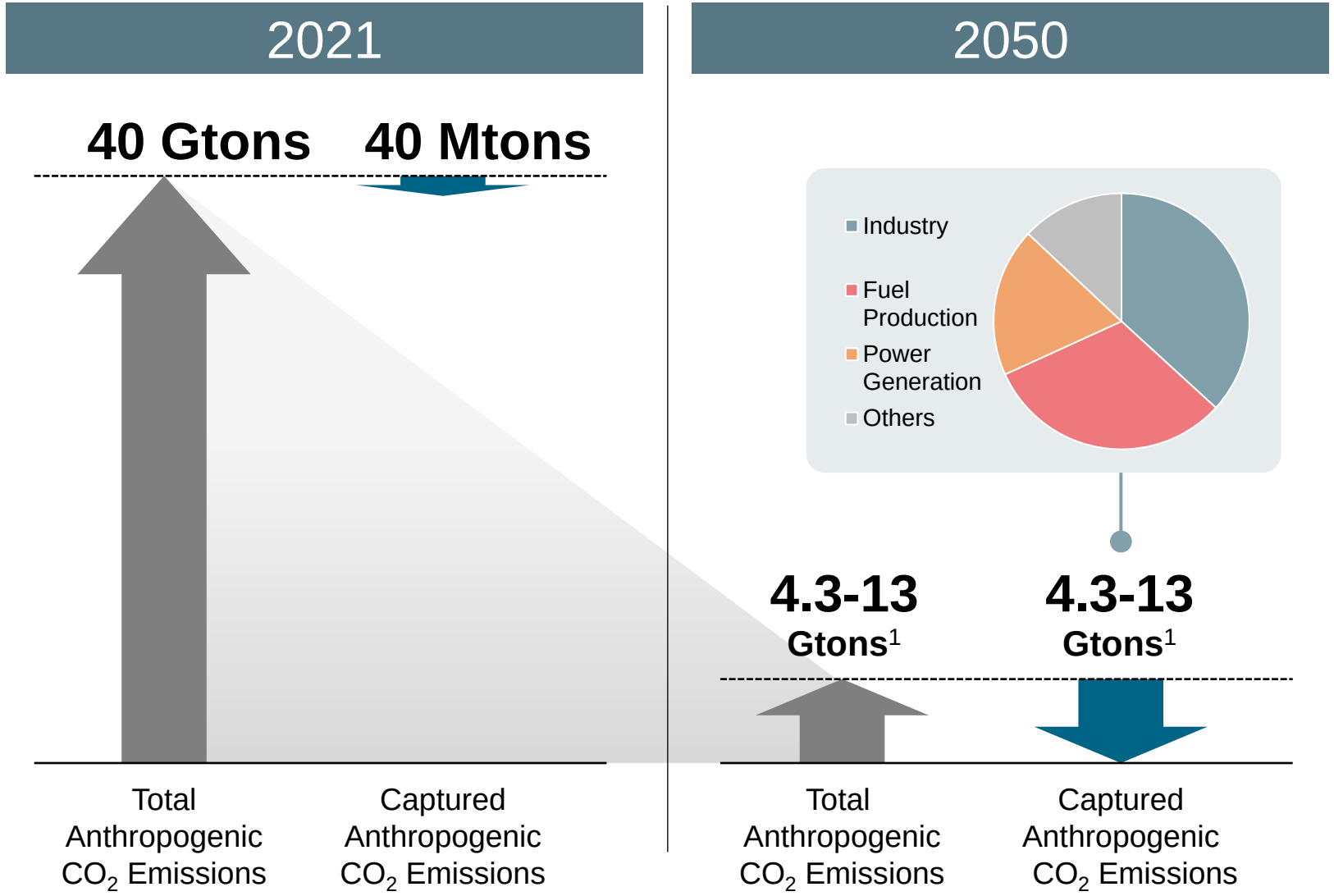
Annual CO_2 Capture Required to Achieve Carbon Neutrality by 2050

- A variety of methods to reduce anthropogenic CO_2 emissions are needed to achieve Carbon Neutrality by 2050. However, even after these reduction efforts, around 4.3-13 Gtons/year of CO_2 emissions are expected to remain.
- To capture this remaining CO_2, 100 to 300 times the current global CO_2 capture capacity will be needed
- By 2050, CO_2 capture will operate in a wide range of industries, including manufacturing, fuel production (including blue fuels), power generation, aviation, and transportation

CCUS will be essential in a wide range of industries in the future



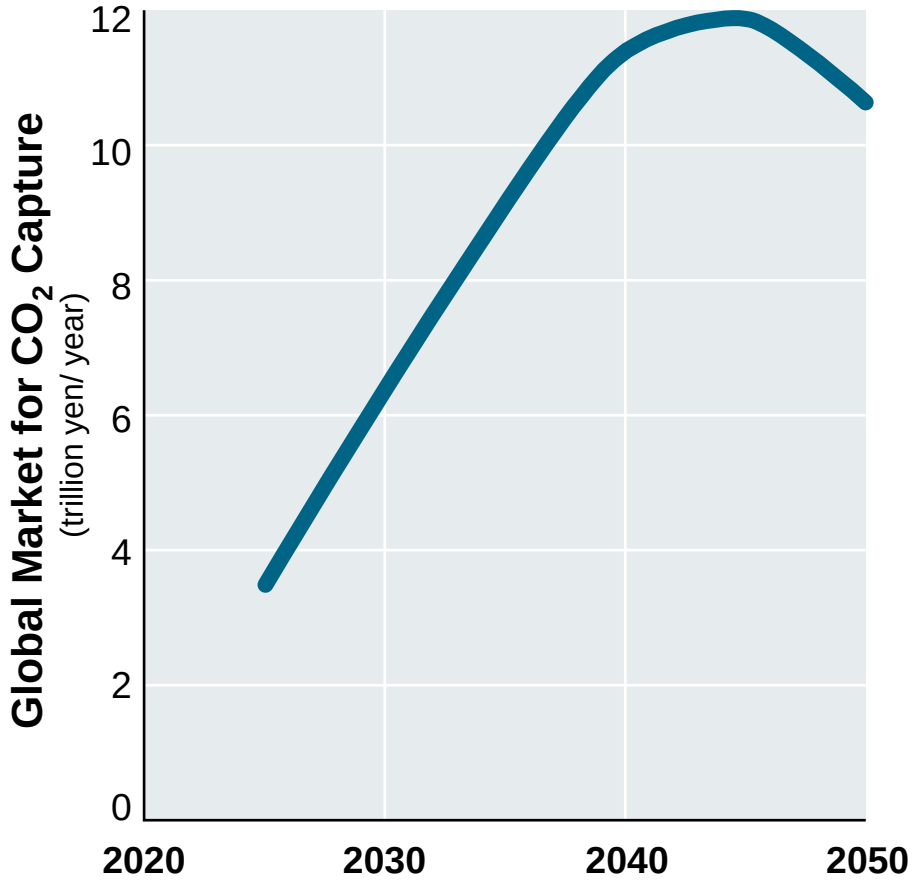
1 Annual estimates based on MHI internal analysis of reports including: McKinsey “1.5°C Scenario Analysis”; International Energy Agency (IEA) “Net Zero by 2050”; IEA “Sustainable Development Scenario”; Intergovernmental Panel on Climate Change (various reports)

Annual CO_2 Capture Required to Achieve Carbon Neutrality by 2050

- The graph to the right shows estimated global market potential for CO_2 capture by decade
- These figures were calculated by multiplying the expected volume of captured CO_2 according to IEA's 2017 Annual Report
  (2 Gtons/yr by 2030 and 8.6 Gtons/yr by 2050)
  and the average cost* of CO_2 capture
  *Average of cost estimates for Japan, U.S., and China

The CO_2 capture market is expected to reach approx. 6 trillion yen by 2030 and exceed 10 trillion yen by 2050

CO_2 Capture Market Estimate



Investment Breakdown		
Capital Cost	62-69%	Plant Construction
Operating Cost	10-25%	Materials, Absorbent
Other	11-23%	Fuel, etc.

