The Path for the Development of CCS in Japan

Innovative Technology Series*

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

Link to survey

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* Series of reports highlighting areas of technology and innovation that can contribute to strengthening the competitiveness of Japanese industry and to solving social issues.

Executive Summary

- Carbon Dioxide Capture and Storage (CCS) is a technology that captures CO2 from fossil fueled power station or industrial facilities and so on, transports it from the place of emission, and stores it in the appropriate place in underground. It is one of the effective way to reduce CO2 emissions, especially in industries that emit a large amount of CO2 in production processes. As a technology that plays an important role to achieve a carbon-neutral society in long-term, global leading players enhance their support to it. Recently, the activities of leading CCS countries that actively promote CCS have been increasing, such as North America, which accelerates business development by utilizing existing infrastructure and providing policy support; Europe and the United Kingdom, which promote national projects as measures for decarbonisation; and Australia, which leveraging a favorable geographic environment for CCS.
- Japan is also planning to develop policy support. "CCS Business Law (p)" will be planned to establish based on the Final Summary of Japanese CCS Long-Term Roadmap announced in 2023, and "Advanced CCS Projects" were selected recently. In addition to these efforts to establish a first CCS project, it will be important to discuss how Japanese CCS should be competitive on global basis in the long term, and the measures to achieve the goal.
- In this report, we review the current global and Japanese CCS environment and the current status of each CCS value chain, and consider the future of the CCS industry in Japan. In particular, we focus on how Japanese CCS industries can be "The growing industry sectors that contributes to the circulation and expansion of Japan's national wealth at each stage of CO2 capture, transportation, and storage, and contributes to achieve a carbon-neutral society in Japan, while also being able to win over global business".
- To realize the future vision of CCS in Japan, it is crucial for Japan to demonstrate its strength and presence at each stage of the CCS value chain. 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.
- 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 optimisation in the use of CCS in Japan and use it as an advantage in acquiring CCS business in global basis.
- These developments require both business players challenges based on the animal spirits, and solid policy support from the government with a long-term strategy for the national wealth. If the joint cooperation from the public and private sectors are promoted, it is quite possible for the CCS in Japan to achieve the future vision.

Source: Compiled by Industry Research Department Mizuho Bank

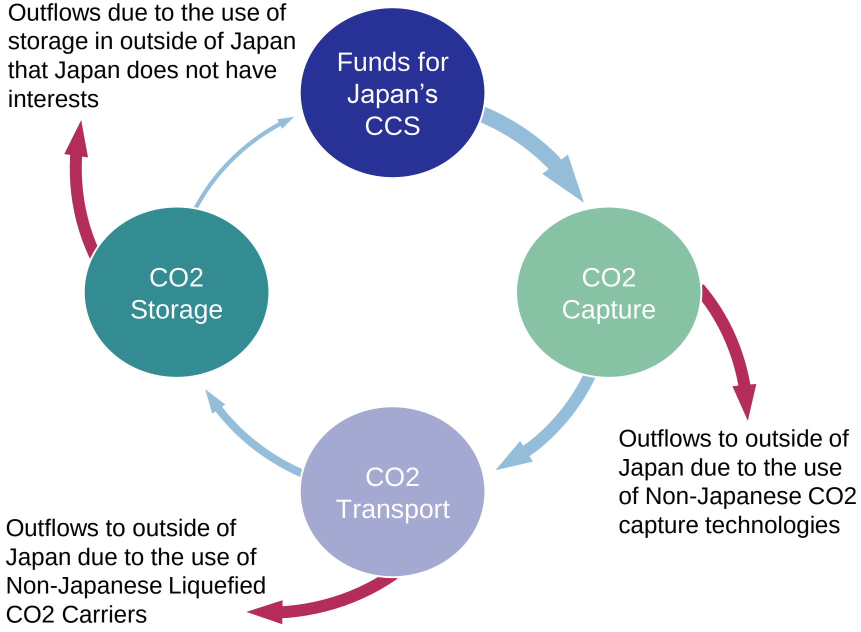
The future of CCS in Japan: The horror story and the goal

- 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

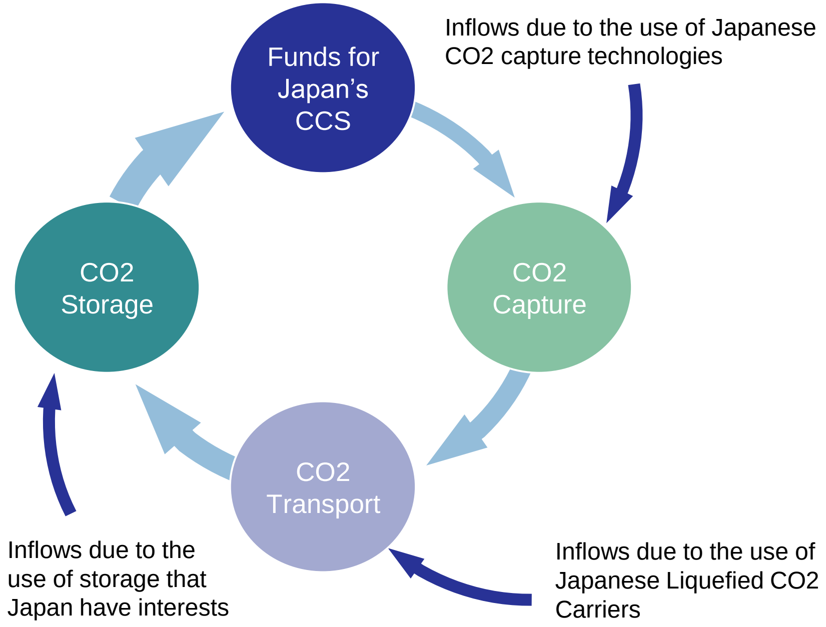
【 The future of CCS in Japan: The horror story in 2050 】

- 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 Mizuho Bank

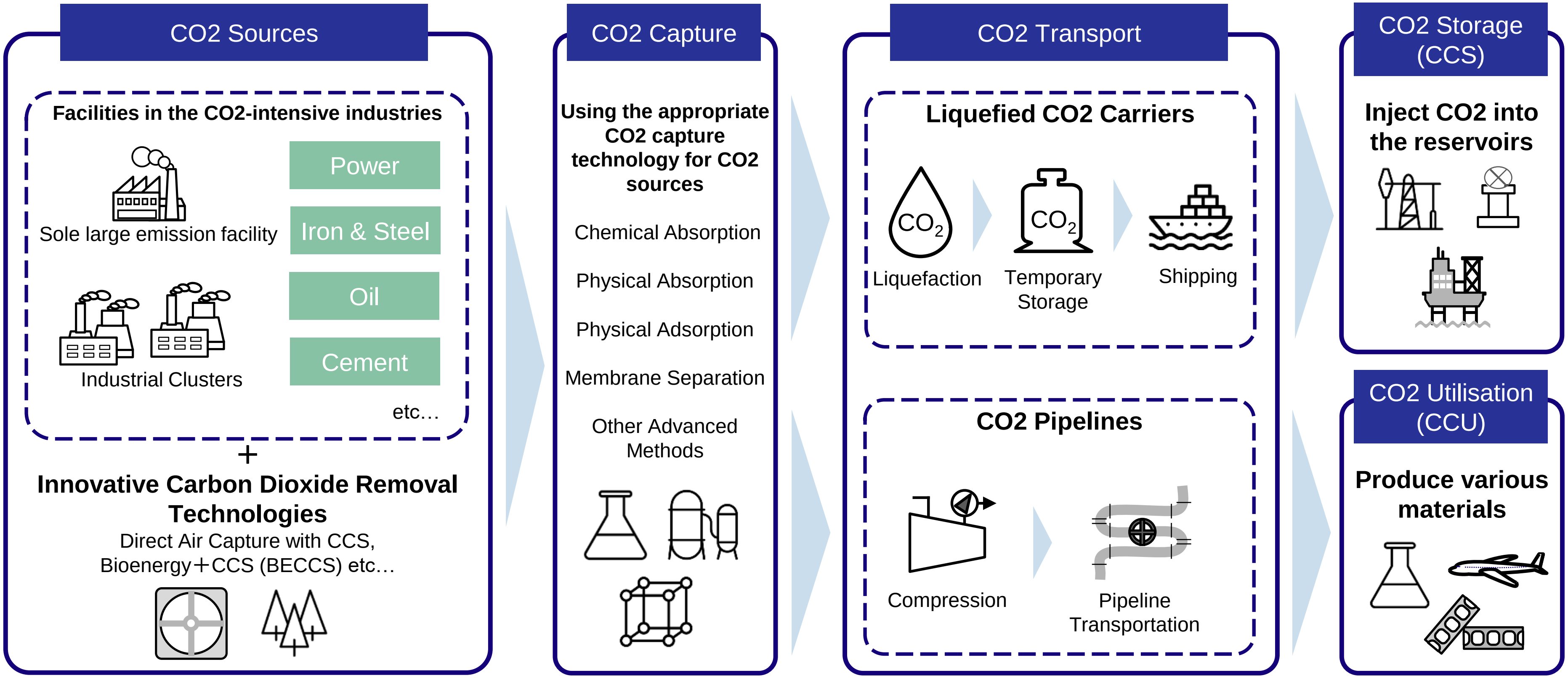
Outlines

1. Overview of CCS

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



CO2 Sources

Facilities in the CO2-intensive industries

Sole large emission facility

Industrial Clusters

Power

Iron & Steel

Oil

Cement

etc…

+

Innovative Carbon Dioxide Removal Technologies

Direct Air Capture with CCS,
Bioenergy+CCS (BECCS) etc…

CO2 Capture

Using the appropriate CO2 capture technology for CO2 sources

Chemical Absorption

Physical Absorption

Physical Adsorption

Membrane Separation

Other Advanced Methods

CO2 Transport

Liquefied CO2 Carriers

Liquefaction

Temporary Storage

Shipping

CO2 Pipelines

Compression

Pipeline Transportation

CO2 Storage (CCS)

Inject CO2 into the reservoirs

CO2 Utilisation (CCU)

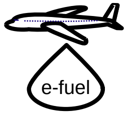
Produce various materials

Source: Compiled by Industry Research Department Mizuho Bank based on IEA (2022a), etc.

(Ref.) Commonalities and Complementarities between CCS and CCU

- CCS and CCU share common technologies and processes for CO2 capture and transportation, while their different characteristics give them complementary roles in reducing carbon emissions.

Type of CCU

Type	Overview	
Chemical production 	Basic Products	Olefins, BTX (Benzene, toluene, and xylene), etc.
	Oxygen-Containing Compounds	Polycarbonate, Urethane, etc.
	Others	bio-derived chemicals
Fuel production 	Liquid Fuel (synthetic fuel)	e-fuel, methanol
	Liquid Fuel (biofuel)	Sustainable Aviation Fuel (SAF)
	Gas Fuel	Synthetic methane (e-methane), etc.
Mineralisation	—	Concrete, cement, carbonate, etc.

Commonalities and Complementarities between CCS and CCU

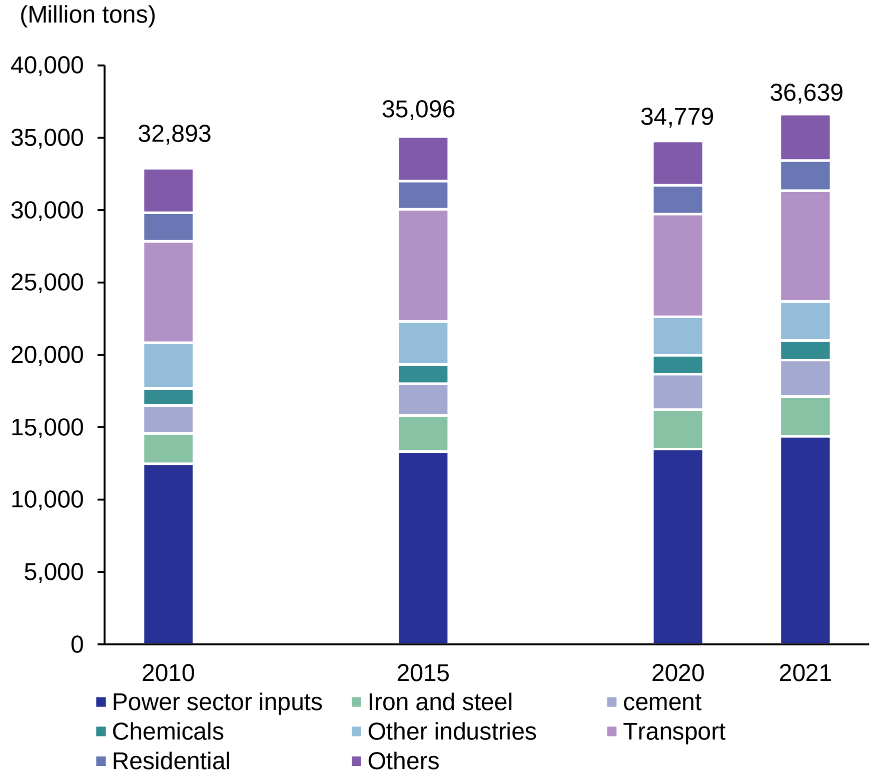
		CCS	CCU
Commonalities			
	Common Technologies for CO2 Capture and Transportation	R&D of cost-competitive CO2 capture technologies and efficient CO2 transportation benefits both CCS and CCU	
	Common Process for CO2 Capture to Transportation	Sharing Infrastructure can lead to Efficient Operation	
Complementarities			
	Potential for Large-Scale CO2 Reduction	• Large Scale Project • Several mt/y scale PJ are planned for 2030 in Japan	• CO2 reduction capacity per site is smaller than that of CCS
	Flexibility of CO2 Reduction	• Limited availability and flexibility of CCS sites and the need for transport	• On-site CCU options available • Production of a variety of products
Others			
	Commercial arrangement	• CCS does not produce valuable goods, and it is necessary to organize a new form of business	• Commercial arrangement is possible with the existing trade flow
	Players	• Consortium of Large Corporations	• Small-Scale Deployment is Possible

Source: Compiled by Industry Research Department Mizuho Bank based on ANRE (Agency for Natural Resources and Energy, 2023a, 2023b), Mizuho Bank (2021), etc.

