Japan CCS Forum 2023 – Global CCS Institute

# The Path for the Development of CCS in Japan

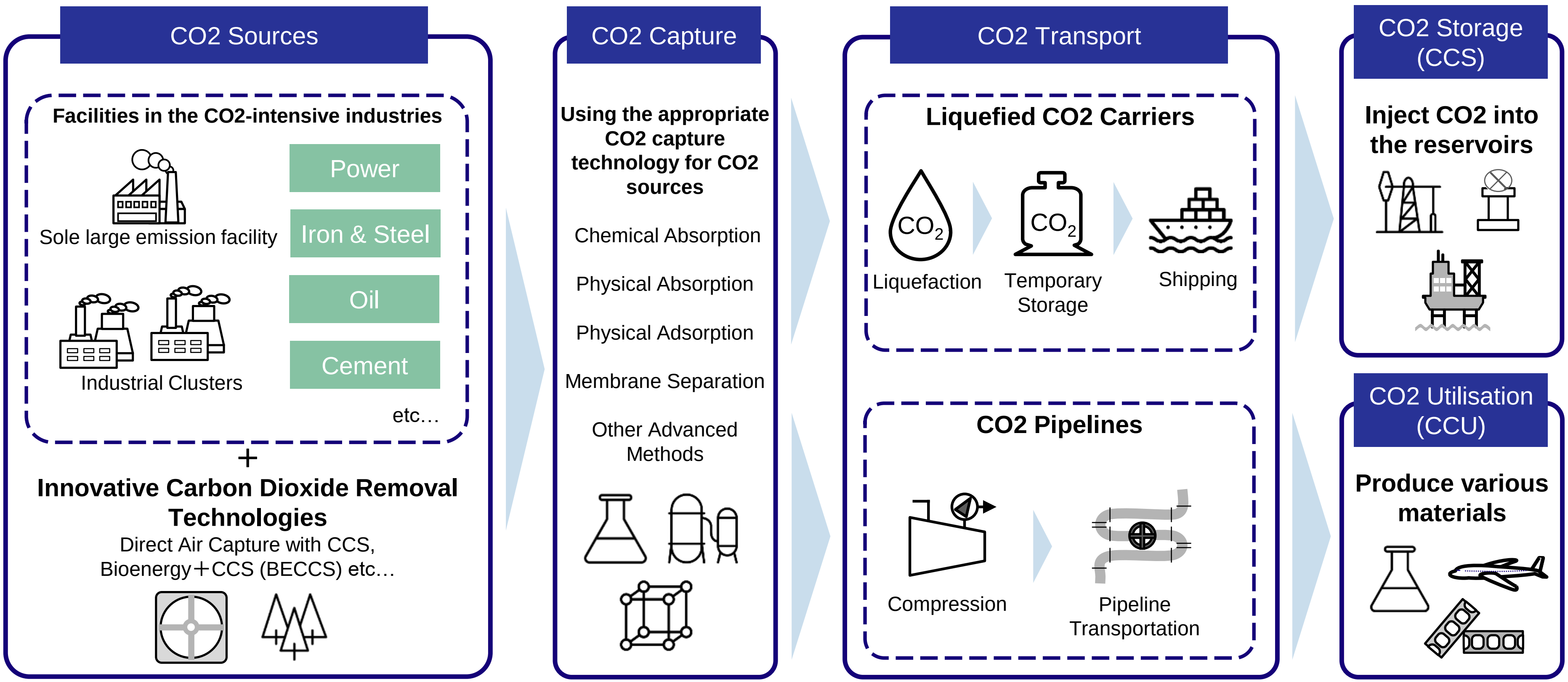
November 2023

**Mizuho Bank Industry Research Department**
**Research & Consulting Unit**
**Mizuho Financial Group**

# Overview of CCS

- Carbon Dioxide Capture & Storage (CCS) is a technology that captures CO2 from CO2 sources, transports it from the place of emission, and stores it in the appropriate place in underground
  - Carbon Capture & Utilisation (CCU) is a technology for producing materials that can use CO2 as a raw material, and CCUS is commonly used as a combination of CCS & CCU. This paper mainly discusses CCS

## CCS/CCUS Process Overview




Source: Compiled by Industry Research Department Mizuho Bank from IEA, etc.

# Growing global importance of CCS

- Policy target and support for CCS/CCUS in developed countries are increasing
  - The G7 Summit Communiqué also shows the importance of CCS/CCUS

### Recent trends in CCS/CCUS

| Countries / Regions | Overview |
|---|---|
| United States | • The Inflation Reduction Act of 2022 (IRA) was established by President Biden in August 2022.<br>• 45Q tax credit, which has been the driving force behind CCS, is expanded further. |
| Europe | • The countries surrounding the North Sea have developed CCS project and policies.<br>• Germany, which had been reluctant to adopt CCS/CCUS, recognized the necessity of CCS/CCUS at the end of 2022 and planned to formulate a Carbon Management Strategy in 2023.<br>• The Net-Zero Industry Act proposed in March 2023 recognized CCS/CCUS as a Net-Zero strategic technology and set a target of securing 50mt-CO2/y of CO2 storage capacity by 2030. |
| United Kingdom | • UK 10 Point Plan showed the plan to reduce CO2 emissions by 10mt-CO2/y by 2030 in Nov 2020.<br>• The roadmap for CO2 capture by 20~30mt-CO2/y (6mt-CO2/y of CCS from industry) was announced in April 2023 |
| Japan | • The CCS Long-Term Roadmap was published, and set a target of securing 120~240mt-CO2/y storage capacity in 2050.<br>• Selection of "Advanced CCS Project" with the aim of starting the project in 2030 is ongoing. Policy aimed at securing 6~12mt-CO2/y storage by supporting 3 to 5 PJs |
| Others | • Various Project initiatives are being announced in the Middle East, Southeast Asia, and others. |

Source: Compiled by Industry Research Department Mizuho Bank

### G7 Hiroshima Leaders' Communiqué

<Energy>

25. We commit to holistically addressing energy security, the climate crisis, and geopolitical risks. In order to address the current energy crisis caused by Russia's war of aggression against Ukraine and achieve our common goal of net-zero emissions by 2050 at the latest, we highlight the real and urgent need and opportunity to accelerate clean energy transitions also as a means of increasing energy security at the same time. While acknowledging various pathways according to each country's energy situation, industrial and social structures and geographical conditions, we highlight that these should lead to our common goal of net zero by 2050 at the latest in order to keep a limit of 1.5°C within reach.