Source: Prepared by Japan Ministry of Economy, Trade and Industry (METI) from materials first presented by the Green Innovation Promotion Council Working Group

https://www.meti.go.jp/policy/energy_environment/global_warming/roadmap/innovation/ccus.html

CCUS Challenges

- CCUS is an abbreviation of **C**O$_2$ **C**apture, **U**tilization, and **S**torage

  (Transportation is also required, though it is not included in the acronym)

CCUS faces institutional, scaling, and technical challenges – all of which require innovative solutions to overcome

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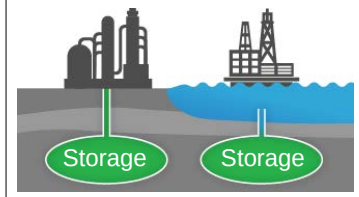
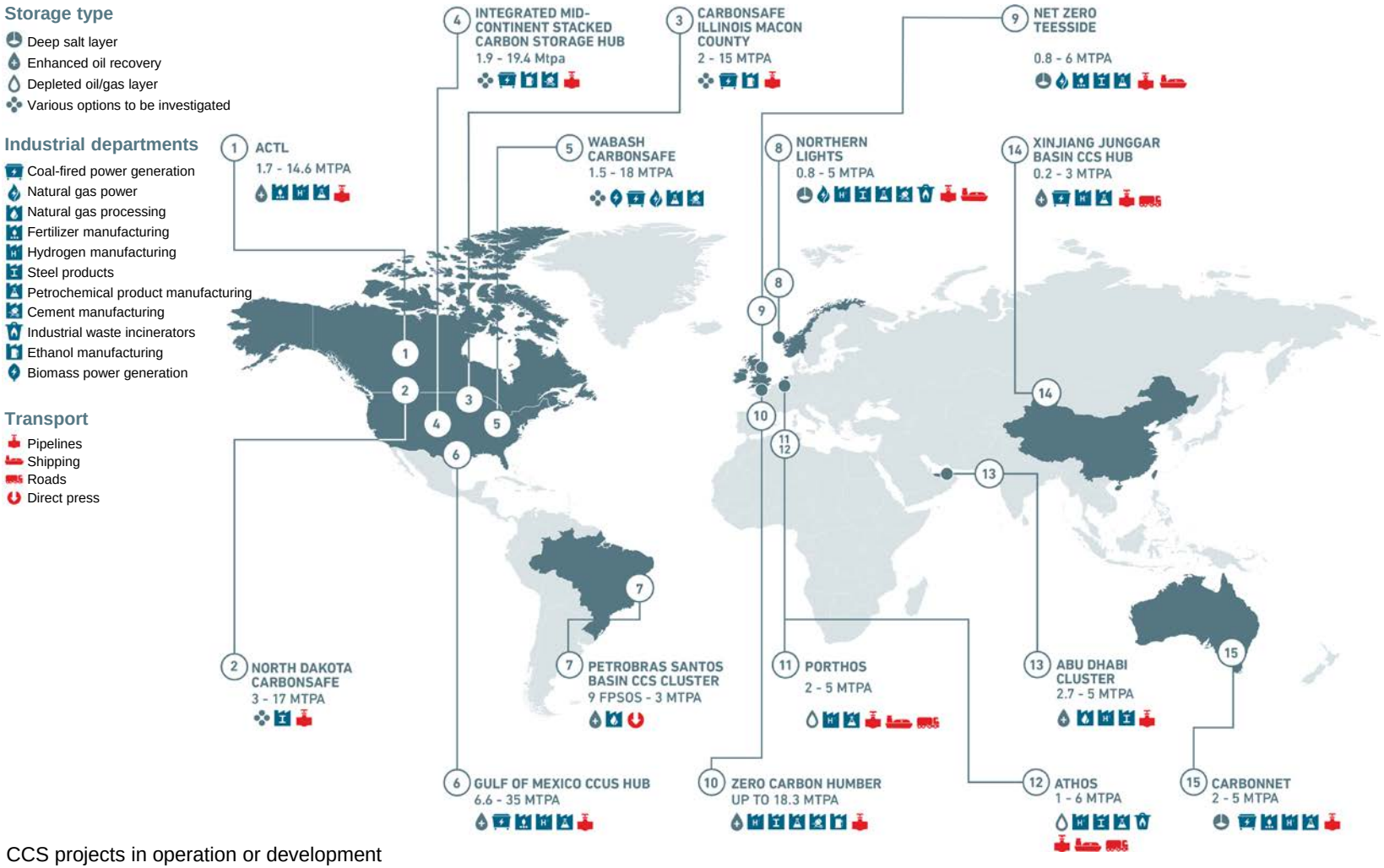
				
Institutional Challenges	■ Balancing CO_2 emissions reduction measures with carbon taxes and carbon pricing ■ Incentives for Corporate Social Responsibility (CSR) initiatives	■ Scope of responsibility for those bearing transportation costs unclear ■ Unable to proceed with investment due to uncertain demand	■ "Green premium" presents little real value ■ Difficult to link directly to CO_2 sequestration	■ Environmental assessment criteria, including for monitoring, not yet decided ■ Complexity in storage business model deterring investment
Scaling Challenges	■ **Limited demand for CO_2 downstream after capture** ■ **High CAPEX and OPEX for CO_2 capture systems**	■ **Transmission and transportation capacity limited** ■ **Transportation costs high**	■ **No novel use cases for captured CO_2. Mainly replacement of current sources for conventional products.** ■ **Low to no profitability discourages new entrants**	■ Active storage sites few in number and inaccessible from many countries and regions ■ High costs due to remote, deep underground storage locations
Technical Challenges	■ **Few capture technologies are commercially ready. Urgent need for expansion of use cases.**	■ **High-volume marine CO_2 transport technology not yet established**	■ **Limited options for CO_2 conversion/use**	■ Monitoring technology still in early development phase

Status of CCUS CO_2 Storage Efforts

- CCS development plans underway mainly in the Americas and Europe
- Size of current CO_2 storage projects ranges from 1 to 35 Mtons/year. Hundreds of storage sites of similar size need to be developed around the world to store the projected 4.3 to 13 Gtons/year of remaining emissions.
- According to the International Energy Agency, worldwide storage potential is estimated to be more than 8 trillion tons (equivalent to more than 600 years of emissions at projected 2050 levels)

Vast acceleration of CCS expansion, including significant increase in number of storage sites and construction of a CO_2 network that includes transportation are needed



CCS projects in operation or development

Source: Global CCS Institute, 2020. The Global Status of CCS: 2020. Australia.
https://www.globalccsinstitute.com/wp-content/uploads/2021/09/Global-Status-of-CCS-Report-Jan-28-1.pdf
IEA, Energy Technology Perspectives 2020