Trends of Global CO2 Emissions

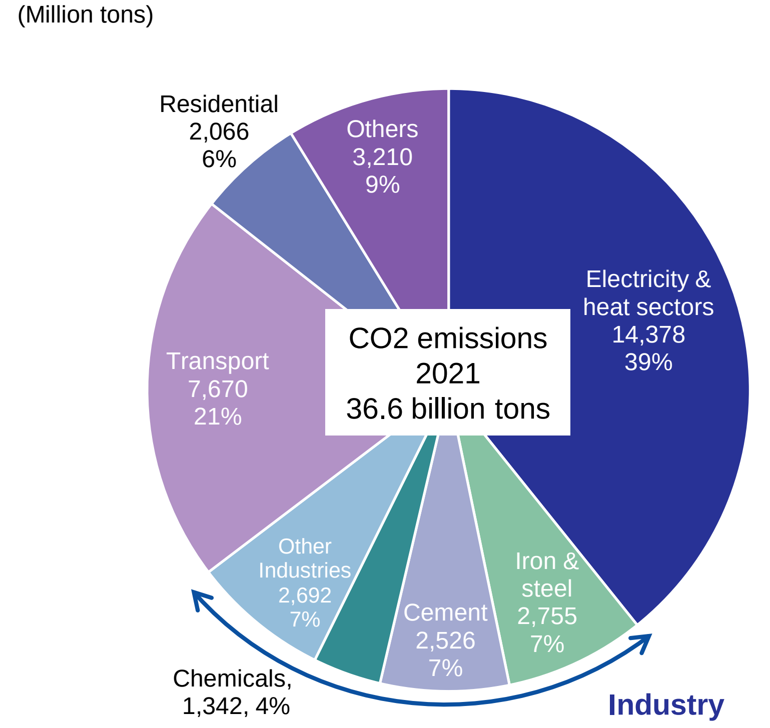
- According to the IEA (2022b), the world emitted 36.6 billion tons of CO2 in 2021. Up 5% from 2020 due to the global economic recovery from the impact of the COVID-19 pandemic.
  - Electricity & heat sector accounted for about 40% and Industry sectors accounted for over 20%. Those CO2-intensive industries are the potential users of CCS

Trends of Global CO2 Emissions



Source: Compiled by Industry Research Department Mizuho Bank based on IEA (2022b)

Breakdown of Global CO2 Emissions



Note: CO2 emissions Includes emissions from industrial processes and flaring.

Source: Compiled by Industry Research Department Mizuho Bank based on IEA (2022b)

Characteristics of CO2 emission sources & IEA Outlook of CO2 Capture

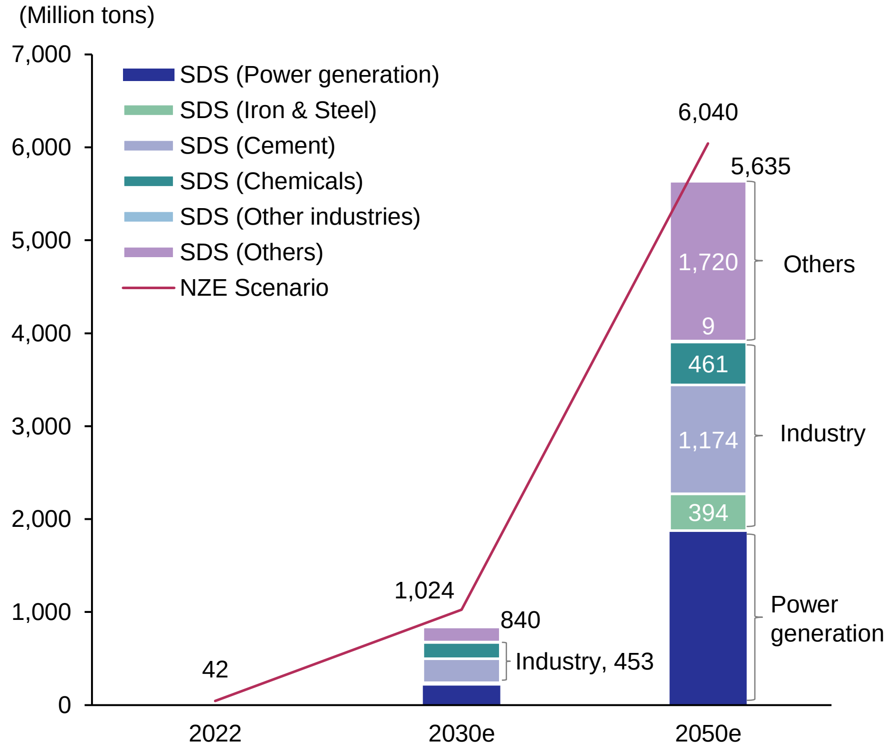
- The characteristics of emitted CO2 exhibits large differences depending on the facility and process
  - — It is needed to use the appropriate CO2 capture technologies for each CO2 emission sources
- According to IEA outlook, CO2 capture volume increase to about 5.6Bt under the Paris Agreement scenario
  - — Expected to increase the use as a decarbonisation solution in power and industries sectors

Characteristics of CO2 emission sources

Sector	CO2 sources	Pre/Post Combustion	CO2 %	Pressure (Mpa)	Other Components
Power	Gas-fired Power	Post	7~10	0.1	N2, O2, SOx, NOx, etc.
	Coal-fired Power	Post	12~14	0.1	
	Oil-fired Power	Post	11~13	0.1	
	IGCC	Pre	8~20	2~7	
Iron & Steel	Emissions from blast furnaces	① Pre	20	0.2~0.3	N2, CO, etc.
		② Post	27	0.1	
Cements	Cement kiln emission gas	Post	14~33	0.1	N2, O2, Sox, etc.
Oil Refining & Chemical	Hydrogen Production	Pre	15~20	2.2~2.7	N2, O2, NOx, Sox, etc.
	Methanol Production	Pre	10	2.7	
(Ref) DAC	Atmosphere	-	0.04	0.1	N2, O2, etc.

Note: IGCC: Integrated coal Gasification Combined Cycle
Source: Compiled by Industry Research Department Mizuho Bank based on IPCC (2005), NEDO (2020), etc.

IEA SDS and NZE Outlook of CO2 Capture

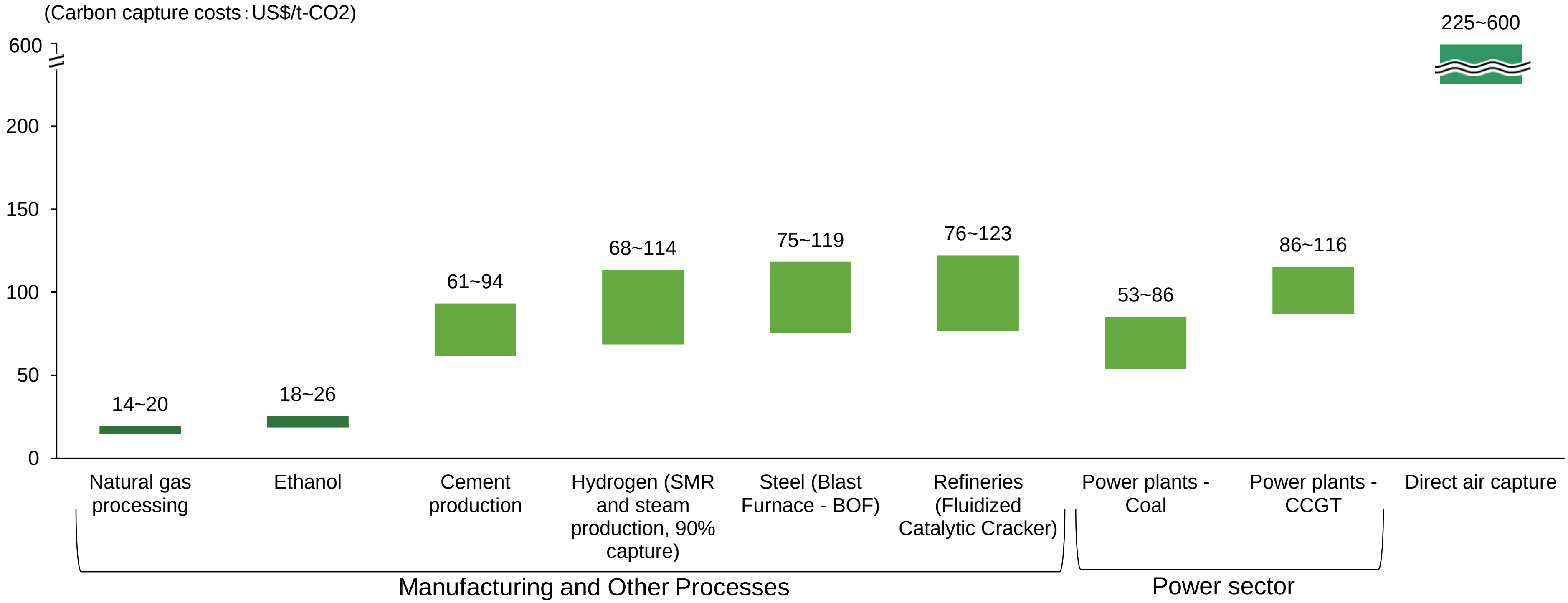


Note: SDS：Sustainable Development Scenario, NZE：Net Zero Emission Scenario
Source: Compiled by Industry Research Department Mizuho Bank based on IEA (2020), IEA (2023a), etc.

CO2 capture costs by CO2 source

- The cost of CO2 capture tends to increase as the CO2 concentration in the emission source decreases
  - Direct Air Capture (DAC) is particularly expensive compared to other CO2 capture methods due to the low CO2 concentration (Approx. 400 ppm).
- However, the actual cost of CO2 capture depends on the specific characteristics of the emission source, such as its concentration and the applicable capture methods

CO2 capture costs by CO2 source



Source: Compiled by Industry Research Department Mizuho Bank based on U.S. Department of Energy (2023)

【CO2 Capture】Major Methods for CO2 Capture

- There are a variety of methods available for the CO2 capture
  - Each method has its own strengths, and the selection of the appropriate method depends on factors such as the concentration of CO2, the purity & volume of the captured CO2, and the specific site conditions

Major Methods for CO2 Capture

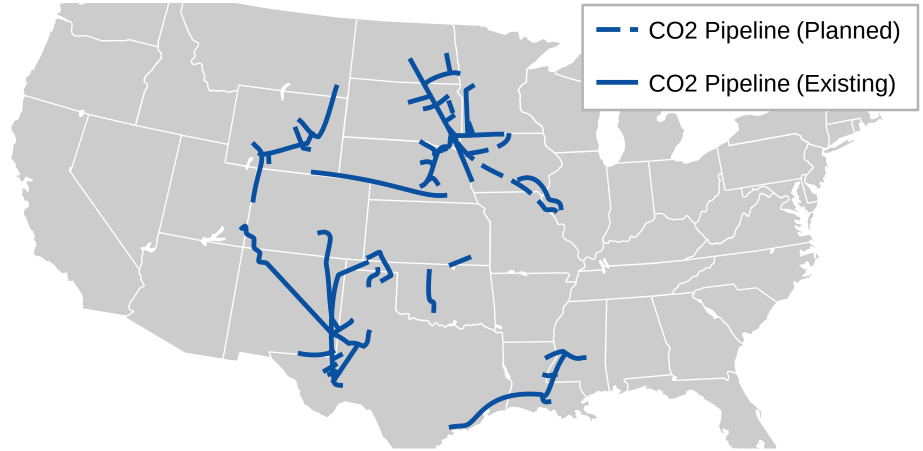
	Driving Force	Overview	Technology Level	Strength	Challenge	Japan's Position (ANRE (2022a))
Chemical Absorption	Temperature Swing Approach (TSA)	Method for capturing CO2 using chemical reaction with liquid (amine absorbing liquid)	Commercial (high concentration)	For Large facilities & Low pressure gas	Large heat for separation, absorbent degradation, Corrosion	Japanese companies developed high-performance absorbents for low pressure gases
Physical Absorption	Pressure Swing Approach (PSA)	Method for capturing CO2 by dissolving it in liquid	Commercial (high concentration)	For Large facilities, and High pressure & Concentration gases	Absorbent degradation	Non-Japanese companies have presence in high pressure gas applications
Physical Adsorption	PSA	Method for capturing CO2 using porous solid such as Zeolite by pressure or temperature swing approach	Commercial (high concentration)	Wide range of applications, High purity of CO2, Simple equipment	Absorbent degradation, Hygroscopicity	Japan is the first country in the world to complete the actual gas demonstration for steel manufacturing (COURSE50).
	TSA		Commercial (high concentration)			
Membrane Separation	PSA	Method for separating CO2 by using membrane having separation function (e.g. Zeolite membrane, etc.)	Commercial - Demonstration (high concentration)	For Small size & High pressure gas, Simple equipment	Cost of membranes, Degradation by impurities	Japanese companies have developed high-performance membranes (Molecular gate membrane and Zeolite membrane), leading the world in core technologies
Cryogenic Separation	Phase Change	Separating only CO2 by using difference of boiling point	Demonstration (high concentration)	For Large Facilities & High concentration gases	Large equipment cost	—
Oxy-Fuel Combustion	Phase Change	Capturing high concentration post combustion CO2 gas by injecting oxygen	Demonstration (high concentration)	High energy efficiency	R&D for equipment	—
Chemical Looping	Phase Change	Using oxidation and reduction of metal	Demonstration (high concentration)	High energy efficiency	Degradation of metal	—

Source: Compiled by Industry Research Department Mizuho Bank based on the Ministry of Economy, Trade and Industry (METI, 2021), ANRE (2021, 2022a), etc.

【Transport】Current status of CO2 pipeline transport

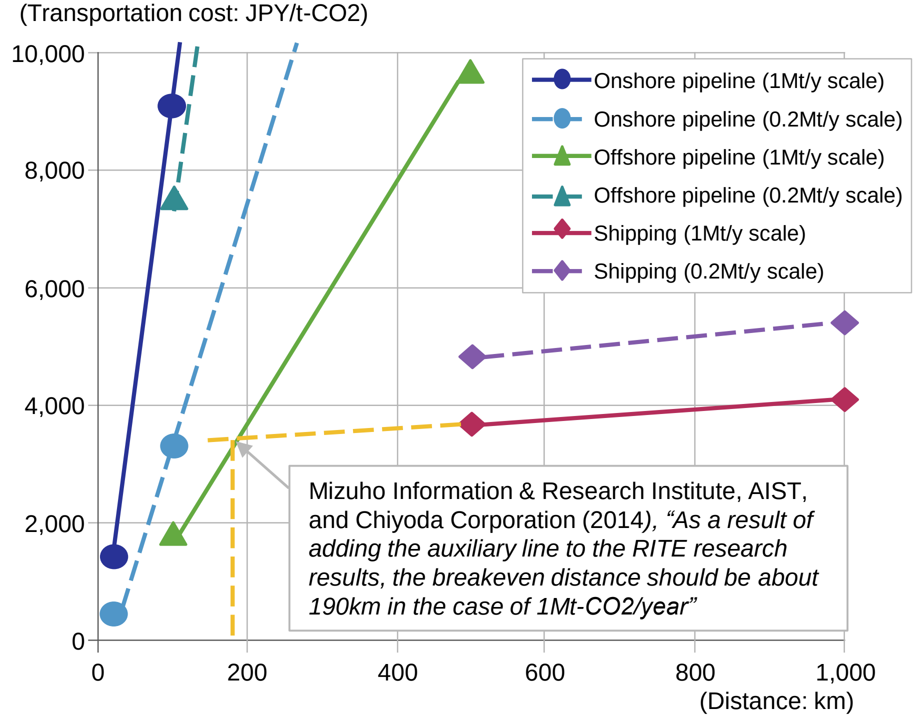
- The total length of CO2 pipelines worldwide is approx, 9,500km, with roughly 90% of them located in the U.S.
  - Since the 1970s, the U.S. has been installing CO2 pipelines for the purposes of implementing Enhanced Oil Recovery (EOR), which increase crude oil production by injecting CO2 into oil fields
- In Japan, pipeline construction costs are generally considered to be high, with shipping options remaining more cost-efficient, especially when transporting over distances greater than 190km

Major US CO2 Pipelines & Comparison of Transportation Methods



Methods	Cost (US$/t-CO2)	Technologies Level	Current Status
Pipeline	US$ 5~25	Matured	Installed in U.S. Canada, Brazil, China, etc.
Shipping	US$ 14~25	Small: Matured Large: Development	Large shipping technologies are under the development
Railway, Truck	US$ 35~60	Small: Matured Large: Development	No Large Scale use case

Comparison of Transportation costs in Japan



Mizuho Information & Research Institute, AIST, and Chiyoda Corporation (2014)*, "As a result of adding the auxiliary line to the RITE research results, the breakeven distance should be about 190km in the case of 1Mt-CO2/year"*

Source: Compiled by Industry Research Department Mizuho Bank based on U.S. Department of Energy (2023), Mizuho Information & Research Institute, AIST, and Chiyoda Corporation (2014).