…

**We acknowledge that Carbon Capture, Utilization and Storage (CCUS)/carbon recycling technologies can be an important part of a broad portfolio of decarbonization solutions to reduce emissions from industrial sources that cannot be avoided otherwise and that the deployment of carbon dioxide removal (CDR) processes with robust social and environmental safeguard, have an essential role to play in counterbalancing residual emissions from sectors that are unlikely to achieve full decarbonization.**

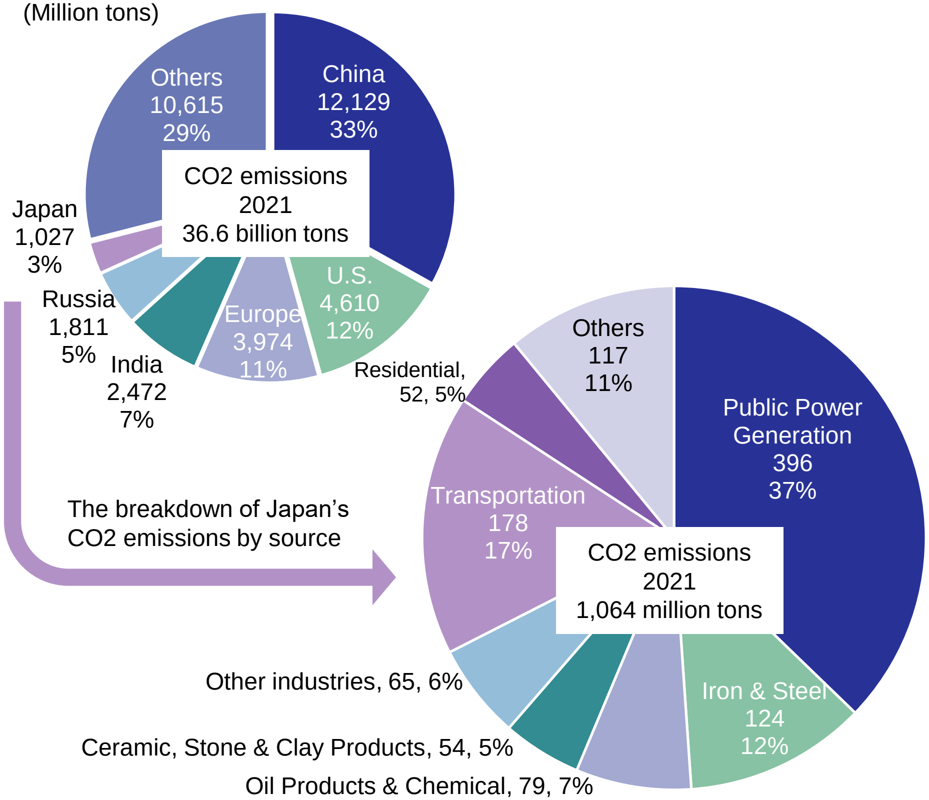
Source: Compiled by Industry Research Department Mizuho Bank from G7 Hiroshima Leaders' Communiqué

MIZUHO

# Trends of CO2 Emissions in Japan

- Japan emitted approx. 1 billion tons in FY2021, accounting for about 3% of global CO2 emissions
  - It was peaked in 2012 when the transition from nuclear to gas-fired power generation occurred after the earthquake, and then decreased

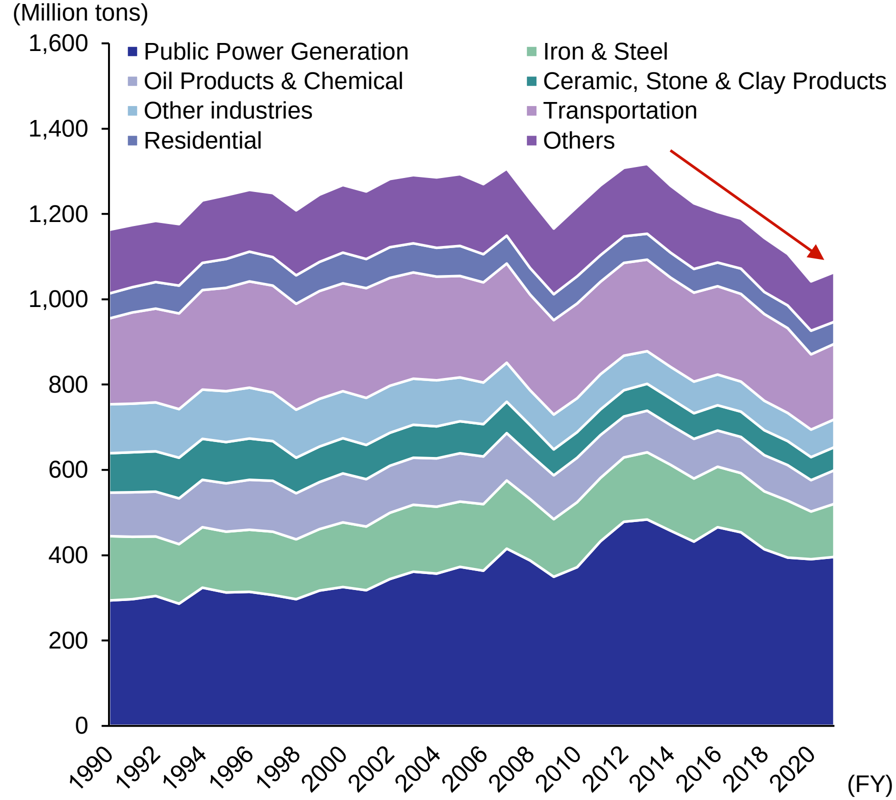
## Breakdown of CO2 Emissions in Japan




Note: "Oil Products & Chemical" and "Ceramic, Stone & Clay Products" include Industrial Processes. CO2 emissions breakdown include statistical errors

Source: Compiled by Industry Research Department Mizuho Bank from IEA, National Institute for Environmental Studies

## Trends of CO2 Emissions in Japan




Note: "Oil Products & Chemical" and "Ceramic, Stone & Clay Products" include Industrial Processes.