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- **Three CCUS Frameworks:（CO_2NTAIN / CO_2NNECT / CO_2NVERT）**
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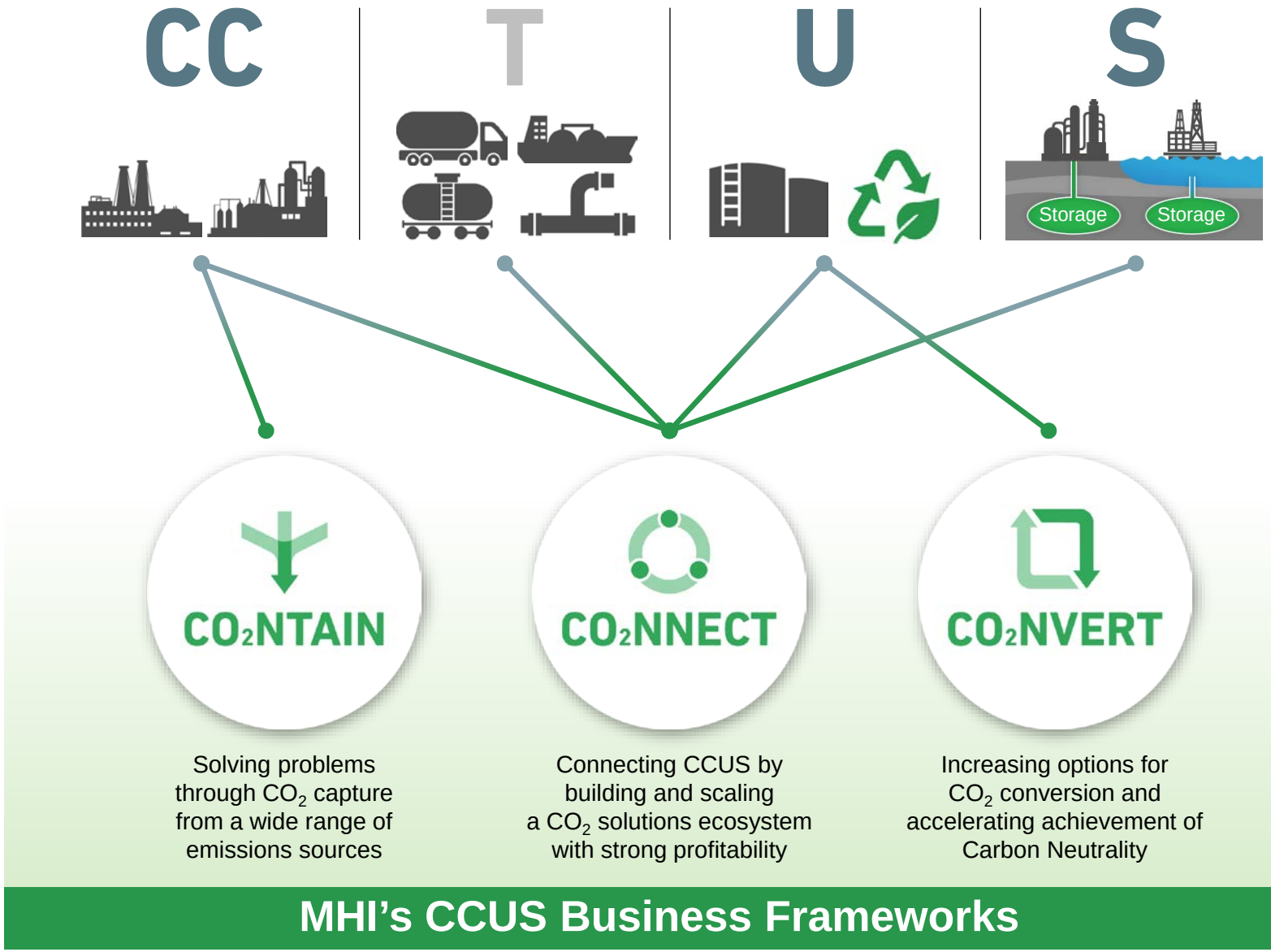
Three CCUS Frameworks（CO_2NTAIN・CO_2NNECT・CO_2NVERT）

- MHI proposes three frameworks to address CCUS technical and scaling challenges



CO_2NTAIN

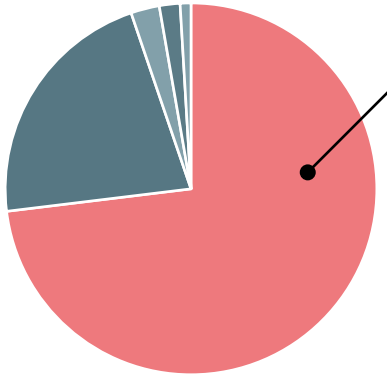
- **KM CDR Process™: CO_2 Capture Technology with the World's Top Market Share**
- **Voice of the Customer**
- **CO_2 Capture from a Variety of Emissions Sources**
- **Voices of Our Partners: drax**

CO_2NTAIN – KM CDR Process™: CO_2 Capture Technology

- A variety of CO_2 capture technologies exists. Currently, chemical absorption is the main method for capturing CO_2 from exhaust gas.

MHI has more than 30 years of experience with the KM CDR Process™, a liquid absorption technology using high performance absorbents (KS-1™, KS-21™). We boast a global market share of over 70% in the exhaust gas carbon capture space.

Technology[1]	Characteristics	Development Status	Companies
Chemical (Liquid) Absorption	• **CO_2 is dissolved into a liquid absorbent, separated from other exhaust gases, and absorbed through a reaction with absorbent components** • **Suitable for separation from combustion exhaust gas** • **Proven track record at high volumes (5,000 tons per day)** • **Amine-based solvents are frequently used**	■ **Commercially ready. Absorbent development, reduction of equipment costs (CAP/OPEX), and expansion of technology application scope are areas of focus.**	**MHI Shell Fluor Aker Toshiba**
Solid Adsorption	• CO_2 is adsorbed onto a solid adsorbent's surface or through pores • After adsorption, CO_2 is desorbed (released) by heat or pressure • Some well-known adsorbents include activated carbon and zeolite, which are also used on the International Space Station	■ Commercially ready. Increasing equipment size, material development, energy consumption reduction, and expansion of technology application scope are areas of focus.	**Air Liquide Air Products Svante CO_2 Solutions**
Membrane Separation	• CO_2 is separated from other gases using osmotic pressure • Suitable for separation from high pressure/concentration gases (Not suitable for capturing CO_2 from exhaust gas)	■ Commercially ready for natural gas separation ■ Many new technologies, such as polymeric membranes, are still in the preliminary testing stage. Material development is an area of focus.	**Air Liquid MTE**



MHI（KM CDR Process™）

- Amine absorbent process (liquid absorption)
- CO_2 capture rate from exhaust gas: 90% and above
- Captured CO_2 purity: 99.9% and above
- Absorbent: KS-1™, KS-21™
- Absorbent characteristics: Low volatility, high stability

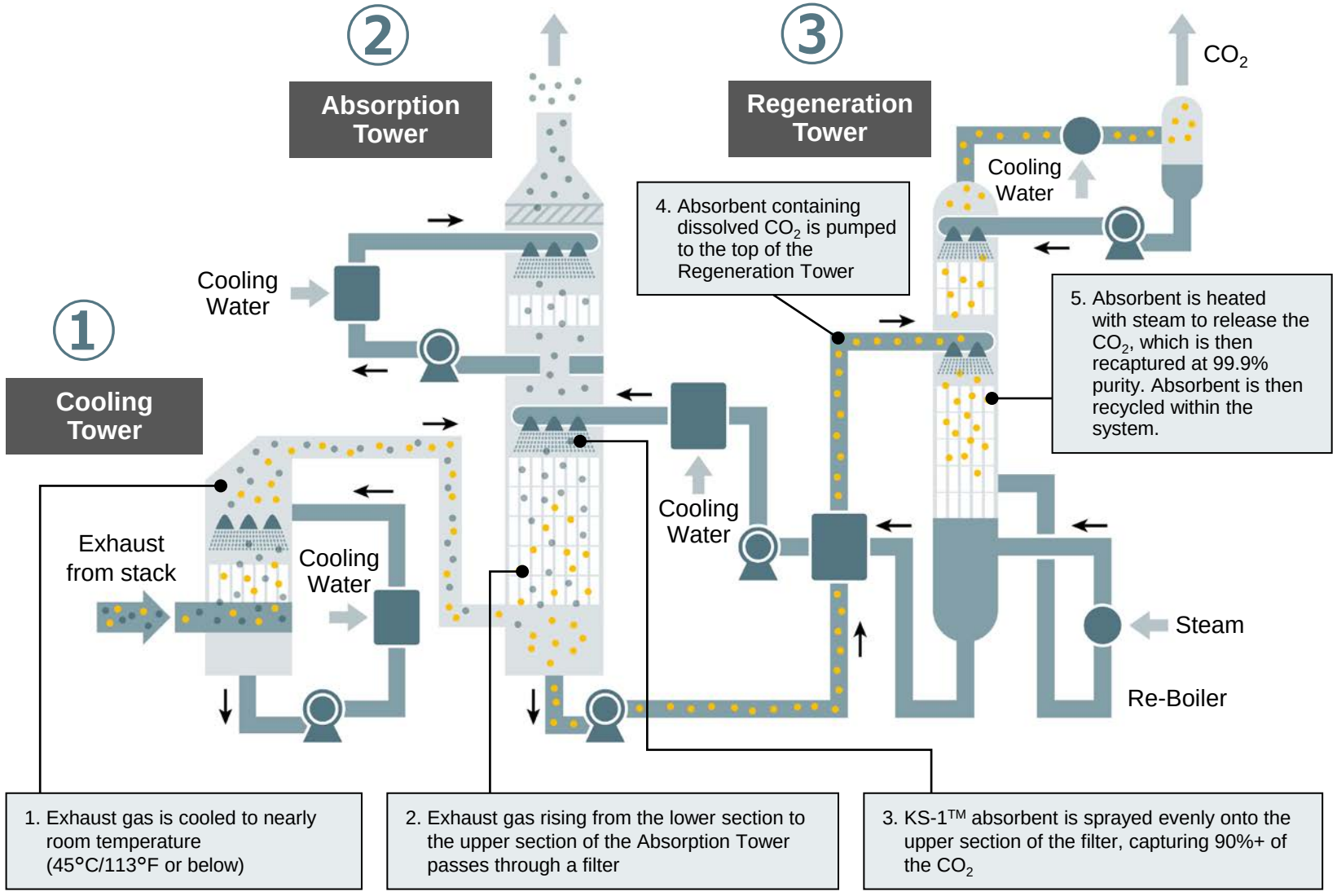
MHI share of exhaust gas CO_2 capture market:
approx. 3.9 Mtons/year of CO_2 captured from approx. 5 Mtons/year of exhaust gas