【Transport】Current status of Ship for Liquefied CO2 (LCO2) Transport

- Only a few small LCO2 carriers are available for the food industry currently, and no large-scale ships for CCS
- Existing LCO2 carriers use “mid-temp & mid-pressure” transportation technologies, which are difficult to scale up
  - New technologies; “low-temp & low-pressure” or “normal-temp & high-pressure”, need to be developed

Ships for LCO2

Name	Vintage Year	Size of Tank (m^3)	Deadweight tonnage (DWT)
Amagimaru (already scrapped)	1986	365	353
Helle	1999	1,250	1,666
Embla	2005	1,800	3,486
Froya	2005	1,800	3,486
Gerda	2005	1,800	3,486

- ✓ Currently, there are four operating LCO2 carriers, and their tank sizes range from approximately 1,000 to 2,000 m^3. These ships are designed with "mid-temp & mid-pressure"
  - At present, there are no CO2 carriers specifically designed for CCS purposes
- ✓ **In order to facilitate the large-scale transportation of CO2 and reduce costs per cargo capacity, the development and practical application of "low-temp & low-pressure" are crucial.**
  - **There are also cases the development of "normal-temp & high-pressure" is being pursued.**

Source: Compiled by Industry Research Department Mizuho Bank based on NEDO

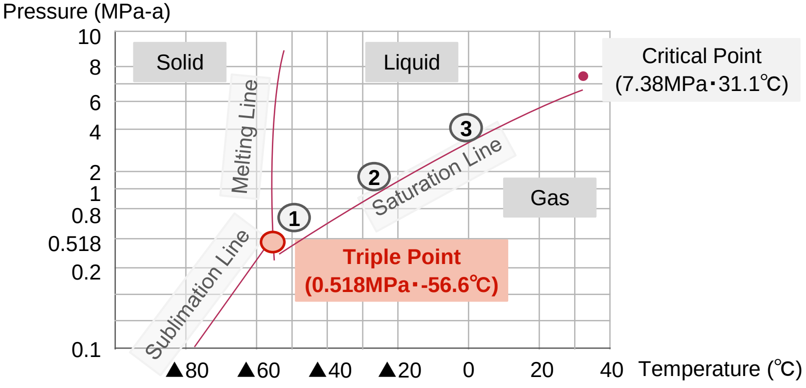
CO2 phase diagram ／ Transportation conditions for LCO2 at sea

	Pressure	Temperature	Transportation records
	Issue		
① low-temp & low-pressure	6-8 bar	approx.▲50℃	×
	It is capable of large-scale transportation, but there is a risk of dry ice formation.		
② mid-temp & mid-pressure	15-18 bar	approx.▲25℃	○
	There are track records. But it is difficult to increase the size of ship, making it unsuitable for large-scale transportation.		
③ normal-temp & high-pressure	35-45 bar	approx.0℃	×
	It is capable of large-scale transportation, but the amount of CO2 that can be accommodated in the same volume is relatively small.		

The future development and practical implementation will be crucial

Existing Status

At present, only a few companies are involved in these efforts



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

【Storage】Appropriate Site for CO2 Storage and the Storage Potential

- CO2 storage needs appropriate site, such as Depleted Oil & Gas reservoirs or Deep Saline Aquifers
- According to OGCI (2022), North America, Australia, China, and Japan have large storage potential
  - However, additional processes are necessary to determine the actual storage amount

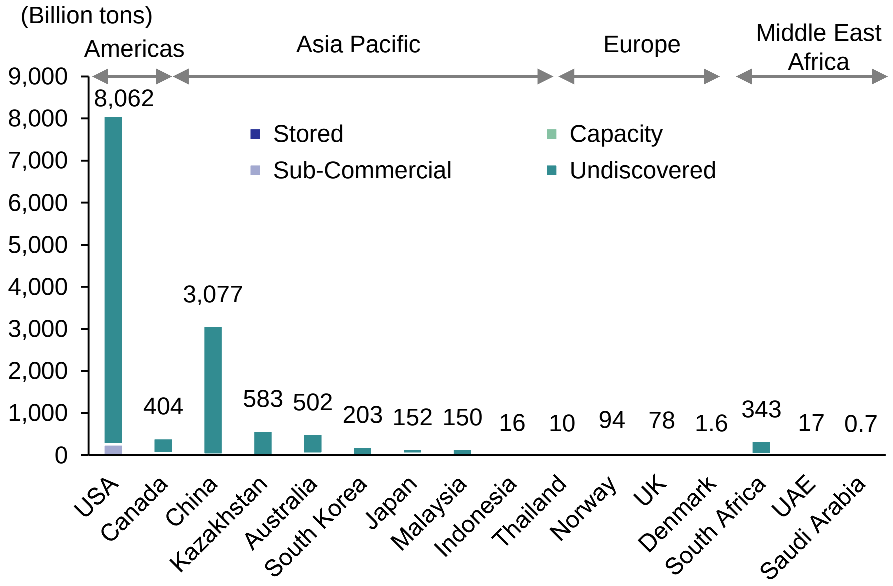
Appropriate Site for CO2 Storage

Geological conditions for CCS	1	Deep from the ground or the sea floor (at least 1km)
	2	The porous rock (reservoir rock) is covered by impermeable rock (cap rock), such as mudstone
	3	Sufficient storage volume

Storage Site	Depleted Oil & Gas reservoirs	Deep Saline Aquifers	Deep Unmineable Coal Seams
Overview	Oil & gas fields have been used to store oil and natural gas for a long time. Hence, it is assumed that it should be appropriate for CO2 storage. Detail data has often been accumulated during the development process in the past.	Porous and permeable sedimentary rocks that contain salty, non-potable water commonly known as brine. It is widely distributed and theoretically has considerable storage capacity. However, due to lack of survey data, the actual capacity available is unknown.	When CO2 is injected into a non-quarry coal seam in the deep underground, the methane (CBM, Coalbed Methane) adsorbed on the coal is replaced with CO2. The process to capture generated CBM are necessary.
Low Case Assumption	675 Gt-CO2	1,000 Gt-CO2	3-15 Gt-CO2
High Case Assumption	900 Gt-CO2	Unknown (It might be over 10,000Gt-CO2)	200 Gt-CO2
Project Case	Acorn (UK) Moomba (Australia)	Gorgon (Australia) Quest (Canada)	-

Source: Compiled by Industry Research Department Mizuho Bank based on IPCC (2005), IEA (2022), JOGMEC HP, etc.

Storage Potential by Countries



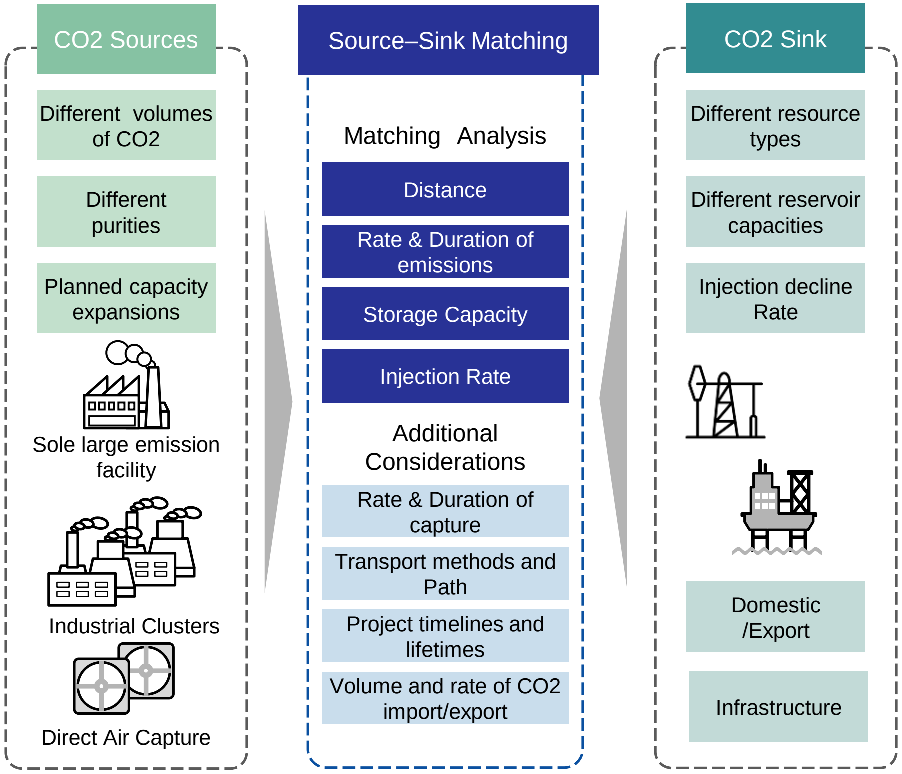
Note: Stored: The quantity of Discovered Storage Resources that has been exploited.
Capacity: Commercial Storage Resources must further satisfy four criteria: The target geologic formation must be discovered and characterized (including containment); it must be possible to inject at the required rates; the development project must be commercial; and the storage resource must remain.
Sub-Commercial : Those quantities of Total Storage Resources estimated to be potentially accessible in known geologic formations, but the applied project(s) are not yet considered mature enough for commercial development.
Undiscovered : The estimated quantity of Total Storage Resources in which the suitability for storage has not been ascertained within the target geologic formation.

Source: Compiled by Industry Research Department Mizuho Bank based on OGCI (2022)

(Ref) Build a CCS value chain

- Matching analysis of CO2 Sources and CO2 Sink (Storage Sites) is necessary for building CCS value chains
  - In the future, 'the aggregator' is expected to optimize the matching process (p.53)
- According to IEA (2023b), there is potential to repurpose oil and gas infrastructure for building the CCS value chain

Source–Sink Matching



Source: Compiled by Industry Research Department Mizuho Bank based on IEA (2022a)

Fossil fuel infrastructure with potential for repurposing for CCS

Infrastructure type	Potential for repurposing	
	CO2	Ref. H2
Pipelines	High	High
Offshore platforms	High	Low
Well infrastructure	Moderate ~ High	-
Natural gas shipping terminals	Low ~ Moderate	Moderate ~ High
Subsea systems	Low ~ Moderate	-
Underground gas storage	-	Moderate ~ High

(Existing and Planned projects to repurpose pipelines to carry CO2)

Project	Pipeline	Country	Original target	Length (km)	Status
Acorn	Goldeneye	UK	Gas	102	In development
Humber Zero	LOGGS 36" trunkline	UK	Gas	118	In development
Cranfield EOR	West Gwinville Pipeline	United States	Gas	80	Operating since 2008
OCAP	OCAP pipeline	Netherlands	Oil	97	Operating since 2005

Source: Compiled by Industry Research Department Mizuho Bank based on IEA (2023b)

Global Major CCS Projects and Development

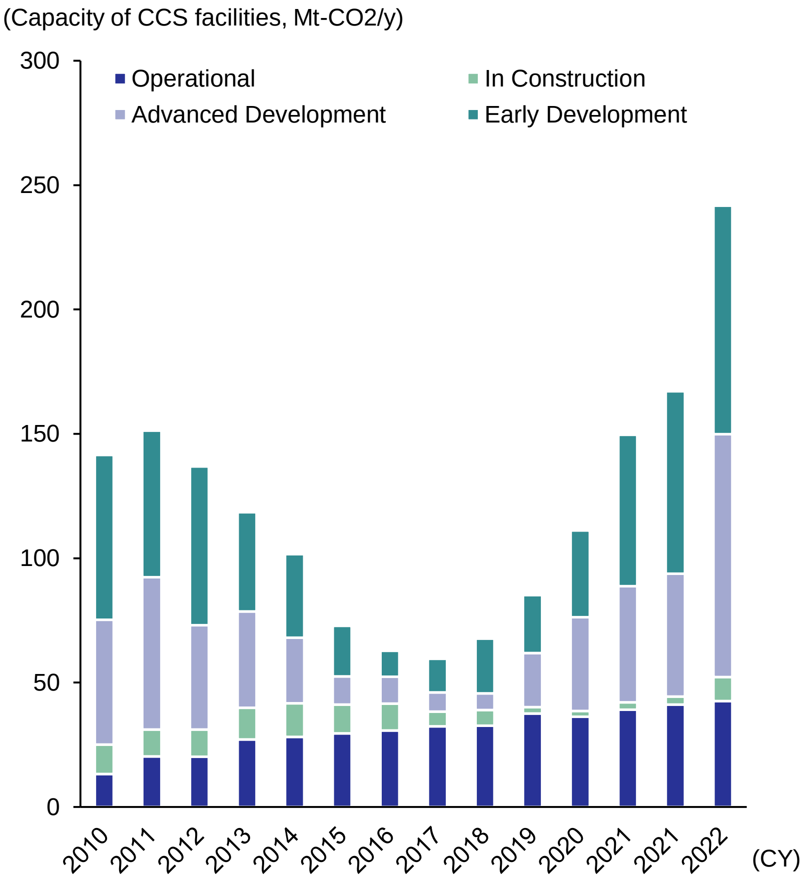
- Since 2017, the number of CCS projects under the development has increased
  - In 2022, the total capture capacity was expanded to 250 million tons, including early development phase

Global Major CCS Projects in Operation

Project name		Country	Project type	Project Capacity Mt-CO2/y	Storage type
1	Shute Creek Gas Processing Plant	USA	Natural Gas	7	EOR
2	Petrobras Santos Basin Pre-Salt Oil Field CCS	Brazil	Natural Gas	7	EOR
3	Century Plant	USA	Natural Gas	5	EOR
4	Gorgon Carbon Dioxide Injection	Australia	Natural Gas	4	Dedicated Storage
5	Great Plains Synfuels Plant And Weyburn-Midale	USA	Synthetic NG	3	EOR
6	Qatar LNG CCS	Qatar	Natural Gas	2.2	Dedicated Storage
7	Alberta Carbon Trunk Line	Canada	Oil Refining	1.6	EOR
8	Quest	Canada	Hydrogen	1.3	Dedicated Storage
9	Sleipner CO2 Storage	Norway	Natural Gas	1.0	Dedicated Storage
10	Air Products Steam Methane Reformer	USA	Ethanol	1.0	Dedicated Storage
(Ref / Direct Air Capture)					
-	ORCA	Iceland	DAC	4 kt	Dedicated Storage

Source: Compiled by Industry Research Department Mizuho Bank based on Global CCS Institute (2022)

CCS Project Development Status



Source: Compiled by Industry Research Department Mizuho Bank based on Global CCS Institute (2022)

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. • 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. • 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. • 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. • 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. • 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.