Source: Compiled by Industry Research Department Mizuho Bank from National Institute for Environmental Studies

# CCS Business Environment in Japan

■ Japan is rapidly proceeding considerations of policies to secure 6~12 mt-CO2/y CCS storage capacity by 2030

**【Mizuho's Understanding】Outline of the "Advanced CCS PJ" in Japan, the CCS Long-Term Roadmap and GX Basic Policies**

- To **establish advanced CCS business models that can be expanded in the future**, the Japanese Government will **intensively support the "Advanced CCS Business Model" project with the goal of starting the projects by 2030.**
- Starting with **3~5 PJs** with different combinations of Carbon Capture Sources, Transportation methods, and CO2 storage areas. The Japanese Government aims to establish **diverse CCS business models and to secure an annual storage capacity of 6~12 mt-CO2/y by 2030.**
- The Model PJ should focus **on large-scale operations** and **significant cost reduction by establishing a hub and cluster model.**
- Project selection criteria; **Early feasibility, Scalability and Economics of PJ.** In addition, it is expected that the development has a focus on **integrating social acceptance across storage sites and that the PJ's has a contribution to the future development of CCS businesses.**

| | Business Model Development Stage | | | Deployment Stage |
|---|---|---|---|---|
| CCS Roadmap & GX Basic Policies | ~2023 | ~2026 | ~2030 | ~2050 |
| **Government Support for CCS Businesses** | Support for "Advanced CCS Business Models" & Secure 6~12 mt-CO2/y CCS capacity by 2030 | | | **2050 Target: 120~240mt-CO2/y** |
| | Schedule: CCS Feasibility Studies | Test Drilling, Evaluation | FID; Construction | Operation |
| | Early Establishment of Advanced CCUS Value Chains: Investment of Approx. 4 Trillion Yen over the Next 10 Years | | | To Achieve the 2050 Target, Further Investment of Trillions of Yen Will be required |
| **Action to Reduce Costs of CCS** | Setting the CCS Cost Target for 2050 to be 75% Lower for Capture, 30% Lower for Transport, and 20% Lower for Storage Compared to 2023<br>Promotion of Research and Development of Technologies that Enable Cost Reduction | | | |
| **Promotion of Public Acceptance of CCS** | To promote Public Acceptance of CO2 Storage Areas, Support Mechanisms for promoting CCS-Based Hubs & Clusters and job creation by Local Governments is needed | | | Development of Promotion |
| | Until 2030, CCUS explanatory meetings will be held in each region under the government initiative | | | |
| **Development and Review of "CCS Action Plan"** | Development of CCS action plan: Storage & Cost targets, Technical Development Guidelines, etc. | Conducted necessary revisions based on progress in decarbonization initiative, such as energy conservation and electrification, and progress in cost reduction, etc. | | |

Source: Compiled by Industry Research Department Mizuho Bank from ANRE

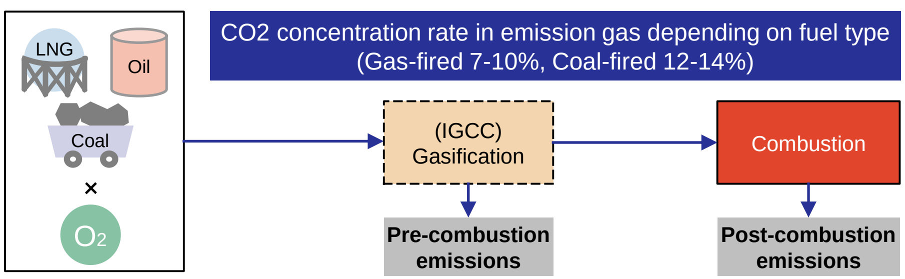
# 【Emitter】Current Status of Power Sector in CCS

- Power sector participates in R&D and PJs to support one of the effective technology options of CO2 reduction
  - The utilization of CCS may change depending on the progress of other carbon neutral technologies

## Emission CO2 characteristics in the power sector

| Characteristics | Overview | |
|---|---|---|
| CO2 emissions (Mt) | FY2021: 396 (37% of total domestic emissions) | |
| Combustion CO2 / Process CO2 | CO2 emissions mainly from fuel combustion (in IGCC, pre-combustion emissions during gasification is also captured) | |
| Emissions per product | Natural gas-fired: 943g-CO2/kWh<br>Coal-fired: 474-599g-CO2/kWh | |
| CO2 concentration / pressure | Gas-fired | 7~10% / 0.1MPa |
| | Coal-fired | 12~14% / 0.1MPa |
| | Oil-fired | 11~13% / 0.1MPa |
| | IGCC | 8~20% / 2~7MPa |
| CO2 capture method | Chemical absorption methods are major. Physical absorption and solid absorption is in R&D stage | |

## CO2 emission flow in the power sector




Source: Compiled by Industry Research Department Mizuho Bank from IPCC, NEDO, METI, ANRE, NIES, etc.

## Major CCS Project and policy proposal from the power sector

| Case | Initiatives |
|---|---|
| Participation in Advanced CCS Projects, etc. | In the "Advanced CCS Project," Hokkaido Electric Power, Tohoku Electric Power, and J-Power are participating. Other consortiums are also in the process of being launched |
| Other CCS related Initiatives | Participation in Tomakomai CCS through Japan CCS, CO2 capture demonstration in Osaki CoolGen, cooperation in solid absorption technology at Maizuru Power Plant, and liquefied CO2 transportation demonstration test |

【February 2022: Summary of proposal from Power sector in the CCS Long-Term Roadmap Study Group】

**FEPC "Status Report of Efforts by the Power sector to deploy CCS"**

(CCS is one of the effective technologies to significantly reduce CO2 emissions, and presented the following requests)

- ✓ In promoting technological development of capture, **financial support is needed for progress under the leadership of the government**
  - ➢ There are issues in determining the feasibility and cost reduction of each CO2 capture method
  - ➢ At present, there is a high degree of uncertainty regarding the establishment of technology and social implementation
- ✓ Development of CO2 transport and storage infrastructure
  - ➢ Need to consider that transportation and storage are common processes to all industries and that there are risks that are difficult for the private sector to assume, such as long-term storage liability
- ✓ Policy support for energy price control, fostering public understanding of cost burdens, appropriate burden sharing, related legislation, and gaining public acceptance of CCS are important.