1 MHI internal comparison of the commercialization status of three main CO_2 capture technologies

CO_2NTAIN – KM CDR Process™: CO_2 Capture Technology

- Process flow for chemical absorption of CO_2 is similar across all manufacturers
- Technologies are differentiated by factors such as initial costs, energy input, absorbent performance, and environmental treatment systems

Customers are looking for commercially proven technologies, not prototypes. MHI's proven track record in CO_2 capture plants with capacities from a few to several thousands of tons is a major advantage



CO_2NTAIN – Voice of the Customer

- Customer feedback indicates that MHI's proven track record, peerless engineering capability, and wide breadth of experience are our strengths

MHI has successfully delivered 13 CO_2 capture plants of a wide range of designs and capacities (range of capture capacity: approx. 200-5,000 tons/day)

*" **MHI** is an **ideal partner** for large industrial providers like us – they have **experience** with our industry and the **engineering talent** needed to pull this off "*

Steel company executive

*" This year is the **first time** we're actually **paying for Carbon emissions**. **Tens of millions**. We are taking this seriously, so we need a **serious provider** to show us a new path "*

Cement company director

*" We don't want to be someone's testing ground. We need a provider with a **proven history and proximity to industry "***

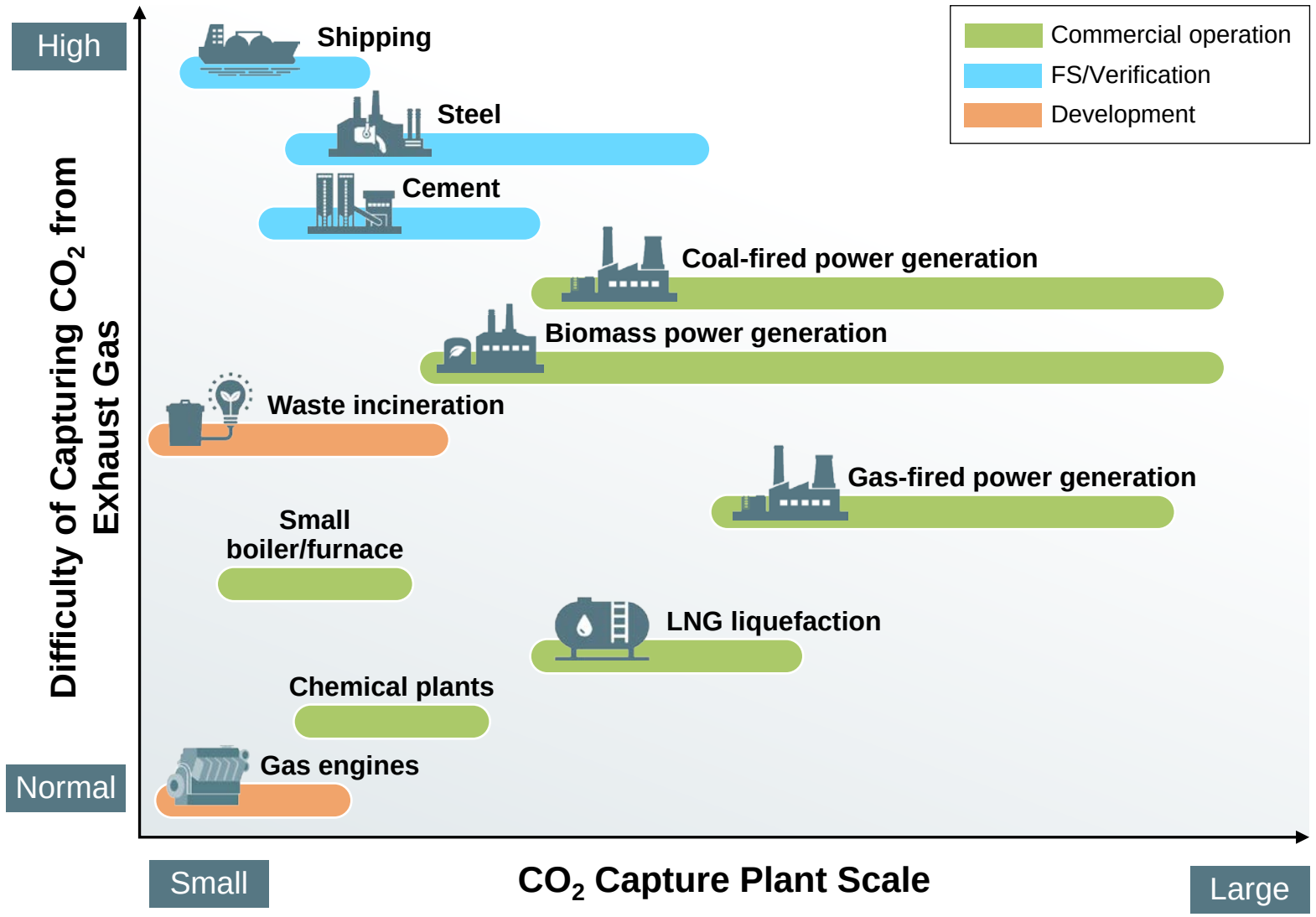
Power generation company business manager

CO_2NTAIN – CO_2 Capture from a Variety of Emissions Sources

- Engineering capability to provide large to small equipment accommodating varying levels of CO_2 capture difficulty is required to address a variety of emissions sources
- CO_2 capture difficulty is based on exhaust gas impurities and temperature, load variability, equipment installation constraints and configuration, and proximity to existing MHI technologies

MHI's CO_2 capture products are highly regarded in many sectors and have moved from validation and feasibility studies to commercial application. Going forward, we will continue to expand our product portfolio

CO₂NTAIN



CO_2NTAIN – CO_2 Capture from a Variety of Emissions Sources

- MHI is further expanding the number of use cases for CO_2 capture based on our core technologies
- Smaller capture plants will be modularized and/or digitalized to meet customers' needs

As a leading player in the carbon capture space, MHI offers a wide range of CO_2 capture technologies