…

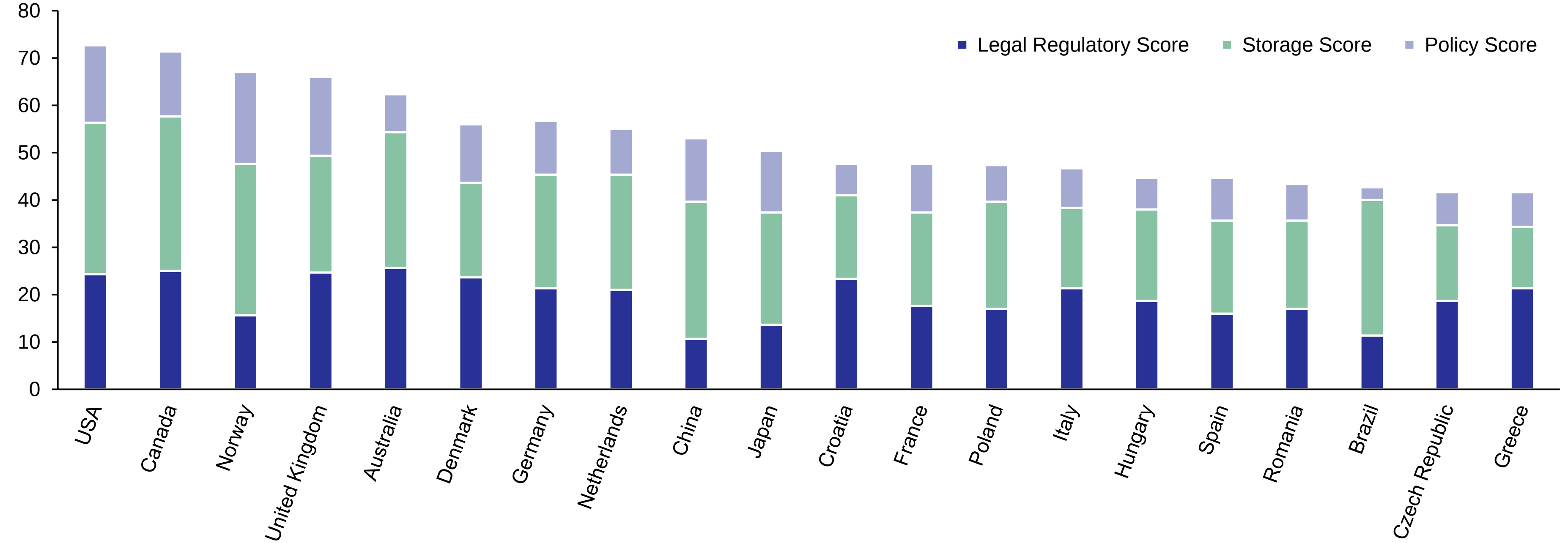
We acknowledge that Carbon Capture, Utilization and Storage (CCUS)/carbon recycling technologies can be an important part of a broad portfolio of decarbonization solutions to reduce emissions from industrial sources that cannot be avoided otherwise and that the deployment of carbon dioxide removal (CDR) 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 based on G7 Hiroshima Leaders' Communiqué

Countries that are active in CCS initiatives

- According to the GCCSI CCS Readiness Index, North America (United States and Canada), Europe (Norway, Denmark, Germany, etc.), the United Kingdom and Australia lead the implementation of CCS.
  - These countries and regions support the implementation of CCS by establishing advanced policy support

The CCS Readiness Index ranking



Note: CCS Readiness Index: The Index tracks a country's requirement for CCS, its policy, law and regulation and storage resources development. Through these indicators, the RI identifies those nations which are leaders in the creation of an enabling environment for the commercial deployment of CCS.

Legal Regulatory Score: The Indicator focuses upon a broad spectrum of administrative and permitting arrangements across the project lifecycle, including issues related to environment assessments, public consultation and long-term liability.

Storage Score: The Index evaluates a country's geological storage potential, maturity of their storage assessments and progress in the development of CO2 injection sites.

Policy Score: The Index tracks a broad spectrum of policies ranging from direct support for CCS to broader implicit climate change and emission reduction policies.

The resulting Index score represents a comprehensive model for tracking progress and opportunities for the development of policies to support CCS deployment.

Source: Compiled by Industry Research Department Mizuho Bank based on Global CCS Institute, *"CCS Readiness Index"*

USA: The IRA has played a leading role in accelerating the development of CCS

- USA is characterized by having vast storage potential and a well-developed infrastructure (e.g. CO2 pipelines)
- Policy support from the Inflation Reduction Act of 2022 (IRA) is expected to drive market expansion and facilitate significant progress in business development

CCS Overview in USA

CCS Readiness Index	Legal Regulatory Score	Storage Score	Policy Score
72 (1st)	73	96	49

Storage potential (Mt)	Undiscovered	7,803,826	Capacity	4
	Sub-Commercial	257,979	Stored	5
CO2 emissions (Mt)	FY2021	4,641	2050e Net Zero	
Major related policies	CCS for Enhanced Oil Recovery (EOR) has been in place since the 1970s, and infrastructure such as CO2 pipelines already exist. IRA to support business expansion by granting Tax Credit (45Q), etc. DOE has set a goal of 450 million tons/year of CO2 capture and storage by 2040.			

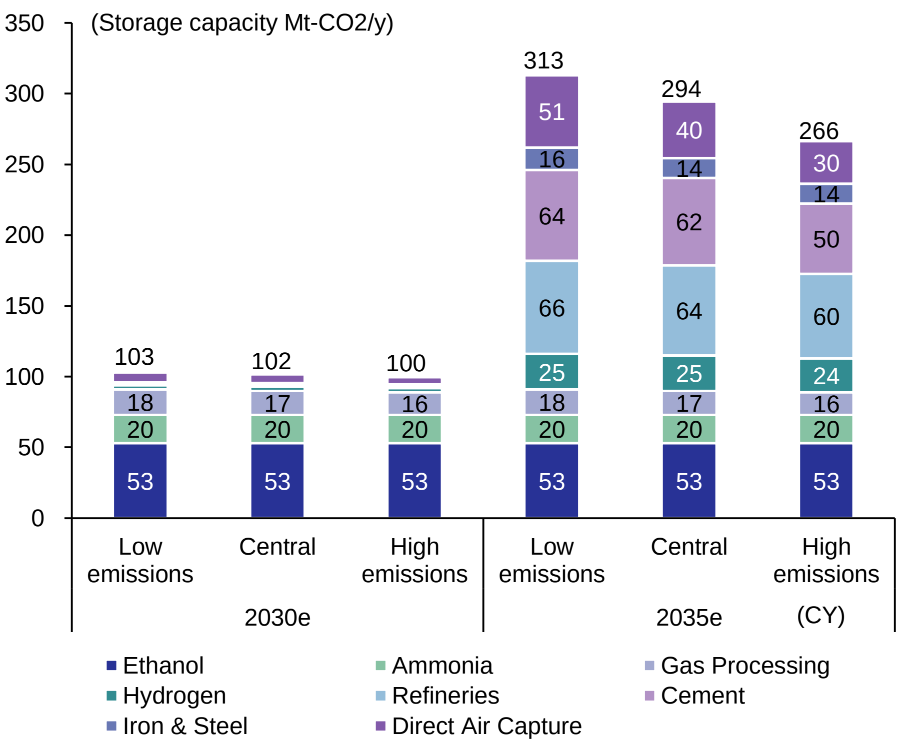
【IRA Tax Credit Overview】

種類	Before IRA introduction (US$/t-CO2)	After IRA introduction (US$/t-CO2)
Storage	42	85
Enhanced Oil Recovery (EOR)	28	60
Storage + Direct Air Capture	-	180
EOR + Direct Air Capture	-	130

Note: Tax Credit requires fulfillment of requirements (1/5 scale if not fulfilled)

Source: Compiled by Industry Research Department Mizuho Bank based on Global CCS Institute, *"CCS Readiness Index"*, OGCI (2022), RITE (2022), etc.

Forecast of CCS business expansion through IRA



Note: Estimated by Rhodium Group based on three EIA scenarios with different CO2 emissions and CCS utilization cases

Source: Compiled by Industry Research Department Mizuho Bank based on Rhodium Group (2022)

Canada: Utilize carbon pricing, carbon credit and support programs

- Canada has the appropriate site and infrastructure for CCS, as well as policy support
  - Incentives driven by credits and subsidies support the establishment of CCS Business Plan

CCS Overview in Canada

CCS Readiness Index	Legal Regulatory Score	Storage Score	Policy Score
71 (2nd)	75	98	41

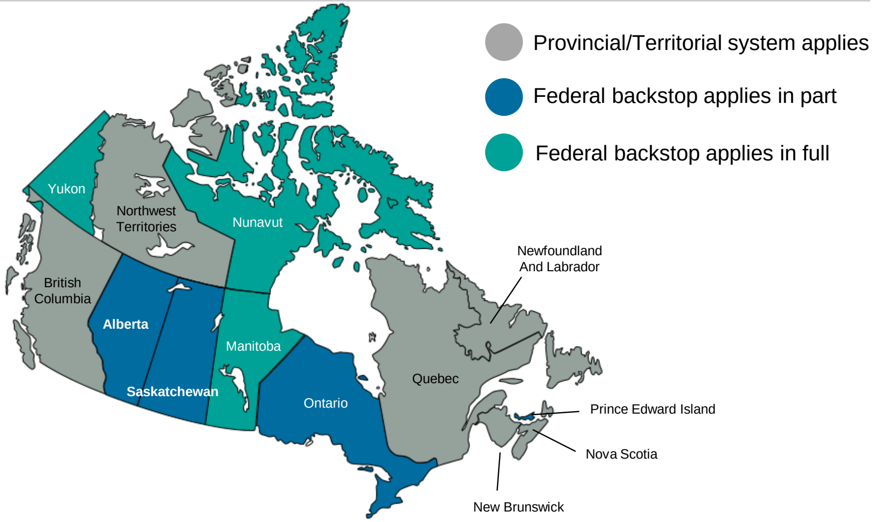
Storage potential (Mt)	Undiscovered	360,270	Capacity	56
	Sub-Commercial	43,641	Stored	5
CO2 emissions (Mt)	FY2021	513	2050e Net Zero	
Major related policies	Domestic policies must be coordinated between the federal government and the provinces. The federal government operates the GGPPA (emissions cap trading and carbon tax for CO2-intensive facilities) as the minimum emission regulation (backstop) in the Canada and automatically applies it if states do not develop equivalent laws. In addition, subsidies for CCS are administered federally and by each province.			

【Major CCS investment support in Alberta (Quest PJ)】

Type	Method	Overview
CAPEX	Direct	2/3 of the direct subsidy is paid for each of the seven stages of the PJ development stage, and the remaining 1/3 is paid when the PJ start operation.
OPEX	Direct	Payable annually subject to fulfillment of requirements
	Carbon Tax Exemption	C$30/t-CO2 (Initially C$15/t-CO2) exemption
	Offset credit	Offset credits equal to the net sequestration amount are granted, and bonus credits of the same amount are granted for deficit years only for a limited period of 10 years

Source: Compiled by Industry Research Department Mizuho Bank based on GCCSI, *"CCS Readiness Index"*, OGCI (2022), RITE (2022)

Status of GGPPA Application in Canada



Typical CCS projects in Western Canada

Boundary Dam	Quest	Alberta Carbon Trunk Line
• PJ for CO2 capture and transport from coal-fired power plants; used for EOR, then permanently stored underground • World's first and only coal-fired power plant integrated CCS	• 1/3 of CO2 from Shell's heavy oil reforming plant is transported and stored permanently underground in a deep saline aquifer. • World's first commercial-scale CCS for oil sands operations	• CO2 capture and transport from refineries and fertilizer plants, used for EOR and then permanently stored underground • World's largest CO2 transport capacity of 14.6 mt/y

Source: Compiled by Industry Research Department Mizuho Bank based on Environment and Climate Change Canada (2022), JOGMEC (2021)

Europe: Promoting flagship PJs through EU-ETS and Government Support

- Europe incentivizes reduction of CO2 emission via EU-ETS and the fund support for decarbonization projects
  - — The EU Innovation Fund will also support CCS and promote its flagship Northern Lights project

CCS Overview in the Europe

Top 3 Countries	CCS Readiness Index	Legal Regulatory Score	Storage Score	Policy Score
Norway	67 (3rd)	47	96	58
Denmark	56 (6th)	71	60	37
Germany	56 (6th)	64	72	34

Storage potential (Total of the 3 countries, Mt)	Undiscovered	39,193	Capacity	37
	Sub-Commercial	56,106	Stored	26
CO2 emissions (Mt)	FY2021	2,632	2050e Net Zero	
Major related policies	In addition to incentives for CO2-intensive industries through the EU-ETS, subsidies of approximately EUR40bn will be provided by 2030 through the EU Innovation Fund, which will be financed by the proceeds from the auction of ETS allowances. Construction and operation of CCS facilities is specified as a target of support.			

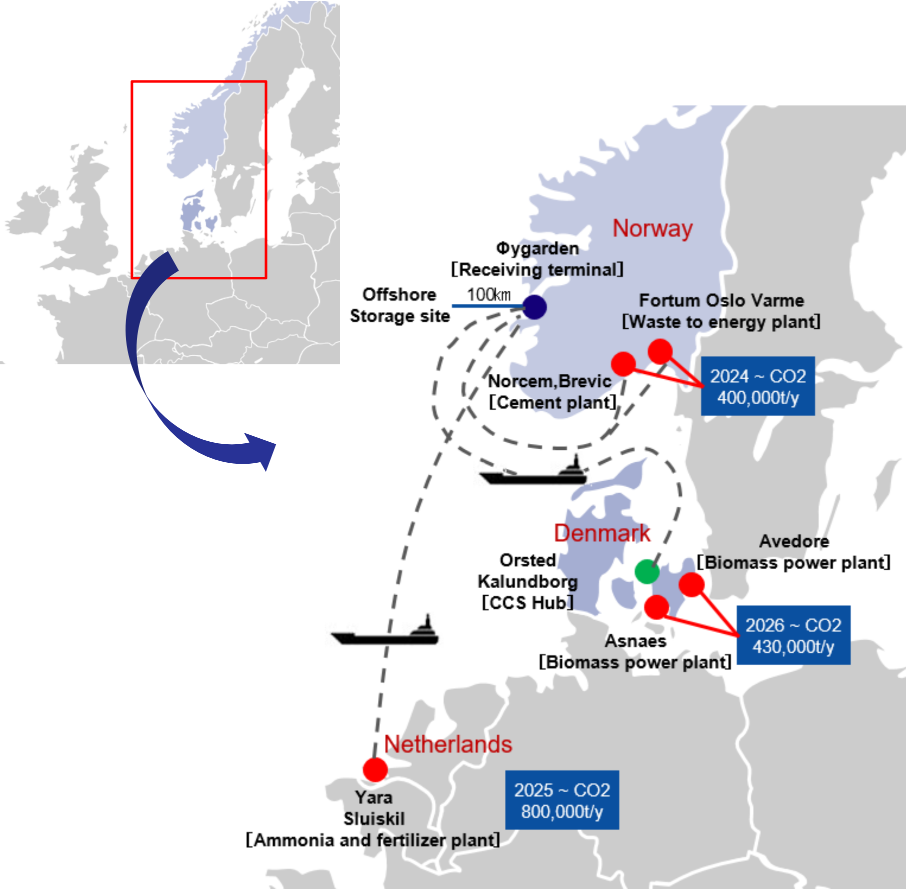
【EU Innovation Fund support for CCS/CCU projects】

Round	Total	Number of Projects	Country
1st (Nov.2021)	EUR 1.1bn	7 (Including 4 CCS PJs)	Finland, Belgium, Sweden, France
2nd (Jul. 2022)	EUR 1.8bn	17 (Including 7 CCS PJs)	Bulgaria, Sweden, France, Germany, Poland, Iceland
3rd (Jul. 2023)	EUR 3.6bn	41 (Including 11 CCS PJs)	Greece, France, Germany, Spain, Belgium, Croatia, Netherlands, etc.