Source: Compiled by Industry Research Department Mizuho Bank from FEPC, and ANRE

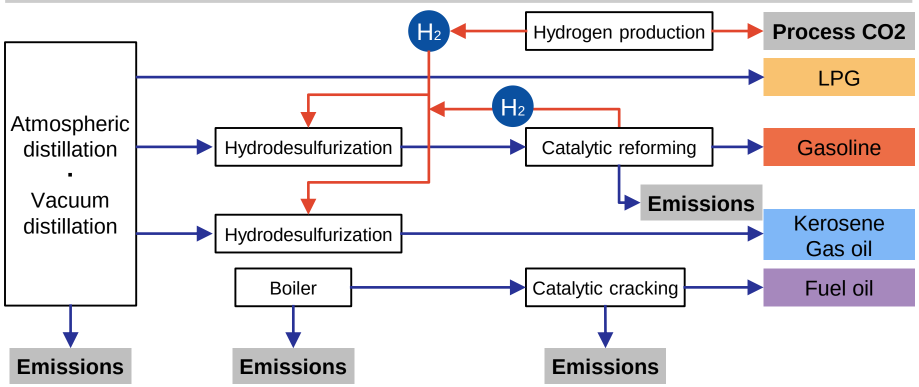
# 【Emitter】Current Status of Oil Sector in CCS

- Oil sector proactively moves to CCS as a measure of reducing $CO_2$ emissions from their refinery facilities
  - — ENEOS leads "Advanced CCS PJ" with upstream development expertise of a group company

### Emission CO2 characteristics in the oil sector

| Characteristics | Abstract |
|---|---|
| CO2 emissions (Mt) | FY2021: 79(Refining and petrochemicals together account for 7% of the total) |
| Combustion CO2 / Process CO2 | CO2 emissions are mainly from refining and chemical processes and from fuel combustion. |
| Emissions per product | CO2 emissions of 21.73 kg per 1kL of oil equivalent |
| CO2 concentration / pressure | Hydrogen production 15~20% / 0.3~0.5MPa |
| | Methanol production 10% / 0.27MPa |
| CO2 capture method | Process CO2: Physical adsorption / Chemical absorption<br>Combustion CO2: Chemical absorption |

### CO2 emission flow in the oil sector




Source: Compiled by Industry Research Department Mizuho Bank from IPCC, NEDO, METI, ANRE, NIES, etc.

### Major CCS Project and policy proposal from the Oil Sector

| Case | Initiatives |
|---|---|
| Participation in Advanced CCS Projects, etc. | In the "Advanced CCS Project," ENEOS and JX Nippon Oil & Gas Exploration are promoting a CCS project off the north to west coast of Kyushu with J-Power. Idemitsu is participating in the Tomakomai CCS project |
| Other CCS related Initiatives | JX Nippon Oil & Gas Exploration has been involved in CO2-EOR for the Petra Nova project in the USA and in the development of CCS projects in Malaysia and other countries |

【October 2022: Summary of proposals for the Introduction and Spread of Carbon-Neutral Fuels】

**PAJ (October 2022) Proposal Summary**

(CCS is recognized as an indispensable technology not only to contribute to decarbonization and stable energy supply in the transition period, but also to achieve global carbon neutrality in 2050. The following requests are presented)

- ✓ Promote R&D, demonstration, and cost reduction related to CO2 capture and storage technologies
- ✓ Promotion of public understanding and development of suitable sites
- ✓ Legislation adapted to the life cycle of CCS
- ✓ Consideration and introduction of long-term support for CCS implementation
- ✓ In particular, since CCS projects are not profitable at this time, full support is requested for the construction and operation phases of the entire value chain, including capture, transportation, and storage.
- ✓ Also, JOGMEC's risk money support function (investment and debt guarantee) for CCS projects is requested to be further strengthened

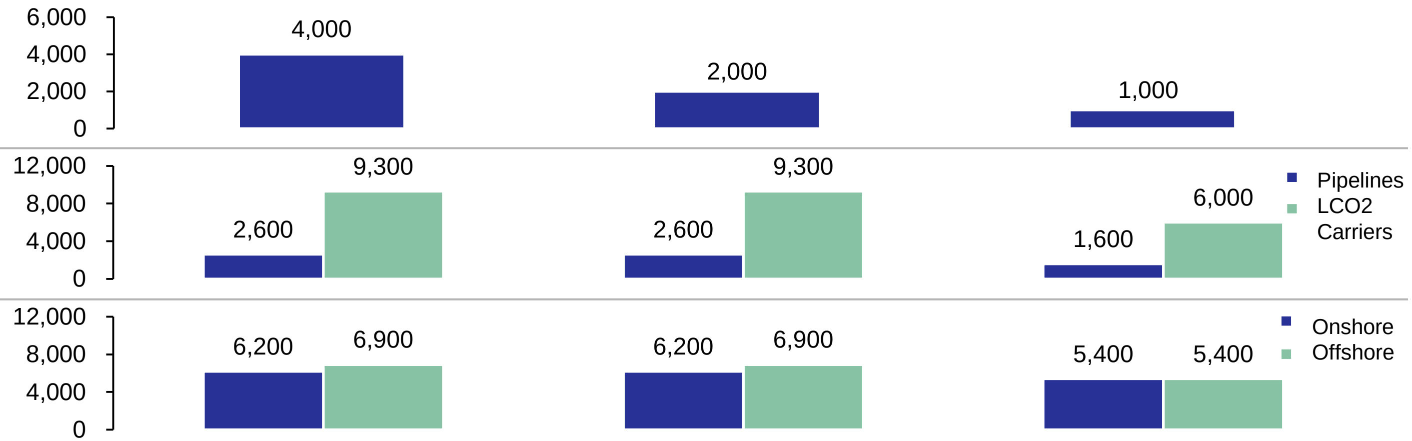
Source: Compiled by Industry Research Department Mizuho Bank from PAJ, ANRE