CO₂NTAIN

Coal/gas power generation	World's largest CO_2 capture plant (as of 2021)	Petra Nova 
Biomass power generation	Annual CO_2 capture capacity of over 8 million tons (planned)	Drax 
LNG liquefaction	Contributing to low-carbon production of LNG	NextDecade 
Cement	Feasibility study in a technically difficult area	Lehigh Cement 
Steelmaking	Technical validation in a hard-to-abate sector	Domestic Steel Co. 
Shipping	World's first validation of onboard CO_2 capture during an actual voyage	"K" Line 
Waste incineration Gas engines Small boilers/furnaces	CO_2 capture with small-scale, modularized plants	

CO_2NTAIN – Voices of Our Partners: drax

Will Gardiner

Group Chief Executive Officer, Drax Group PLC

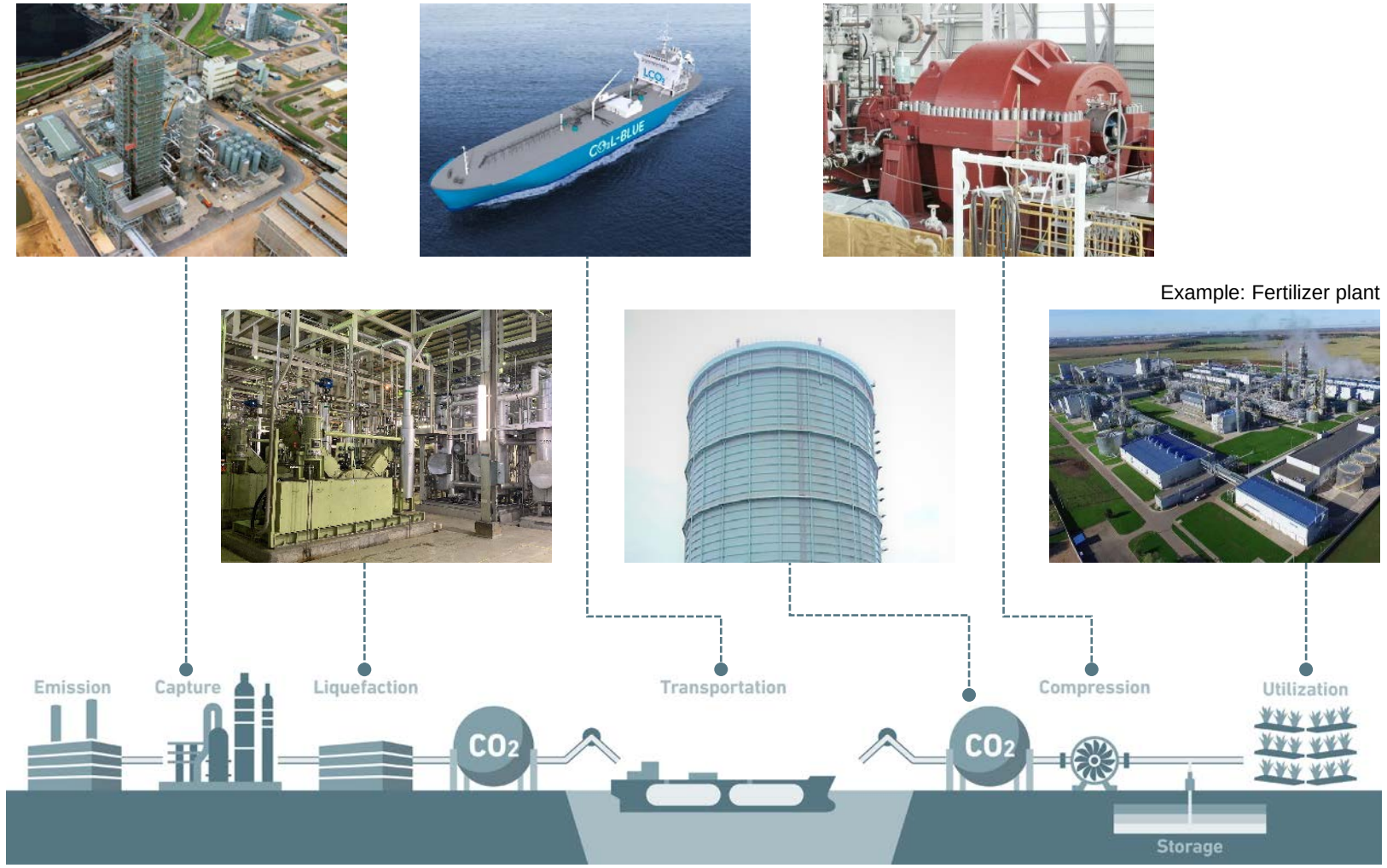
CO_2NNECT

- Key Components of the CCUS Value Chain
- Participating in the CCUS Value Chain
- CCUS Visualization Platform
- Voices of Our Partners: IBM

CO_2NNECT – Key Components of the CCUS Value Chain

- MHI Group provides core technologies essential for CCUS, including CO_2 capture, transportation, and compression
- We aim to further expand our business in the areas of large liquefied CO_2 carriers and CO_2 compression, which will become important as the volume of captured CO_2 increases

MHI is helping to establish a robust value chain by offering a wide variety of CCUS-related technologies