Note: Storage potential is the sum of Norwegian, Swedish, and German figures

Source: Compiled by Industry Research Department Mizuho Bank based on GCCSI *"CCS Readiness Index"*, OGCI (2022), RITE (2022), JOGMEC (2023a), European Commission HP, etc.

Northern Lights CCS Project Overview



Source: Compiled by Industry Research Department Mizuho Bank based on JOGMEC (2023a), Northern Lights HP, etc.

UK: CCUS Cluster Sequencing and CCUS Investment Roadmap

- UK government provides policy support to establish hub & cluster CCUS with CO2-intensive industries
- Announced CCUS roadmap aiming for 20-30 mt-CO2/y by 2030 (6 mt-CO2/y come from industries)

CCS Overview in the UK

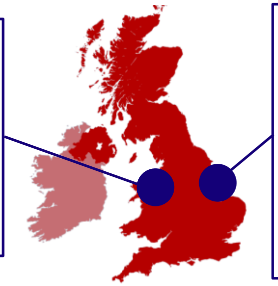
CCS Readiness Index	Legal Regulatory Score	Storage Score	Policy Score
66 (4th)	74	74	50

Storage potential (Mt)	Undiscovered	60,565	Capacity	0
	Sub-Commercial	17,111	Stored	0
CO2 emissions (Mt)	FY2021	325	2050e Net Zero	
Major related policies	The UK has developed support measures aimed at decarbonizing its Industrial Clusters and attracting new low-carbon businesses. CCUS Clusters will be established in four regions by 2030, aiming to capture 20-30 mt-CO2/y. In 2023, the government announced a CCUS Investment Roadmap and other support measures, including a GBP20bn investment in early social implementation of CCS over the next 20 years			

【Track-1 CCUS Clusters】

Hynet North West Cluster

- Hanson Cement plant CCS
- Buxton Lime plant CCS
- Viridor Waste to power plant CCS
- Protos Waste to power plant CCS
- Hynet Hydrogen plant

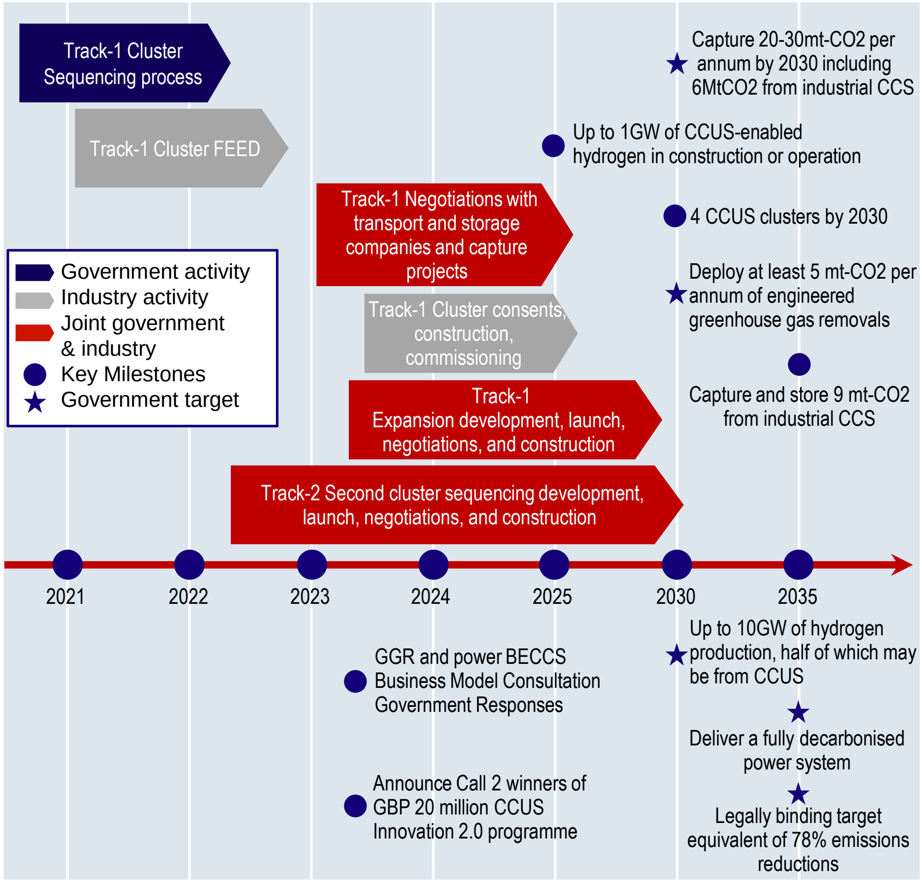


East Coast Cluster

- Net Zero Teesside Power (Large-scale power plant with CO2 capture facility)
- bp H2 Teesside (Blue hydrogen production plants)
- Teesside (CO2 capture hydrogen plants)

Source: Compiled by Industry Research Department Mizuho Bank based on GCCSI *"CCS Readiness Index"*, OGCI (2022), RITE (2022), UK Government Dept. for Energy Security and Net Zero (2023)

UK Government "CCUS Investment Roadmap" (excerpts)



Track-1 Cluster Sequencing process

Track-1 Cluster FEED

Track-1 Negotiations with transport and storage companies and capture projects

Track-1 Cluster consents, construction, commissioning

Track-1 Expansion development, launch, negotiations, and construction

Track-2 Second cluster sequencing development, launch, negotiations, and construction

- ▬ Government activity
- ▬ Industry activity
- ▬ Joint government & industry
- ● Key Milestones
- ★ Government target

★ Capture 20-30mt-CO2 per annum by 2030 including 6MtCO2 from industrial CCS

● Up to 1GW of CCUS-enabled hydrogen in construction or operation

● 4 CCUS clusters by 2030

★ Deploy at least 5 mt-CO2 per annum of engineered greenhouse gas removals

● Capture and store 9 mt-CO2 from industrial CCS

● GGR and power BECCS Business Model Consultation Government Responses

● Announce Call 2 winners of GBP 20 million CCUS Innovation 2.0 programme

★ Up to 10GW of hydrogen production, half of which may be from CCUS

★ Deliver a fully decarbonised power system

★ Legally binding target equivalent of 78% emissions reductions

Source: Compiled by Industry Research Department Mizuho Bank based on UK Government Dept. for Energy Security and Net Zero (2023)

Australia: Leveraging geography advantage for CCS

- Australia has been promoting the development of laws and regulations and the expansion of subsidy programs from the perspective of utilizing the geography advantage for CCS
- Although there is a review of the support structure for CCS after the change of government in May 2022, there are calls for continued and expanded support, particularly from industry
  - CCUS Hubs and Technologies program (A$250 million CCUS support) in the 2022 and 2023 budgets has been withdrawn, but a CO2 capture technology support (A$140 million) has been announced in its place
  - In September 2023, based on requests from industry, the government announced its intention to include all CO2 emission reduction technologies, including CCS, in the National Recovery Fund (A$15bn)

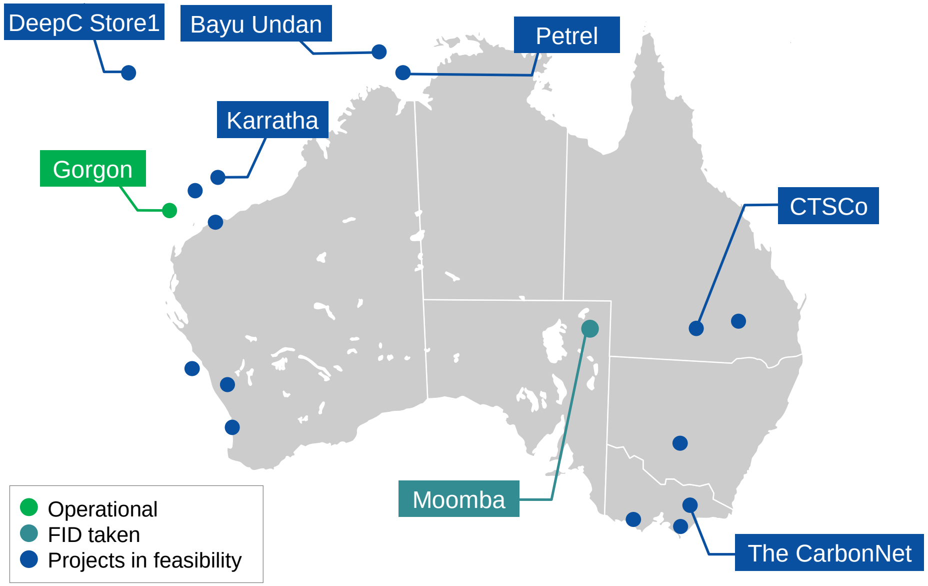
CCS Overview in the Australia

CCS Readiness Index	Legal Regulatory Score	Storage Score	Policy Score
62 (5th)	77	86	24

Storage potential (Mt)	Undiscovered	471	Capacity	0
	Sub-Commercial	31	Stored	0
CO2 emissions (Mt)	FY2021	365	2050e Net Zero	
Major related policies	The Conservative Coalition government has previously positioned CCS as a "necessary tool to achieve the Net Zero goal" and announced a A$250 million grant for CCS/CCUS PJs. However, the Labor Party, which took power in May 2022, withdraw this subsidy in its budget proposal for FY2022/2023. It announced a new grant of A$140 million to support CO2 capture technologies. In addition, the need to introduce CCS in new gas field projects has increased due to the lowering of emission limits under the revised Safeguard Mechanism			

Source: Compiled by Industry Research Department Mizuho Bank based on GCCSI *"CCS Readiness Index",* OGCI (2022), RITE (2022), JETRO (2023)

Major CCUS Projects



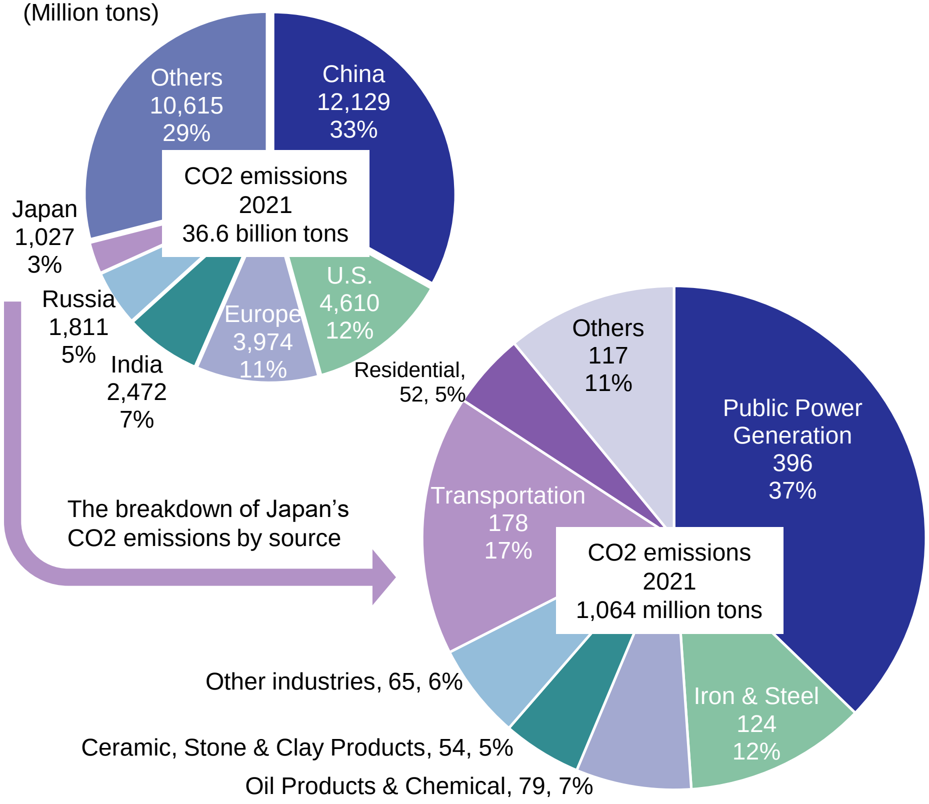
Source: Compiled by Industry Research Department Mizuho Bank based on CO2CRC HP, etc.