# Set a CCS cost reduction target of at least 40% by 2050

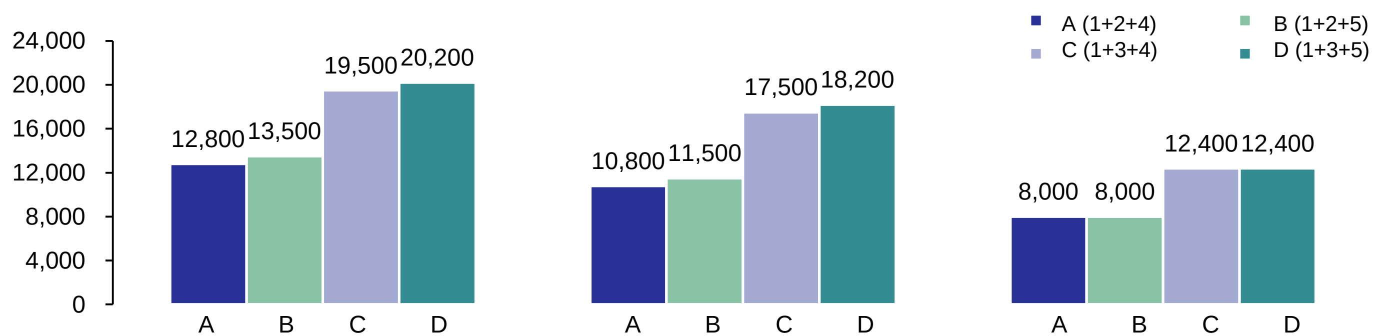
- Aim to reduce costs of CCS at least 40% by accumulating cost reductions in Capture, Transport and Storage

### The Targets of the Cost Reduction in CCS in the CCS Long-Term Roadmap

| CCS Value Chain | | Yen/t-CO2 | Current Status | 2030 | 2050 |
|---|---|---|---|---|---|
| 1 | CO2 Capture | | 4,000 | 2,000 | 1,000 |
| 2 | Pipelines Transport (20km) | | 2,600 | 2,600 | 1,600 |
| 3 | LCO2 Carrier Transport (1,100km) | | 9,300 | 9,300 | 6,000 |
| 4 | Onshore Storage | | 6,200 | 6,200 | 5,400 |
| 5 | Offshore Storage | | 6,900 | 6,900 | 5,400 |




| Total Cost of CCS | | | Yen/t-CO2 | Current Status | 2030 | 2050 |
|---|---|---|---|---|---|---|
| A | Pipelines + Onshore | 1 + 2 + 4 | | 12,800 | 10,800 | 8,000 |
| B | Pipelines + Offshore | 1 + 2 + 5 | | 13,500 | 11,500 | 8,000 |
| C | LCO2 Carriers + Onshore | 1 + 3 + 4 | | 19,500 | 17,500 | 12,400 |
| D | LCO2 Carriers + Offshore | 1 + 3 + 5 | | 20,200 | 18,200 | 12,400 |




Note: Assumptions for transport (2, 3): The Current Transport Capacity will be 0.5mt-CO2/y until 2030, and the Capacity will expand to 3.0mt-CO2/y until 2050
Assumptions for Storage (4, 5): The Current Storage Capacity will be 0.2mt-CO2/y until 2030, and the Capacity will expand to mt-CO2/y until 2050

Source: Compiled by Industry Research Department Mizuho Bank from ANRE

# 【CO2 Capture】The Direction of R&D and Cost Reduction

- In the CCS value chain, CO2 capture is an area where cost reduction is expected to be significant
  - In particular, progress of R&D to solve the challenges of capturing low-concentration CO2 is important

## Roadmap and Direction of Cost Reduction in Carbon Capture

| | Current | 2030 | 2040~ |
|---|---|---|---|
| Carbon Recycle Technologies Roadmap (July 2021) | Cost Target for High-Pressure CO2: Assuming Chemical Processes or Combustion Gas with High Concentrations Using Physical Absorption, Membrane Separation, or Physical Adsorption<br>by 2030 around 1,000 Yen/t-CO2<br>Cost Target for Low-Pressure CO2: Assuming Combustion Gas, Blast Furnace Gas, Etc. with Low Concentrations of gas (<10%). Using Chemical Absorption, Solid Absorption, and Physical Adsorption<br>by 2030 around 2,000 Yen/t-CO2 | | After 2040, the goal is to achieve practical application of CO2 capture with a cost of 1,000 to several hundred yen/t-CO2 |
| Green Innovation Fund PJ R&D Plan (Jan 2022) | Achieve Capture Cost of less than 2,000 yen/t-CO2 for Low-Pressure/Low-Concentration Gas (Atmospheric Pressure and Concentration of <10%) by 2030<br>Current Status 6,000 Yen/t-CO2, By 2030 around 2,000 Yen/t-CO2 | | |
| CCS Long-Term Roadmap (March 2023) | Reduce capture costs by approx. half compared to 2023 by 2030 and by 2050, aim to reduce costs to one quarter or less<br>Current Status 4,000 Yen/t-CO2, by 2030 around 2,000 Yen/t-CO2, by 2050 around 1,000 Yen/t-CO2 | | |

Source: Compiled by Industry Research Department Mizuho Bank from METI and ANRE

## The challenges of CO2 capture from low-concentration CO2

| | |
|---|---|
| 1 | CO2 capture from low concentrations of CO2 (<10%) requires large volumes of gas to be processed, resulting in larger equipment and increased energy consumption for pumps and auxiliary machinery<br>**To Address the Technical Challenge:**<br>To minimize the increase in the size of equipment, it is necessary to design equipment to reduce pressure loss and improve the energy efficiency of auxiliary equipment |
| 2 | To efficiently recover CO2 from a low concentration of CO2, it is necessary to use a CO2 separation material with strong CO2 absorption and adsorption characteristics and increase the amount of material injected. However, both strategies require more energy for CO2 capture.<br>**To Address the Technical Challenge:**<br>To solve these challenges, the following strategies can be pursued:<br>Amine absorption: Develop new solid materials that can absorb CO2 by reducing water enthalpy or latent and sensible heat.<br>Physical Adsorption: Develop phase change materials that can be regenerated by pressure difference rather than heat.<br>In addition, comprehensive energy management such as effective utilization of waste heat is important. |
| 3 | Exhaust gas with Low-concentration CO2 is relatively high in oxygen concentration, which promotes the degradation of materials and leading to an increase in maintenance costs, such as material replacement<br>**To Address the Technical Challenge:**<br>Developing materials with strong resistance to oxidation and degradation |

Necessary to establish CO2 capture technologies suitable for low-concentration CO2 and systems that incorporates the most appropriate technology

Source: Compiled by Industry Research Department Mizuho Bank from METI

# 【CO2 Capture】Potential of the Cost Reduction

- CO2 capture process is assumed to have room for innovation and is expected to result in large cost reduction
  - Development of CO2 capture technologies with cost advantages is an important field that will lead to the competitiveness of future carbon removal
- In the US, pipelines are mainly used for CO2 transport, and there is moderate expectation for cost reduction. However, in Japan, there is also expectation for cost reduction in transport by Liquefied CO2 (LCO2) Carriers