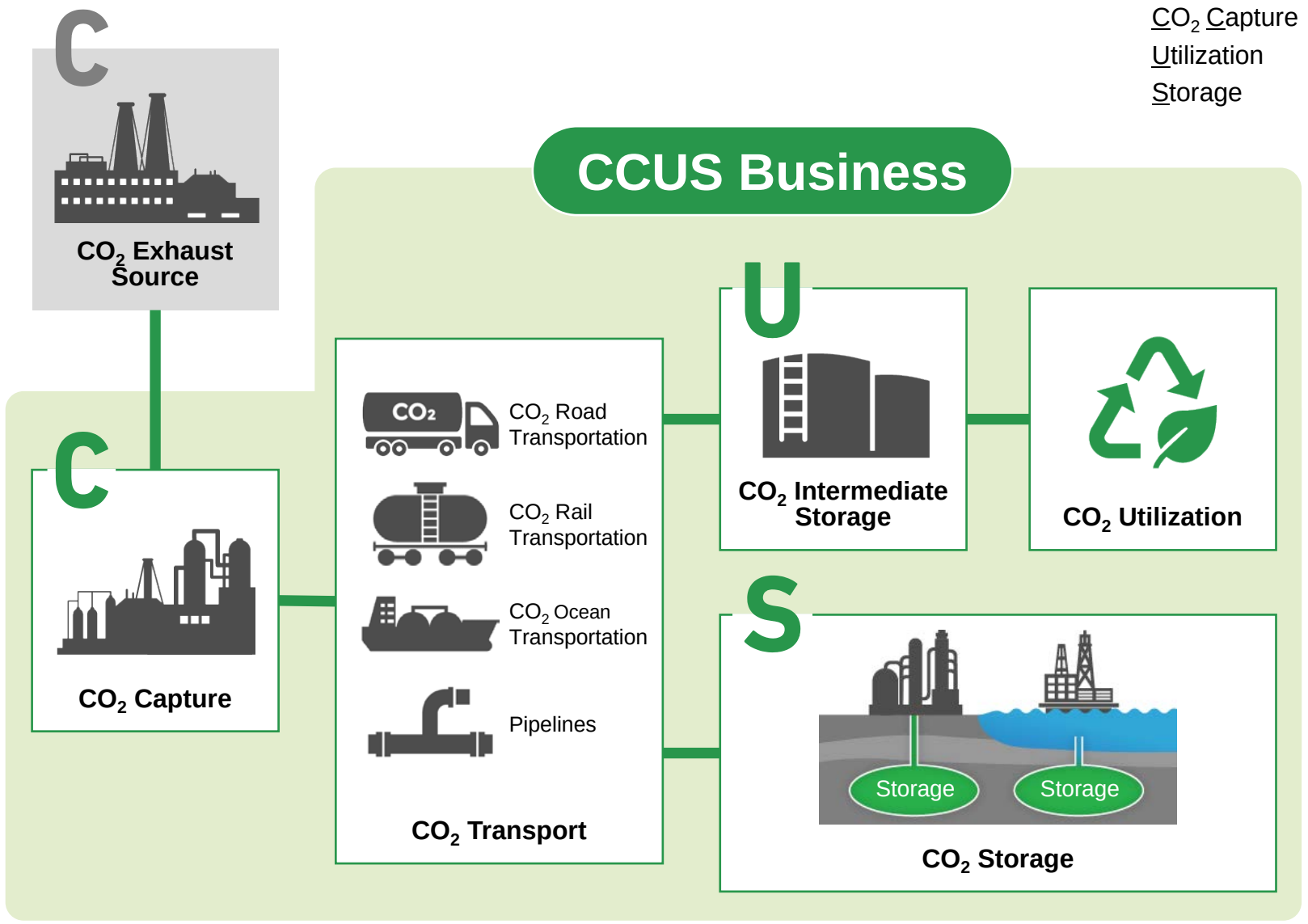


CO_2NNECT – Participating in the CCUS Value Chain

- Currently, CCUS business is conducted via bilateral agreements between individual players in each area. As the scale of CCUS expands, we will see larger integration of CCUS business.
- MHI's CCUS business will span the entire process from CO_2 capture to downstream handling (including transportation, storage, and utilization) to reduce initial investment and complexity on the emissions source side

In addition to offering numerous technologies within CCUS, MHI is working to integrate CCUS businesses through the CO_2NNEX platform and other solutions

CO_2NNECT



CO_2 Capture
Utilization
Storage

CO_2NNECT – CCUS Value Chain Visualization Platform

- CO_2NNEX is a digital platform which will enable visualization of the CCUS value chain. MHI jointly announced this product concept with IBM Japan on May 6, 2021.

Working together with several dozens of partners supporting our CO_2NNEX concept, we have formed cross-company working groups and are currently planning trials in Japan and around the world

CO_2NNECT

CO_2NNEX

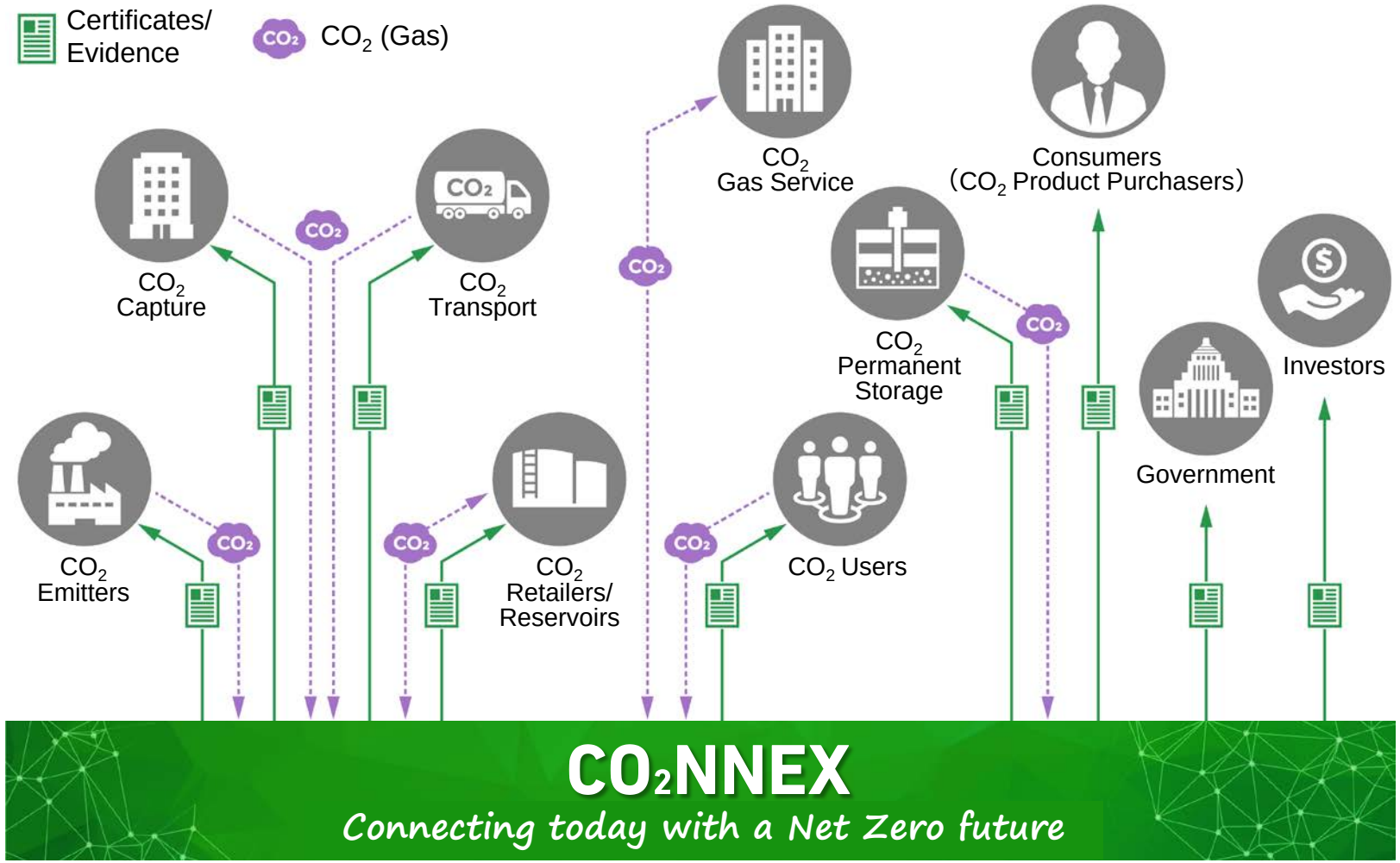
Connecting today with a Net Zero future

CO_2NNEX will give CO_2 value by connecting and accelerating the development of CO_2 solutions ecosystems around the world. This will help realize a Carbon Neutral world as quickly as possible.

CO_2NNECT – CCUS Value Chain Visualization Platform

- CO_2NNEX will visualize actual CCUS activities in a virtual space using blockchain technology and IoT-enabled devices such as smart meters
- CO_2NNEX will quantify value and provide evidence for CO_2 emissions reductions. It will also create a wide range of matching opportunities among participants

This open platform will allow participating companies to build a CO_2 solutions ecosystems together by combining each of their individual business models



CO_2NNECT – Voices of Our Partners: IBM

Akio Yamaguchi

General Manager and
President, IBM Japan, Ltd.

CO_2NVERT

- Utilizing Captured CO_2
- MHI's CCU Business Initiatives

CO_2NVERT – Utilizing Captured CO_2

- There are two ways to utilize captured CO_2: direct use and conversion to other valuable commodities
- MHI has experience with direct use and CO_2 in fertilizer production (urea) and enhanced oil recovery
- In addition to experience with CO_2 conversion using chemical synthesis, we are investing in start-ups working in fuel synthesis and other innovative areas

We will grow our portfolio in both conversion and direct use technologies as we explore new methods in a variety of areas

https://www.iea.org/reports/about-ccus

CO_2NVERT – Utilizing Captured CO_2

- Based on our expertise in CO_2 capture, we will propose MHI or our partners' technologies to meet the needs of global customers with the goal of realizing a Carbon Neutral world while also generating profit

MHI Group will offer solutions spanning the CO_2 value chain, from capture and utilization technologies to CCU matching

CO_2 Emissions Sources

Clients with CO_2 emissions

- Introduction to CO_2 Users

MHI Group CCU Initiatives

CO_2 Conversion

(possible use case)

Clients Utilizing CO_2

- Provide CO_2 utilization technologies
- Introduction to CO_2 emitters

CO_2 Direct Use

(possible use case)