2. CCS Value Chain in Japan

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

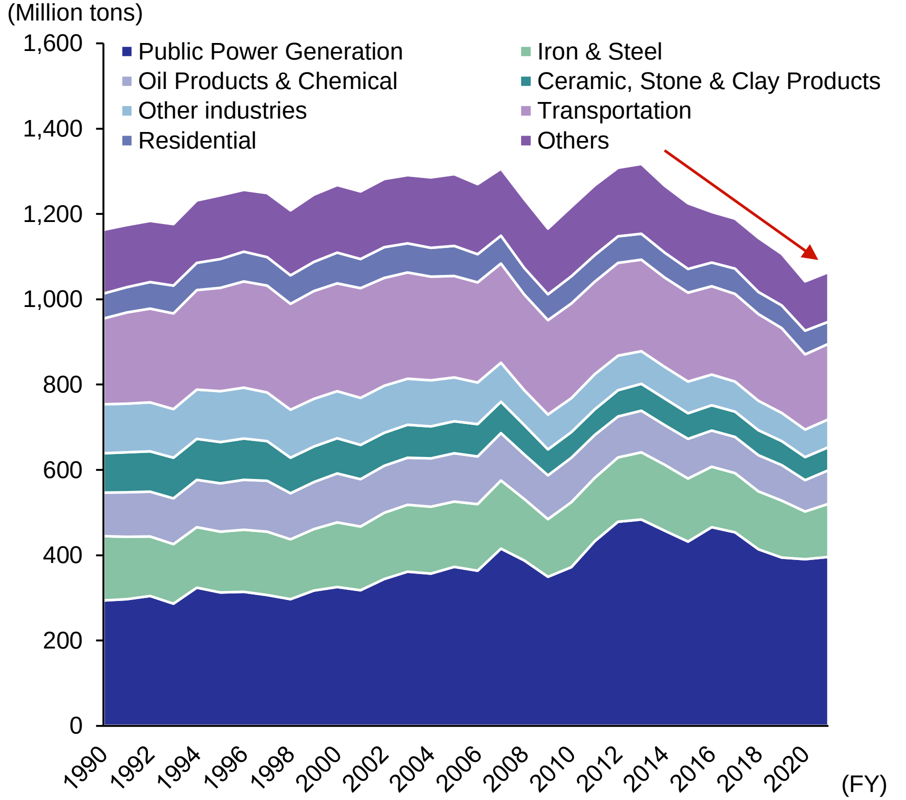
Breakdown of CO2 Emissions in Japan



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 based on IEA (2022b), National Institute for Environmental Studies (2023)

Trends of CO2 Emissions in Japan



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

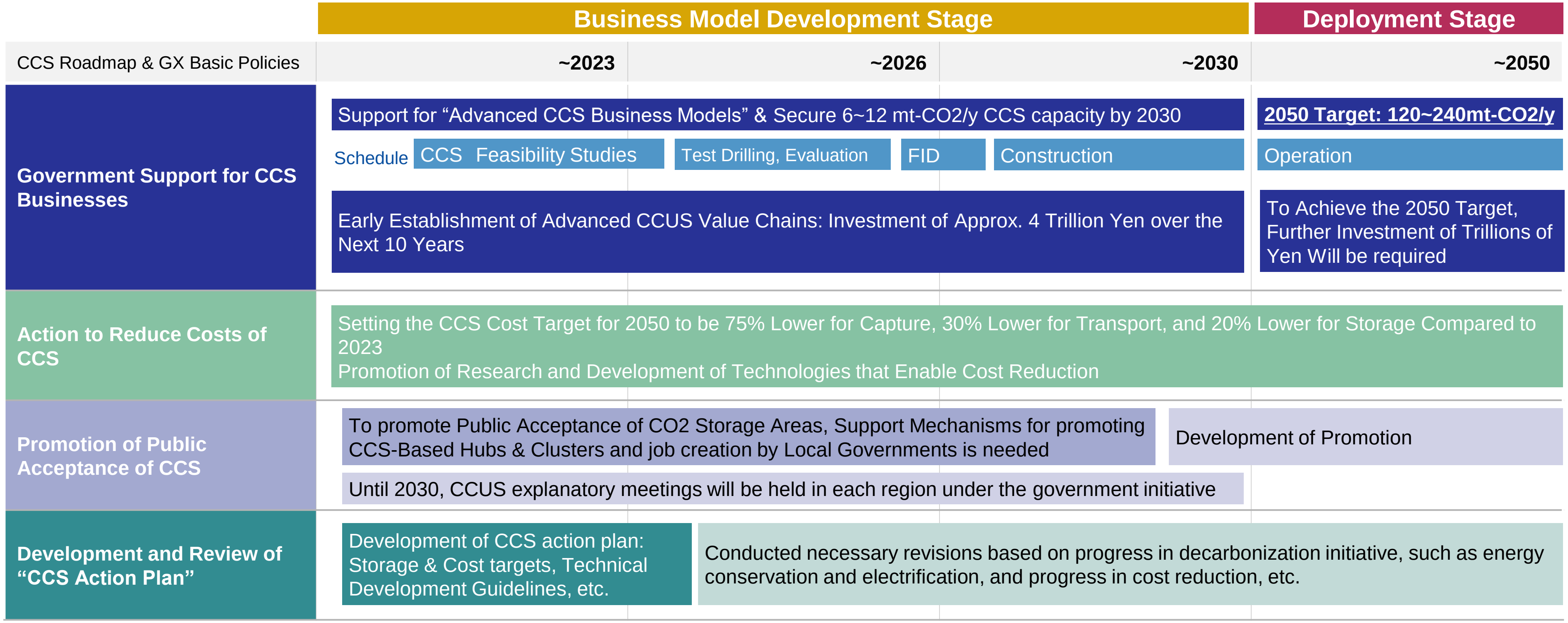
Source: Compiled by Industry Research Department Mizuho Bank based on National Institute for Environmental Studies (2023)

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

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 based on ANRE (2023c)

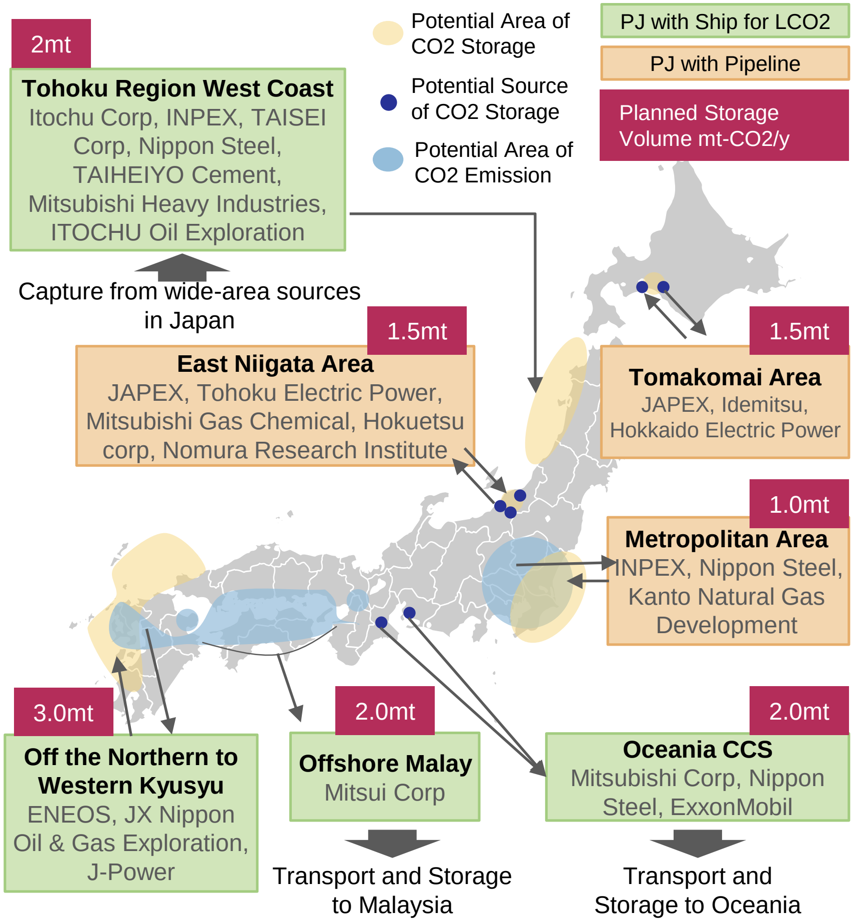
“Advanced CCS Business Models” in Japan

- The total storage volumes of the 7PJs selected for the “Advanced CCS” in FY2023 was approx. 13 mt-CO2/y
  - 5 PJs (Planned to CCS in Japan) are planned to be 9 mt-CO2/y with expansion plans to be 30 mt-CO2/y

Project Selection Criteria for “Advanced CCS Business Models” and Support in FY2023

Project Selection Criteria for “Advanced CCS Business Models”		
Projects that plan to scale up and reduce costs significantly through the clustering of CO2 sources and the establishment of hubs in CO2 storage sites in 2050		
Conditions		
1	Operation start by 2030 and at least 0.5mt-CO2/y at the start	
2	PJ which has the business plan that covers CCS value chain (capture, transportation, and storage), and has any of the following characteristics	
	CO2 source	Capture **from multiple industries** (Power, Oil, Steel, Chemicals, Paper, Cements, etc.) or **from Decarbonized Fuels** (Blue Ammonia or Hydrogen)
	Transport	Pipelines or Ship for Liquefied CO2 (LCO2)
	Storage	Onshore or Offshore
Criteria		
Early feasibility	Validity of Project, Schedule, and understanding from storage area	
Scalability	Plan to develop capture, transport and storage volumes with cost reductions	
Economics	Projected cost per t-CO2 and future profitability business plan	
Influence	Publicity activities, sharing of knowledge and contribution to local communities	

Support in FY2023 from JOGMEC	
Support started from 3~5 PJs with different combinations of CO2 sources, transport, and storage areas, aiming to secure 6~12mt-CO2/y by 2030	
Budget	3.5 billion Yen
Support For	Preliminary investigation of storage sites for CCS commercialization, preliminary study on engineering, Technical examination and various preparatory works for selection of prospecting positions



Potential Area of CO2 Storage

● Potential Source of CO2 Storage

Potential Area of CO2 Emission

PJ with Ship for LCO2

PJ with Pipeline

Planned Storage Volume mt-CO2/y

2mt
Tohoku Region West Coast
Itochu Corp, INPEX, TAISEI Corp, Nippon Steel, TAIHEIYO Cement, Mitsubishi Heavy Industries, ITOCHU Oil Exploration

Capture from wide-area sources in Japan

1.5mt
East Niigata Area
JAPEX, Tohoku Electric Power, Mitsubishi Gas Chemical, Hokuetsu corp, Nomura Research Institute

1.5mt
Tomakomai Area
JAPEX, Idemitsu, Hokkaido Electric Power

1.0mt
Metropolitan Area
INPEX, Nippon Steel, Kanto Natural Gas Development

3.0mt
Off the Northern to Western Kyusyu
ENEOS, JX Nippon Oil & Gas Exploration, J-Power

2.0mt
Offshore Malay
Mitsui Corp

Transport and Storage to Malaysia

2.0mt
Oceania CCS
Mitsubishi Corp, Nippon Steel, ExxonMobil

Transport and Storage to Oceania

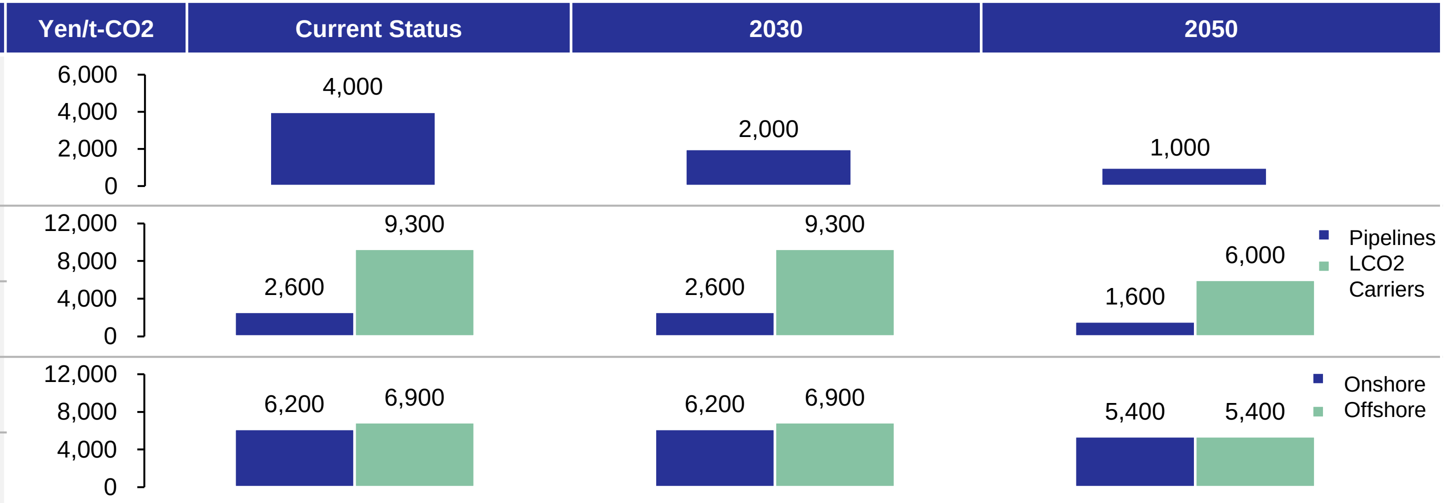
Source: Compiled by Industry Research Department Mizuho Bank based on ANRE (2023b, 2023c), etc.

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

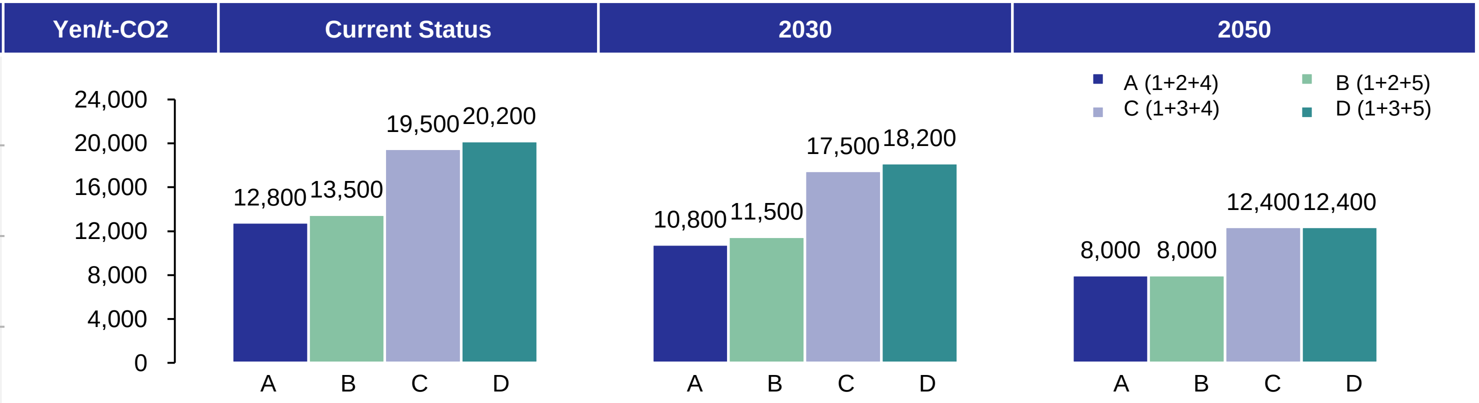
- Aim to reduce costs of CCS at least 40% by accumulating cost reductions in Capture, Transport and Storage

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

CCS Value Chain	
1	CO2 Capture
2	Pipelines Transport (20km)
3	LCO2 Carrier Transport (1,100km)
4	Onshore Storage
5	Offshore Storage



Total Cost of CCS		
A	Pipelines + Onshore	1 + 2 + 4
B	Pipelines + Offshore	1 + 2 + 5
C	LCO2 Carriers + Onshore	1 + 3 + 4
D	LCO2 Carriers + Offshore	1 + 3 + 5



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 based on ANRE (2023c)

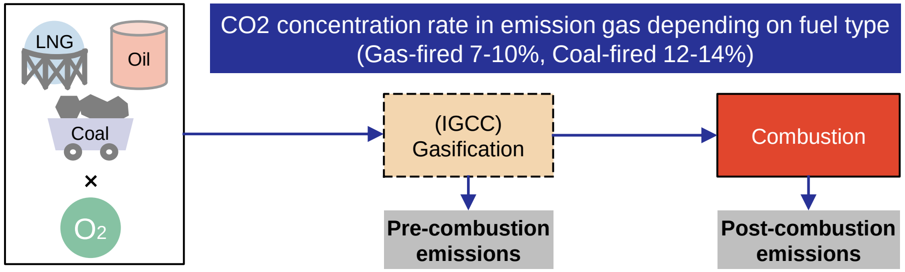
【Emitter】Current Status of Power Sector in CCS