**Potential of the Cost Reduction in CCS process based on the U.S. Department of Energy (2023)**

| | CO2 capture | CO2 transport | | CO2 storage |
|---|---|---|---|---|
| | | Pipeline | Ref. LCO2 Carrier | |
| Current costs (US$/t-CO2) | 25~175 | 5~25 | 14~25 | 5~15 |
| Cost reductions possible? | Large Reductions | Moderate Reductions | 【Mizuho's View】<br>Compared to the pipelines, there is a possibility of cost reduction through the scale-up development of ships and other innovations | Small Reductions |
| Current cost Reduction levers | • Economies of scale, targeting largest capture sources<br>• Technology innovations for novel capture technologies<br>• Learning by doing<br>• Modularization and standardization | • Siting close to reservoirs to minimize distance<br>• Economies of scale (e.g., increasing diameter and added compression)<br>• Aggregation of various CO2 sources in a hub<br>• Utilization of existing right-of ways | 【Mizuho's View】<br>• Large-scale development, R&D and innovation of LCO2 Carriers<br>• Standardization | • Siting on well-characterized site with existing infrastructure and good monitorability<br>• Economies of scale, leveraging large reservoir capacities<br>• Reduction of MMV (Measurement, Monitoring and Verification) costs by R&D and learning by doing |

Source: Compiled by Industry Research Department Mizuho Bank from U.S. Department of Energy, etc.

# 【CO2 Transport】Status of Development of LCO2 Carriers in Japan

- Japanese LCO2 carrier is being developed through the NEDO demonstration Project in Tomakomai, and built by Mitsubishi Shipbuilding
  - — It will actively develop ocean-going vessels in cooperation with other companies to meet global demand

## NEDO Demonstration of LCO2 carrier

【NEDO Project "CCUS R&D and Demonstration Related Project / Large-scale CCUS Demonstration in Tomakomai / Demonstration Project on CO2 Transportation"】

＜R&D on CO2 Liquefaction and Storage Systems and Social Implementation on large vessels＞

Japan CCS (JCCS) → Re-entrust → Mitsui O.S.K. Lines, Nippon Steel Pipe & Engineering

＜Feasibility study＞

ITOCHU Corporation, Nippon Steel

**＜ R&D on transport vessels ＞**

Engineering Advancement Association of Japan → Re-entrust → Kawasaki Kisen Kaisha, Nippon Gas Line, Ochanomizu University

Sanyu Kisen (Ship Owner) → Bareboat charter → Kawasaki Kisen Kaisha, Nippon Gas Line, Ochanomizu University

Sanyu Kisen (Ship Owner) → Order → **Mitsubishi Shipbuilding**

Mitsubishi Shipbuilding → Construction and Delivery → Sanyu Kisen (Ship Owner)

**Limited number of shipbuilders are working on development of LCO2 carriers in Japan**

**The shipbuilders currently involved in the development will be the main players in the shipbuilding in Japan**

Source: Compiled by Industry Research Department Mizuho Bank from NEDO, etc.

## Direction of Development of LCO2 carriers by Mitsubishi Shipbuilding

| | Initiatives to develop LCO2 carriers |
|---|---|
| ① | **Development and commercialization of the first ship**<br>— Development of First Ship for NEDO Demonstration |
| ② | **Collaboration with global players to develop LCO2 carriers**<br>— Aim to promote the development of LCO2 carriers through collaboration with Equinor and TotalEnergies and participation in the CO2LOS III project (including FS implementation to verify effectiveness and information sharing with PJ members). |
| ③ | **Development of large vessels**<br>— Aim to promote develop small to large vessels through joint development with NYK<br>— Consider Joint development of large LCO2 carriers for ocean-going with Nihon Shipyard. Aim to complete after 2027 |
| ④ | **Other initiatives to improve transportation efficiency and reduce transportation costs**<br>— Announced the completion of a concept study for an ammonia and liquefied CO2 dual-use vessel in cooperation with Mitsui O.S.K. Lines. Aim to improve transportation efficiency by transporting ammonia on the outward route and liquefied CO2 on the return route. |

Source: Compiled by Industry Research Department Mizuho Bank from Mitsubishi Shipbuilding.

# 【CO2 Transport】Competition with Global Shipbuilding Companies

- Japan is expected to build and deliver the world's first liquefied CO2 carrier for CCUS use
- However, shipbuilders in South Korea and China are also actively engaged in orders for LCO2 carriers and development of large ships
- In order for Japan to lead the global competition, it is urgent to consider further project creation and early commercialization of large ships

**LCO2 carriers on order and trends in the development at major shipbuilders in South Korea & China**

| Shipbuilding company | Owner | Tank Size ($m^3$) | Contract period to construction period (year) 2021–2026 |
|---|---|---|---|
| Mitsubishi Shipbuilding (Japan) | Sanyu Kisen (Japan) | 1,450 (small) | Sep. 2021 → **Dec. 2023** — **World's First LCO2 carrier for CCUS** |
| Dalian Shipbuilding Industry (China) | Northern Lights (Norway) | 7,500 | Oct. 2021 → Mar. 2024 |
| Dalian Shipbuilding Industry (China) | Northern Lights (Norway) | 7,500 | Oct. 2021 → Jun 2024 |
| Dalian Shipbuilding Industry (China) | Northern Lights (Norway) | 7,500 | Aug. 2023 → After 2025 |
| Hyundai Heavy Industries (South Korea) | Capital Maritime (Greece) | 22,000 | Jul. 2023 → Jan. 2026 |
| Hyundai Heavy Industries (South Korea) | Capital Maritime (Greece) | 22,000 (large) | Jul. 2023 → Apr. 2026 |

Further increase in size is expected

## South Korea

| | |
|---|---|
| Hyundai Heavy Industries | ✓ In August 2021, announced that it would work with POSCO to develop larger vessels of 20,000 $m^3$ or larger by 2025, and to study the rules.<br>✓ In July 2022, Korea Register of Shipping granted AiP for 40,000 $m^3$ type design. |
| Hanwha Ocean (Former Daewoo Shipbuilding) | ✓ In September 2021, announced with ABS (American Bureau of Shipping) that it would jointly develop 70,000 $m^3$ LCO2 carriers. In April 2022, obtained AiP from ABS. |

## China

| | |
|---|---|
| China State Shipbuilding Corporation | ✓ In August 2021, the company announced that its subsidiary, Jiangnan Shipyard has developed an ammonia-fueled LCO2 carrier. Already obtained AiP from Korea Register of Shipping. |

Note: AiP : Approval in Principle

Source: Compiled by Industry Research Department Mizuho Bank from various public materials

# 【CO2 Transport】Issues and the Importance of Government Support in LCO2 Carrier

- While the players in the domestic market for LCO2 carriers are already being in place, government support is needed to strengthen the competitiveness of LCO2 carrier business and the shipbuilding industry as a whole.