Timeline

Development/validation
Commercial use

2020 2025 2030

CCUS Technology/ After-Sales Service Development

KS-1™ CO_2 capture plant
Current CO_2 absorbent

Source: Technology Center Mongstad

▼Aug 2021 KS-21 verification completed at TCM

KS-21™ CO_2 capture plant

▼Jun 2021 Executed license contract with Drax

Improved CO_2 absorbent
Validation complete/
Begin commercial use

▼Aug 2021 Began validation testing of CO_2 capture system with Kawasaki Kisen

Small CO_2 capture equipment

▼Aug 2021 Installed on CC-Ocean vessel

Modular CO_2 capture systems
Build product line-up

▼Sep 2021 Acquired LCO_2 carrier cargo tank Approval in Principle

LCO_2 carrier

▼Aug 2021 Began feasibility study on liquefied CO_2 carrier with TotalEnergies

Large-scale CO_2 transport
Proceeding with feasibility study with a shipping company

CO_2NNEX

▼ May 2021 Executed MOU for joint development with IBM Japan

CO_2 distribution platform
Discussions ongoing with potential validation partners

CO_2NNEX

Business model

CCUS Technology provider

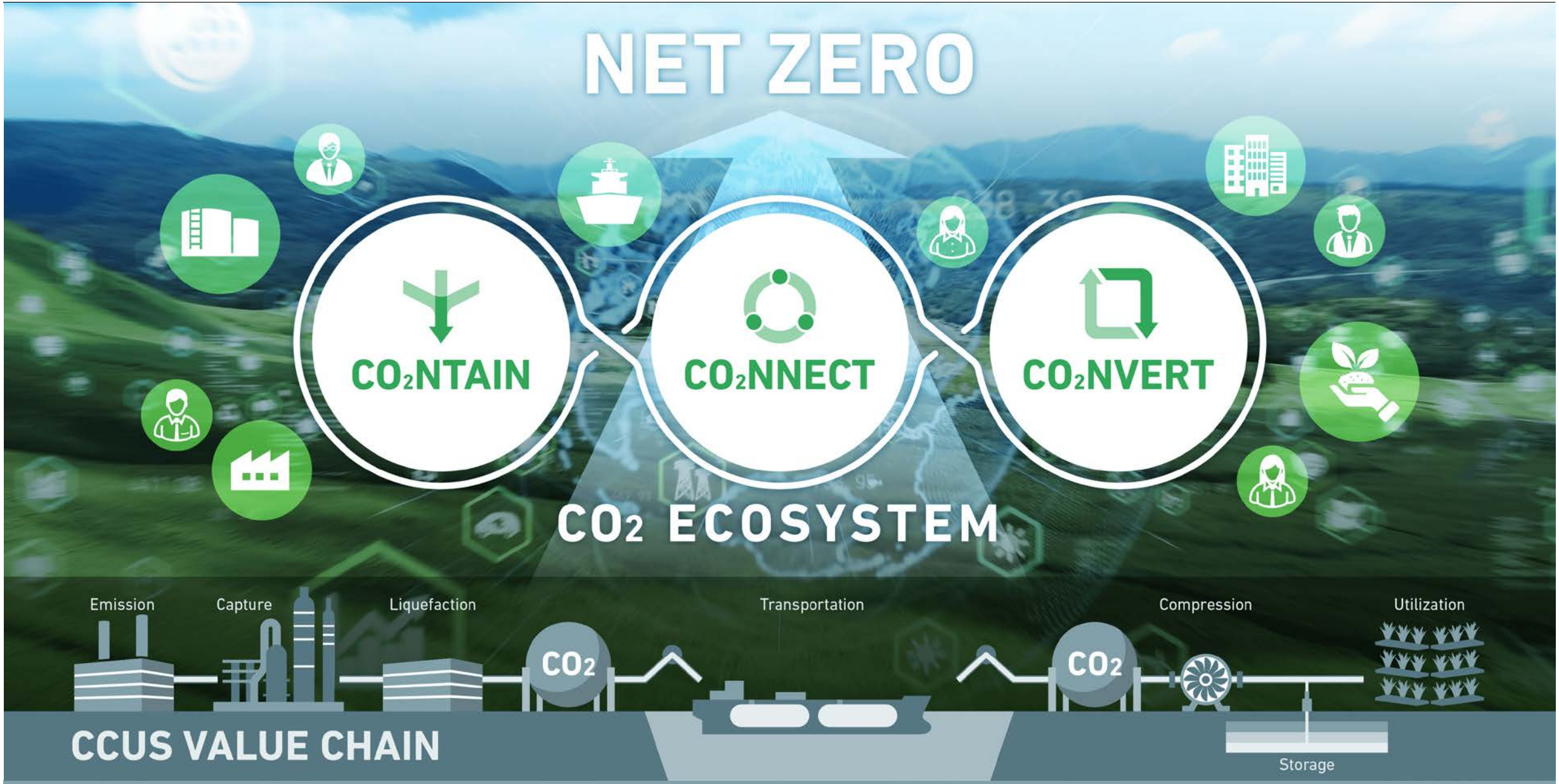
CCUS business

▼ Aug 2021 Executed MOU for joint study with SUEZ

CO_2 capture and downstream handling with matching services

Thank you for your attention

- **CCUS is essential to achieving Carbon Neutrality by 2050**
- **MHI Group has developed a broad portfolio of CCUS-related technologies and will expand our capabilities to cover the entire CCUS ecosystem**
- **As a global leader in CCUS, we are contributing to both economic development and the reduction of industry's environmental impact**




MITSUBISHI
HEAVY INDUSTRIES

CCUS, transport and trade: creating a holistic carbon market

In order to hit its 2050 net zero target for carbon dioxide emissions, the world will have to virtually eliminate the 40 gigatonnes of CO_2 that it currently pours into the atmosphere every year. Even if the significant growth of renewables and other carbon free energy sources continues, we redouble our efforts to reduce consumption and also improve energy efficiency, a sizeable gap will remain: an annual 4-12 gigatonnes of CO_2 will somehow have to be removed from the atmosphere to reach a carbon neutral world.

https://spectra.mhi.com/ccus-transport-and-trade-creating-a-holistic-carbon-market

Makoto Susaki is leading MHI Group's CCUS business taskforce.

How carbon capture can become more affordable

https://spectra.mhi.com/how-carbon-capture-can-become-more-affordable

Achieving net-zero goals will be virtually impossible without carbon capture technologies, according to analysis from the International Energy Agency's (IEA) landmark Net Zero by 2050: A Roadmap for the Global Energy Sector report.

Carbon capture, utilization and storage (CCUS) systems trap CO_2 emissions from the exhaust flues of industrial processes, and these are then either used by industry or stored deep below ground.

When retrofitted to existing power or industrial plants, the capture process can prevent many millions of tonnes of CO_2 emissions reaching the atmosphere, help decarbonize hard-to-electrify industrial sectors and support the production of low-carbon hydrogen from fossil fuels. But this emissions-busting technology comes at a cost.

Despite its many benefits, there are currently only 26 commercial-scale operations in place globally, capturing 40 million tonnes of carbon dioxide annually. So, when and how will the price of CCUS come down so that it can take off?

MHI's CCUS technology captures more than 90% of CO_2 emissions from power plants ©NRG

News Related to CCUS

PRESS INFORMATION

Mitsubishi Shipbuilding Receives Approval in Principle from Classification Society for LCO_2 Carrier Cargo Tank from France's Bureau Veritas

2021-09-02

・Project part of MHI Group's effort to expand businesses for the CCUS value chain, utilizing the advanced gas handling technologies of Mitsubishi Shipbuilding.