- 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 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



CO2 concentration rate in emission gas depending on fuel type (Gas-fired 7-10%, Coal-fired 12-14%)

(IGCC) Gasification

Combustion

Pre-combustion emissions

Post-combustion emissions

Source: Compiled by Industry Research Department Mizuho Bank based on IPCC (2005), NEDO (2020), METI (2021), ANRE (2021･2022a), NIES (2023), 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)

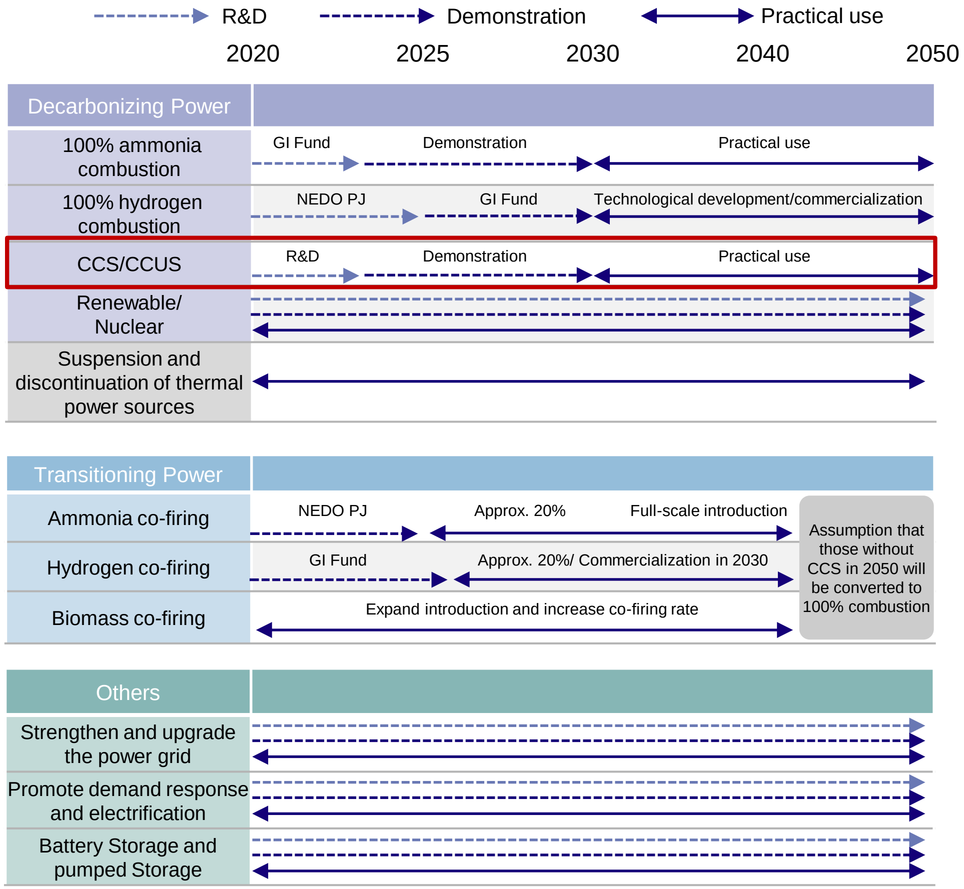
- ✓ In promoting technological development of capture, **financial support is needed for progress under the leadership of the government**
  - ➢ There are issues in determining the feasibility and cost reduction of each CO2 capture method
  - ➢ At present, there is a high degree of uncertainty regarding 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 based on FEPC (2022), and ANRE (2023c)

【Emitter】Transition Roadmap and location of major facilities in the power sector

- On the transition roadmap, CCS/CCUS is planned to be established after 2030
  - — Reduce CO2 emissions from power plants by utilizing both CCS/CCUS and hydrogen/ammonia

Transition roadmap for decarbonizing the power sector



R&D
Demonstration
Practical use

2020 2025 2030 2040 2050

Decarbonizing Power

100% ammonia combustion: GI Fund, Demonstration, Practical use

100% hydrogen combustion: NEDO PJ, GI Fund, Technological development/commercialization

CCS/CCUS: R&D, Demonstration, Practical use

Renewable/ Nuclear

Suspension and discontinuation of thermal power sources

Transitioning Power

Ammonia co-firing: NEDO PJ, Approx. 20%, Full-scale introduction

Hydrogen co-firing: GI Fund, Approx. 20%/ Commercialization in 2030

Biomass co-firing: Expand introduction and increase co-firing rate

Assumption that those without CCS in 2050 will be converted to 100% combustion

Others

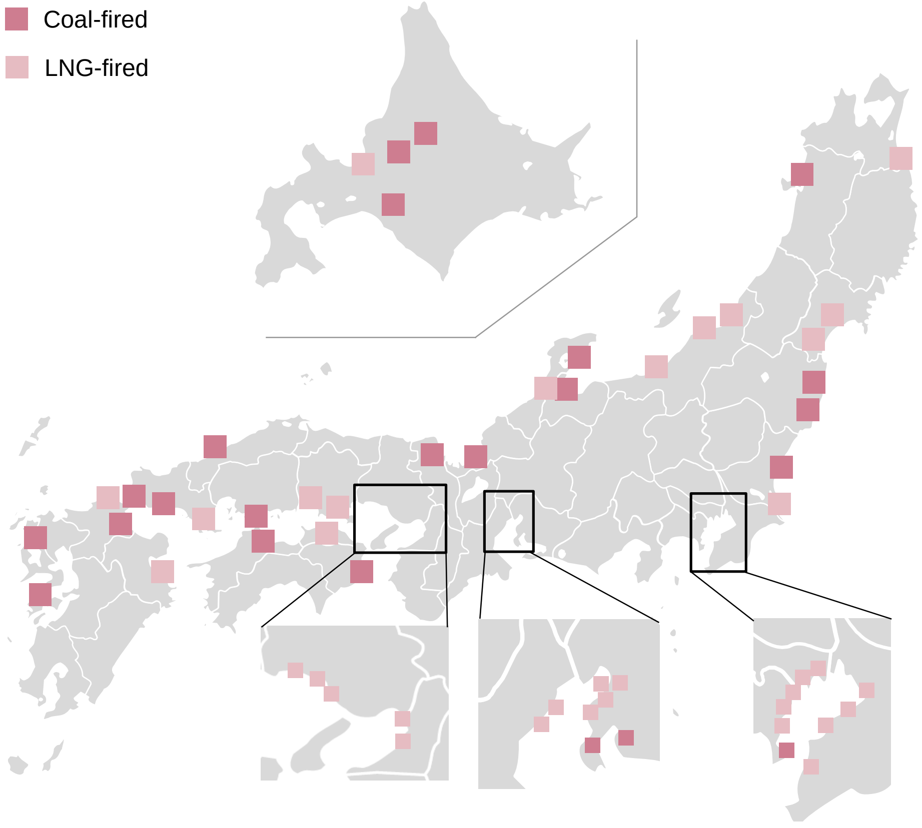
Strengthen and upgrade the power grid

Promote demand response and electrification

Battery Storage and pumped Storage

Note: All co-firing rates are on a calorific value basis.
Source: Compiled by Industry Research Department Mizuho Bank based on ANRE (2022d)

Location of LNG/coal-fired power plants



Note: Some plants are mixed with oil-fired power generation facilities
Source: Compiled by Industry Research Department Mizuho Bank based on various public materials

【Emitter】Current Status of Steel & Iron Sector in CCS

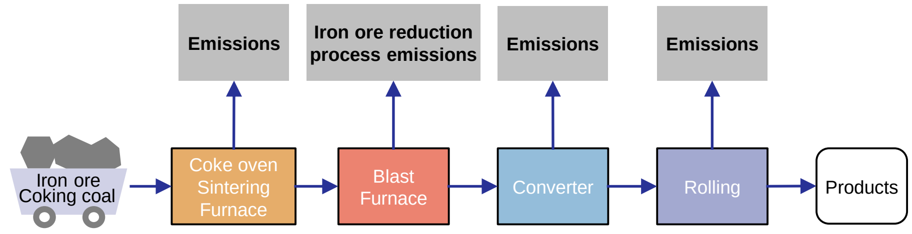
- Steel & Iron sector positions CCS as one of the measure to reduce CO2 emissions, and requests social infrastructure support to reduce process CO2 emissions and achieve zero-carbon steel production

Emission CO2 characteristics in the Steel & Iron Sector

Characteristics	Overview
CO2 emissions (Mt)	FY2021: 124 (12% of total domestic emissions)
Combustion CO2 / Process CO2	Mainly process CO2 emissions during reduction process and fuel combustion in blast furnaces
Emissions per product	Approximately 2 tons of CO2 emissions per ton of steel production
CO2 concentration / pressure	Blast furnace gas ① 20% / 0.2~0.3MPa
	Blast furnace gas ② 27% / 0.1MPa
CO2 capture method	The chemical absorption method developed in CORSE50 is the mainstream. Physical adsorption PJ is R&D stage

CO2 emission flow in the Steel & Iron Sector

Each process emits CO2, but most of the emissions are from the blast furnace during iron ore reduction process (Concentration is as high as 20%-27%)



Source: Compiled by Industry Research Department Mizuho Bank based on IPCC (2005),NEDO (2020), METI (2021), ANRE (2021･2022a) and NIES (2023), etc.

Major CCS Project and policy proposal from the Steel & Iron Sector

Case	Initiatives
Participation in Advanced CCS Projects, etc.	In the "Advanced CCS Project," Nippon Steel is participating in the Tohoku Region West Coast CCS, Metropolitan Are CCS, and Oceania CCS consortiums.
Other CCS related Initiatives	Joint study on development of chemical absorption and physical adsorption methods in CO2 Ultimate Reduction System for Cool Earth 50 (COURSE50)

【February 2022: Summary of recommendations by the CCS Long-Term Roadmap Study Group】

JISF "The Challenge of Zero Carbon Steel" Summary

(JISF has identified the following challenges to achieving zero carbon steel)

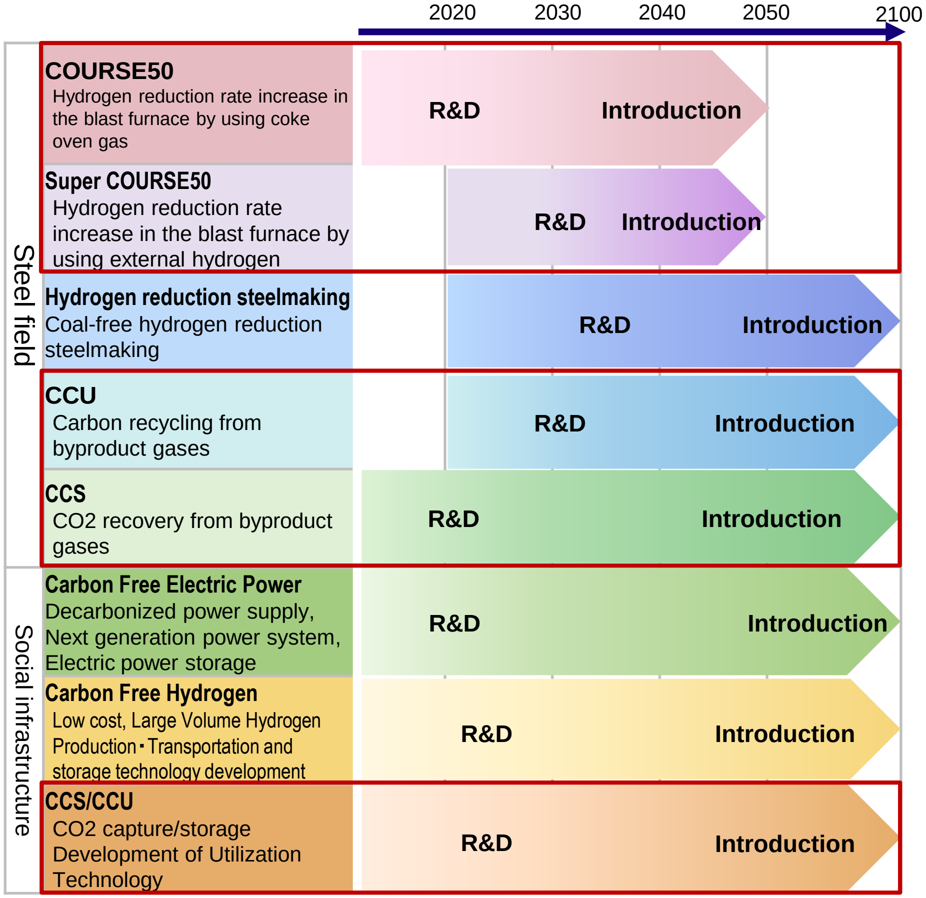
- ✓ Innovative technology development
  - ➢ Commercial-scale realization of Hydrogen-reduced steelmaking
- ✓ Social infrastructure development
  - ➢ Large volume Clean hydrogen/ammonia resource development and supply chain establishment
  - ➢ **Solving technical and social science issues and developing legislation to realize commercial-scale CCS**
  - ➢ Stable supply of large volume of carbon-free electricity
- ✓ Equipment transformation
  - ➢ Transformation of steelmaking to innovative processes, securing funding (hundreds of billions to trillions of yen level)
  - ➢ Existing processes become stranded assets (extraordinary losses in the hundreds of billions to trillions of yen)
- ✓ Cost sharing rules
  - ➢ Capital investment that neither improves product performance nor production efficiency
  - ➢ Production costs associated with the use of high-cost utilities and raw materials
- ✓ Business environment
  - ➢ Level of development, production activities, and capital investment that can be sustained

Source: Compiled by Industry Research Department Mizuho Bank based on JISF(2022), ANRE (2023c)

【Emitter】Transition roadmap and location of major facilities in the steel sector

- ■ Effective use of CCS/CCU is required due to the long time horizon of Hydrogen-reduced steelmaking
- ■ Most steel mills are located in waterfront areas and are suitable for shipping to CCS storage site