## Issues in LCO2 carriers

**Design and development**

✓ Implement initiatives including development of large vessels, mainly at Mitsubishi Shipbuilding

Point (Mizuho's View)

**Concept of "common design (unification) of LCO2 carriers" in Japan**

⇒ Narrowindown designs g leads to a virtuous cycle of enhanced cost competitiveness and speedy performance improvement by concentrating design feedback, etc.

**Expansion monetization points**

✓ Expanding the scope of business related to LCO2 carriers, including consideration of licensing business for each underlying technology (build a business that does not solely rely on construction).

**Construction**

✓ Collaboration between Mitsubishi Shipbuilding and Nihon Shipyard (NSY) paves the way for Imabari Shipbuilding and Japan Marine United, NSY's shareholder's to build LCO2 carriers.

Point (Mizuho's View)

**To achieve carbon neutrality in the marine transport industry, it is expected that there will be an expansion in the demand energy transportation (such as LCO2, hydrogen, etc.) and a conversion to alternative fuels for marine vessels (ammonia, etc.), which will lead to an increase in capital investment for various developments.**

**Supply chains**

✓ From an economic security perspective, it is also important to establish domestic supply chains that do not rely on other countries. (e.g., large tank manufacturing)

Source: Compiled by Industry Research Department of Mizuho Bank

## Key points of government support and expected future developments

**Support for demand creation for early commercialization**

↓

**Japanese LCO2 carriers become global de facto standard**

↓

**Increase in the number of vessels built by Japanese shipbuilders**
**Expanding licensing business**

**Support for capital investment**

↓

**Stimulating capital investment for the construction of next-generation vessels (Eliminate bottlenecks in construction)**

↓

**Strengthen the competitiveness of Japan's shipbuilding industry**

Source: Compiled by Industry Research Department of Mizuho Bank

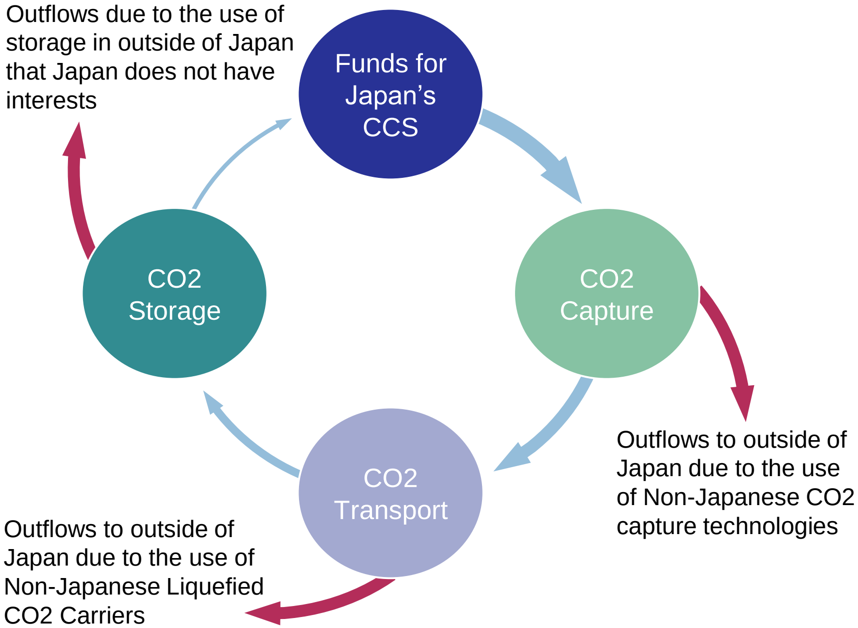
# The future of CCS in Japan: The horror story and the goal

■ Based on importance of the CCS in Japan, fostering industry with aim of circulating national wealth is essential

**【Mizuho's View】The future of CCS in Japan: The horror story and the goal**

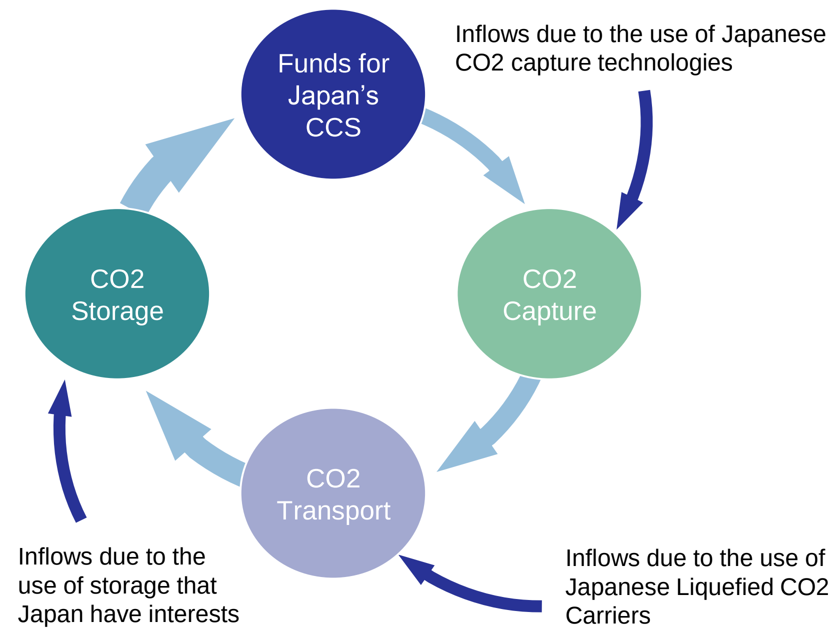
【 The future of CCS in Japan: The horror story in 2050 】