・With the acquisition of this AIP, MHI Group will focus on developing and offering the technologies needed to bring LCO_2 carriers to the market.

https://www.mhi.com/news/210902.html

CO2NNECT

News Related to CCUS

PRESS INFORMATION

Mitsubishi Shipbuilding and French Company TotalEnergies Initiate Feasibility Study of LCO_2 Carrier -- Project for Technology Development and Market Formation in the CCUS Value Chain Aimed at Reducing CO_2 Emissions --

https://www.mhi.com/news/21082602.html

2021-08-26

・Feasibility study launched with the French broad energy company TotalEnergies.
・Project part of MHI Group's effort to expand businesses for the CCUS value chain, utilizing the advanced gas handling technologies of Mitsubishi Shipbuilding.

News Related to CCUS

PRESS INFORMATION

Mitsubishi Shipbuilding Begins Verification Testing of Marine-based CO_2 Capture System -- "CC-Ocean" Project in Partnership with "K" Line and ClassNK Part of Japan Government Initiative to Support Development of Marine Resource Technologies --

2021-08-05

・Verification testing, a world first on actual voyage, operability and safety evaluations to support practical application of the Marine-based CO_2 Capture System.

・Installation of the equipment completed on board a coal carrier for Tohoku Electric Power operated by "K" Line.

https://www.mhi.com/news/21080501.html

News Related to CCUS

PRESS INFORMATION

MHI and IBM Japan to Develop the "CO_2NNEX^{TM}" Digital Platform for Visualization of the CCUS value chain -- New Platform to Strengthen the CO_2 Ecosystem and Support Early Achievement of Carbon Neutrality --

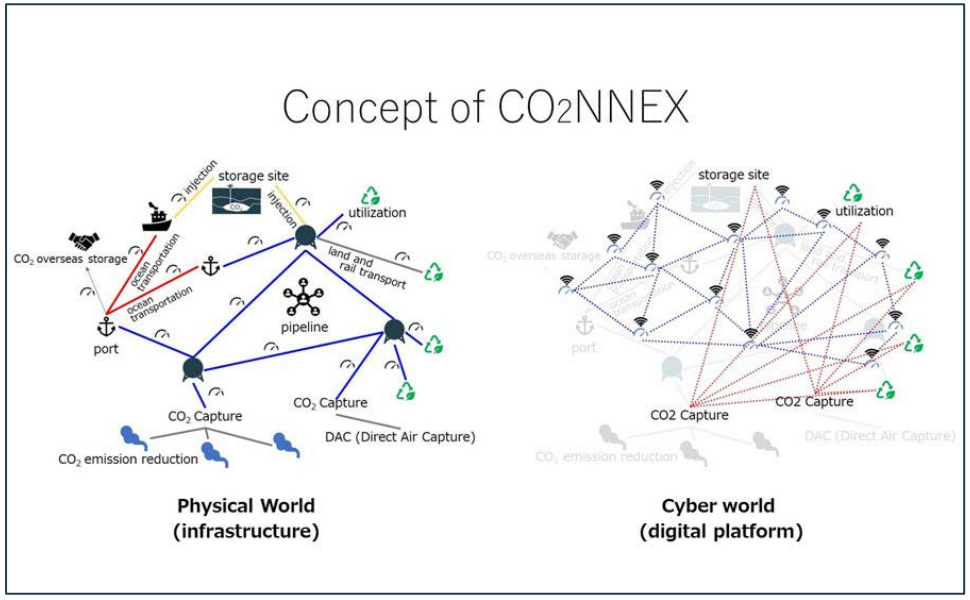
2021-05-06

https://www.mhi.com/news/210506.html

・Visualization of the CCUS (CO_2 Capture, Utilization and Storage) value chain and streamlining of the CO_2 supply chain will highlight existing issues and expand the range of utilization options.

・MHI to build efficient CO_2 infrastructure in the physical world, with IBM Japan handling the digital network in the cyber world.

CO₂NNECT CO₂NVERT



News Related to CCUS

PRESS INFORMATION

NextDecade and Mitsubishi Heavy Industries America Execute Engineering Services Agreement for Carbon Capture at Rio Grande LNG Project in Texas

https://www.mhi.com/news/210414.html

2021-04-14

NextDecade Corporation
Mitsubishi Heavy Industries America, Inc.

HOUSTON -- April 14, 2021 -- NextDecade Corporation (NextDecade) (NASDAQ: NEXT) and Mitsubishi Heavy Industries America, Inc. (MHIA), part of Mitsubishi Heavy Industries (MHI) Group, have announced today that they have signed an engineering services agreement (ESA) for the design, license, and performance guarantee of the KM CDR Process™, a post-combustion carbon capture technology to be applied at NextDecade's Rio Grande LNG project in the Port of Brownsville, Texas.

News Related to CCUS

PRESS INFORMATION

Mitsubishi Heavy Industries Engineering to test carbon capture technology at Technology Centre Mongstad in Norway

2021-03-04

Mitsubishi Heavy Industries Engineering
Technology Centre Mongstad

- Testing of proprietary solvent KS-21™ will start from May 2021 at TCM
- TCM offers state-of-the-art facilities and expertise to ensure successful demonstration
- MHIENG aims to expand its carbon capture business in the United Kingdom and Europe

https://www.mhi.com/news/210304.html

News Related to CCUS

PRESS INFORMATION

Low Carbon on Cement Possible with CCS

2021-01-21

Edmonton, January 21, 2021 - A low carbon future for cement is advancing through a unique feasibility study to see carbon capture and storage (CCS) on Lehigh Cement's plant in Edmonton, Alberta. Recognizing the substantial role that large-scale CCS has in reducing greenhouse (GHG) emissions, the Lehigh Cement, International CCS Knowledge Centre (Knowledge Centre), and Mitsubishi Heavy Industries America (MHIA), part of Mitsubishi Heavy Industries (MHI) Group, are moving forward with the engineering design for this feasibility study of the cement plant's carbon capture system.

https://www.mhi.com/news/21012102.html

News Related to CCUS

PRESS INFORMATION

MHI Completes Installation of CO_2 Capture Unit at Nippon Ekitan's Mizushima Plant -- Recovery Capacity of 283 Metric Tons per Day for New Liquefied Gas Production Facility --

2017-12-18 No.2098

- Recovered CO_2 from Mitsubishi Chemical Corporation's Mizushima Plant used to produce liquefied carbonic acid gas
- Project delivered safely and on-schedule, highlights MHI capabilities

https://www.mhi.com/news/1712182098.html

PRESS INFORMATION

Mitsubishi Heavy Industries America Completes Construction of World's Largest Post-Combustion CO2 Capture System for the Petra Nova Carbon Capture Project

https://www.mhi.com/news/1701102039.html

2017-01-10 No.2039

Houston, January 10, 2017 - Mitsubishi Heavy Industries America, Inc. (MHIA), a wholly-owned subsidiary of Mitsubishi Heavy Industries, Ltd. of Japan (MHI), has successfully completed construction of the world's largest post-combustion CO2 capture and compression system. Managed and executed in the U.S., the system is based on MHI's proprietary KM CDR Process® and high-performance KS-1™ amine solvent which was jointly developed by MHI and Kansai Electric Power Co. and is used for CO2 absorption and desorption. The system captures CO2 from a 240 MW equivalent coal exhaust slipstream from Unit 8 at NRG Energy Inc.'s (NRG's) W. A. Parish coal-fired generating station in Thompsons, Texas, and is rated at 4,776 metric tons per day of CO2 captured.

News Related to CCUS

CO_2 Capture Plant

PRODUCTS

https://www.mhi.com/products/engineering/co2plants.html

MITSUBISHI HEAVY INDUSTRIES ENGINEERING

https://www.mhi.com/group/mhieng/

LCO_2 Carriers

PRODUCTS

https://www.mhi.com/group/mhimsb/products

MITSUBISHI SHIPBUILDING

https://www.mhi.com/group/mhimsb/company

Compressor

PRODUCTS

https://www.mhi.com/products/industry/geared.html

MITSUBISHI HEAVY INDUSTRIES COMPRESSOR

https://www.mhi.com/group/mco/

Gas Holder

PRODUCTS

https://www.mhi-ms.com/products/steelstructures/gas/

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