- In order to maintain Japan's industries and ensure energy security, it is essential for Japan to continue using CCS
- However, if it was not possible to foster leading players in CCS technologies and business in Japan, Japan would have to continuously pay the cost for using CO2 capture technologies, Liquefied CO2 Carriers, and CO2 storage to outside of Japan.
- In this horror story case, although a huge amount of funds is required to operate the CCS value chain, the outflow of funds to outside of Japan occurs and the national wealth does not circulate sufficiently




【 The future of CCS in Japan: The goal in 2050 】

- Thanks to the domestic demand of CCS and policy support, Japan succeeds in developing leading CCS players. Japanese companies will win CCS projects in Japan based on their competitiveness, and CO2 capture technology and Liquefied CO2 Carriers are exported to outside of Japan. In addition, some of the storage interests in global are acquired by Japanese companies
- The amount of funds used to operate the CCS value chain and the inflow of funds from CCS-related businesses in outside of Japan expansion will circulate in Japan, and it leads further development of the industry




Source: Compiled by Industry Research Department of Mizuho Bank

# 【Mizuho's View】How to realize the future vision of CCS in Japan

- To realize the future vision of CCS in Japan, it is crucial for Japan to demonstrate its strength and presence at every stage of the CCS value chain
- In order to achieve the goal, Japan should effectively leverage its large CO2 emissions and centralize and standardize the technologies and best practices of top runners within the country, ultimately refining them to achieve lower costs and higher quality
- In addition, when the trade volume of CO2 increases in the future, frictional inefficiency in the value chain of CCS will become a cost push issue
  - If Japan can establish an entity that plays the role of an "aggregator" that performs optimization functions in order to minimize cost inefficiencies, Japan may be able to promote optimization in the use of CCS in Japan and use it as an advantage in acquiring CCS business in global basis

**【Mizuho's View】How to realize the future vision of CCS in Japan**

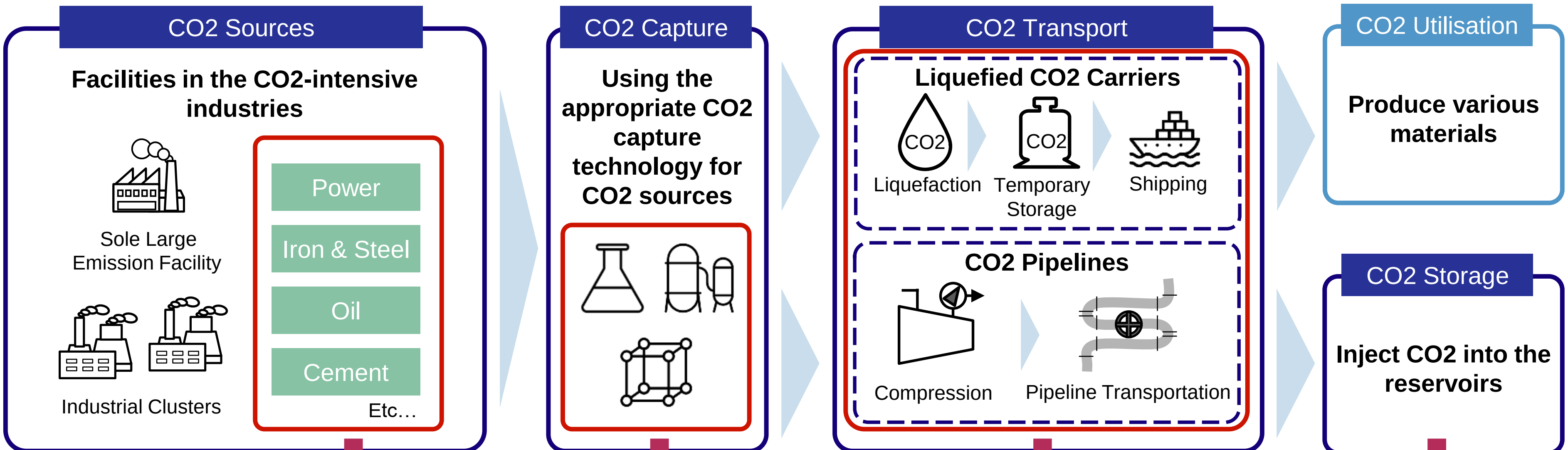
| How to realize the future vision of CCS in Japan | Strategies to Strengthening Competitiveness of CCS in Japan | The future of CCS in Japan: The goal in 2050 |
|---|---|---|
| It is crucial for Japan to demonstrate its strength and presence at every stage of the CCS value chain | Japan should effectively leverage its large CO2 emissions | Avoid the Outflow of Japanese Capital and Develop CCS Industry in Japan |
| R&D of cost-competitive CO2 capture technologies<br>Construction of Ships for Liquefied CO2 Transportation in Japan<br>Securing CO2 storage capacity | Centralize & Standardize the technologies and best practices, refining them to achieve lower costs and higher quality<br>Establishing an "Aggregator" Function for Optimizing the operation of CCS Value Chain | Create a Growth Industry that can Contribute to the Realization of Japan's Carbon-Neutral Society, the expansion of Japanese Capital at Each Stage of CCS value chain, and Success in the Global Business |

Source: Compiled by Industry Research Department of Mizuho Bank

# Strengthening Competitiveness Through Establishment of Best Practices

- Japan should leverage its large CO2 emissions and standardize technologies based on the best practices of top runners. By thoroughly utilizing these technologies, their lower cost and higher quality can be achieved

**【Mizuho's View】Strengthening Competitiveness in the CCS Value Chain Through Establishment and Refinement of Best Practices**




Focusing early on industry-wide CO2 capture technologies that match the characteristics of each CO2 intensive-industries

Developing a testing system for actual gas in Japan and establish a demonstrative environment on a national scale. The technology that has shown a high level of performance should be treated as the optimal technology for the industry

Standardize specifications for each transportation method

Constructing the infrastructure based on the best practice standards and utilize Japanese finance support to build LCO2 Carrier

Establishing best practices for monitoring methods and introduce them at storage sites

Effectively leverage Japan's large CO2 emissions and centralize & standardize the technologies and best practices of top runners, ultimately refining them to achieve lower costs and higher quality

Expand low-cost green products and industry-specific capture technologies for each global markets

Expansion of Japan's LCO2 Carrier and transportation technologies

Expansion of technologies for global

Source: Compiled by Industry Research Department of Mizuho Bank