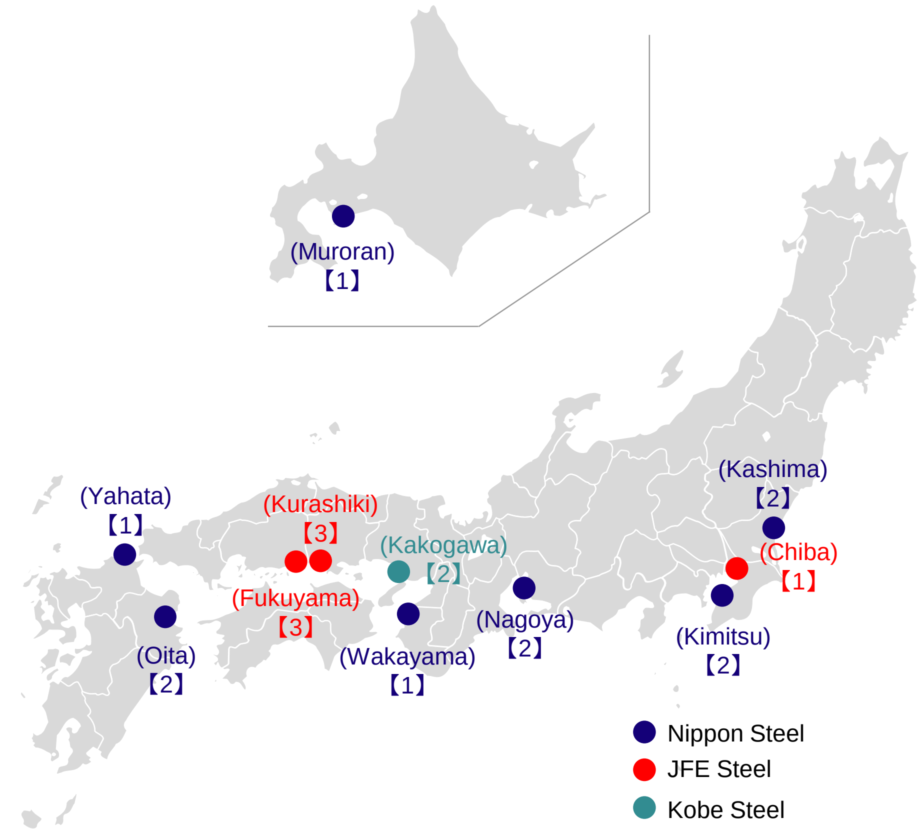
Transition roadmap for decarbonizing the steel sector



Steel field	**COURSE50** Hydrogen reduction rate increase in the blast furnace by using coke oven gas	R&D	Introduction
	Super COURSE50 Hydrogen reduction rate increase in the blast furnace by using external hydrogen	R&D	Introduction
	Hydrogen reduction steelmaking Coal-free hydrogen reduction steelmaking	R&D	Introduction
	CCU Carbon recycling from byproduct gases	R&D	Introduction
	CCS CO2 recovery from byproduct gases	R&D	Introduction
Social infrastructure	**Carbon Free Electric Power** Decarbonized power supply, Next generation power system, Electric power storage	R&D	Introduction
	Carbon Free Hydrogen Low cost, Large Volume Hydrogen Production・Transportation and storage technology development	R&D	Introduction
	CCS/CCU CO2 capture/storage Development of Utilization Technology	R&D	Introduction

Source: Compiled by Industry Research Department Mizuho Bank based on JISF (2022)

Location of major steel mills



Note: Figures in【】are the number of blast furnaces
Source: Compiled by Industry Research Department Mizuho Bank based on Japan Metal Dairy (2022)

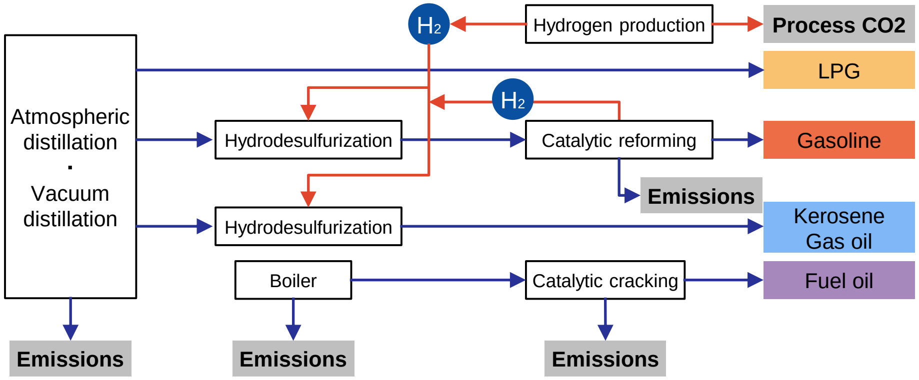
【Emitter】Current Status of Oil Sector in CCS

- Oil sector proactively moves to CCS as a measure of reducing CO2 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 Combustion CO2: Chemical absorption

CO2 emission flow in the oil sector



Source: Compiled by Industry Research Department Mizuho Bank based on IPCC (2005), NEDO (2020), METI (2021), ANRE (2021・2022a), NIES (2023), 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)

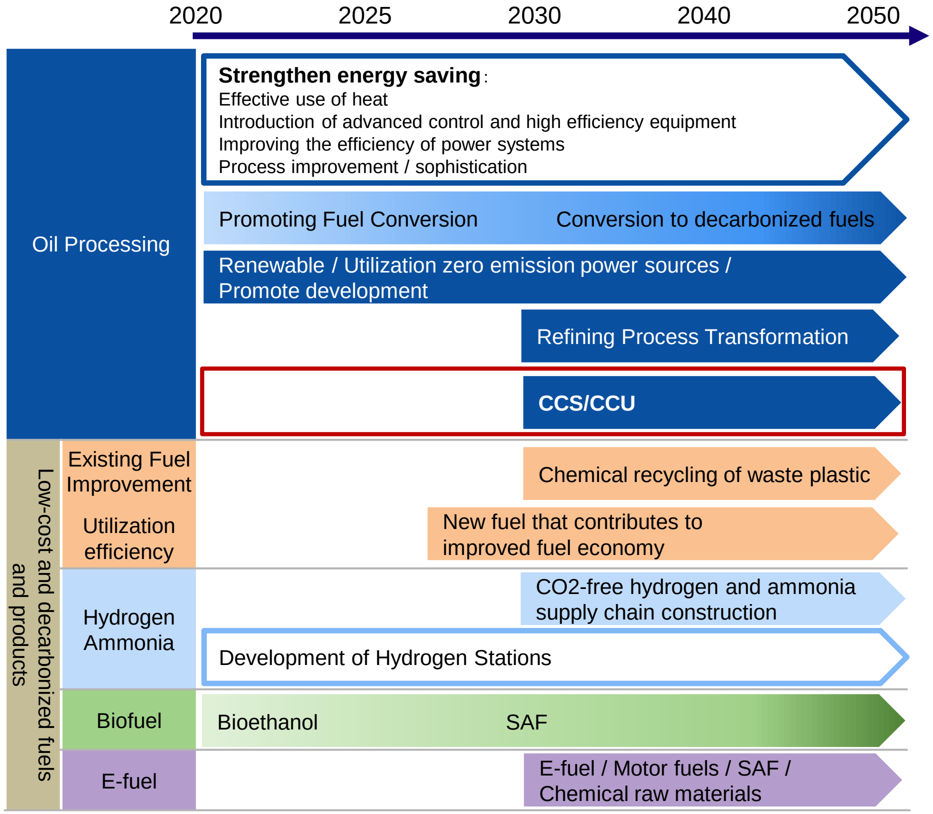
- ✓ Promote R&D, demonstration, and cost reduction related to CO2 capture and storage technologies
- ✓ Promotion of public understanding and development of suitable sites
- ✓ Legislation adapted to the life cycle of CCS
- ✓ Consideration and introduction of long-term support for CCS implementation
- ✓ 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 based on PAJ (2022), ANRE (2023c)

【Emitter】Transition roadmap and location of major facilities in the oil sector

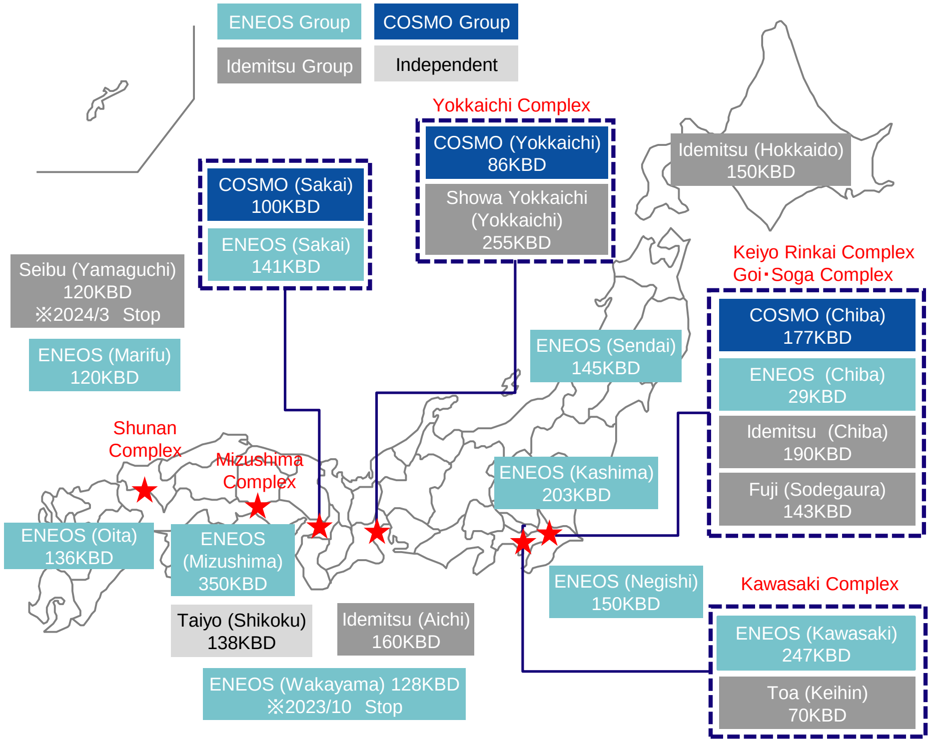
- The roadmap specifies the use of CCS/CCU after 2030 as one of the measures in the oil processing process
- Many of the industrial complexes in the area where the refineries located are moving toward carbon neutral
  - — Possibility of considering hub and cluster CCS with CO2 emissions from surrounding facilities

Transition roadmap for decarbonizing the oil sector



Source: Compiled by Industry Research Department Mizuho Bank based on ANRE(2022e)

Location of refineries and carbon-neutral complexes



Note: KBD：Crude oil throughput per day, kilo barrel per day
Red figures indicate industrial complexes with ethylene plants

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

【Emitter】Current Status of Cement Sector in CCS

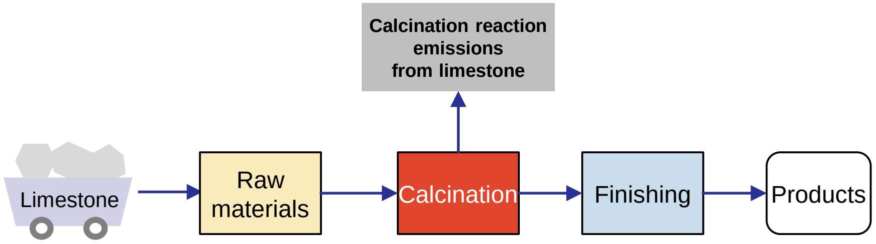
- Cement Sector recognizes CCUS as an important technology to reduce process CO2 emissions from limestone
  - Support is needed to address the deteriorating competitive environment with import products

Emission CO2 characteristics in the cement sector

Characteristics	Overview
CO2 emissions (Mt)	FY2021: 54(Ceramic, Soil and Stone Products together account for 5% of the total)
Combustion CO2 / Process CO2	Process CO2 emissions from calcination (from limestone, about 60%) and fuel combustion CO2 emissions (about 40%) are the main sources
Emissions per product	763 kg CO2 emissions per ton of cement
CO2 concentration / pressure	Cement kiln off-gas 14~33% / 0.1MPa
CO2 capture method	Chemical absorption is the mainstream

CO2 emission flow in the cement industry

About 60% of the CO2 in cement production comes from limestone (process CO2). The remaining 40% comes from energy



Source: Compiled by Industry Research Department Mizuho Bank based on IPCC (2005), NEDO (2020), METI (2021), ANRE (2021･2022a), NIES (2023), JCA (2022), etc.

Major CCS Project and policy proposal from the cement sector

Case	Initiatives
Participation in Advanced CCS Projects, etc.	In the "Advanced CCS Project," Taiheiyo Cement participates in the Tohoku Region CCS on the Sea of Japan side.
Other CCS related Initiatives	Joint demonstration of CO2 emission capture technology during cement production by Tokuyama and MHI Engineering, basic research at the GI Fund, and other CCS technology development initiatives

【February 2022：Summary of Recommendations by the CCS Long-Term Roadmap Study Group】

JCA "CCUS Policy on the Use of CCUS to Help the Cement Industry Become Carbon Neutral by 2050" Summary

(Recognizes that a significant portion of achieving carbon neutrality in 2050 will require relying on CCUS. The following requests are presented)

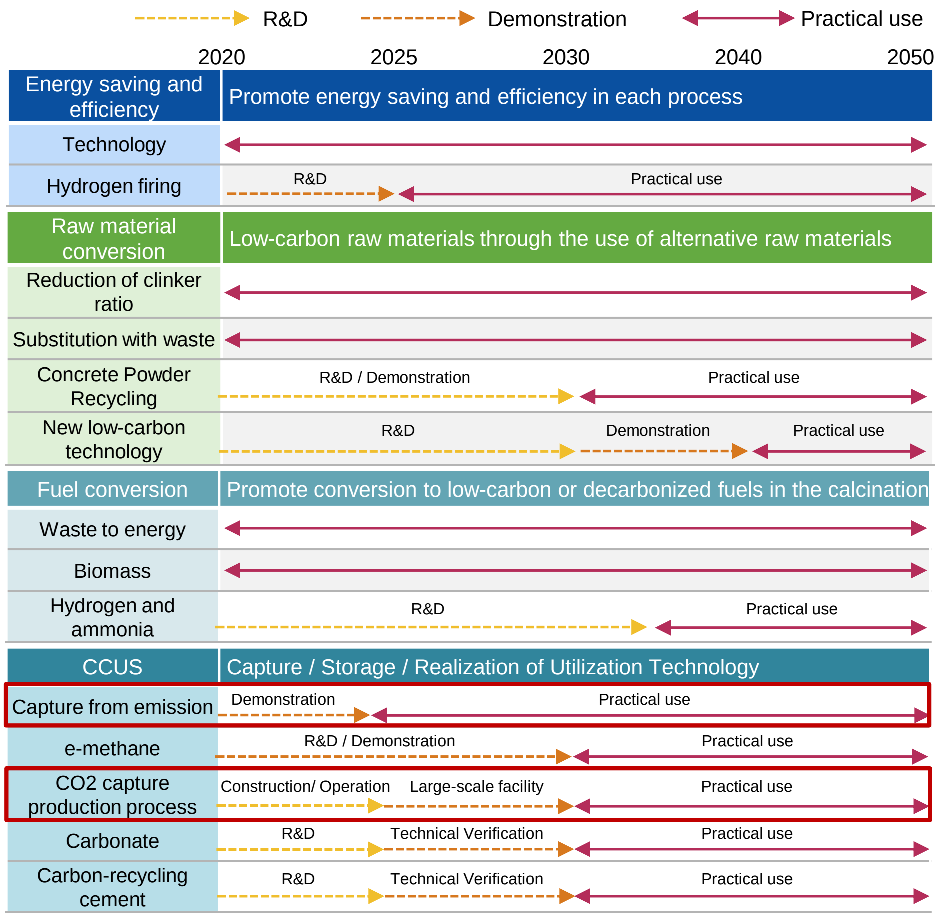
- ✓ Further government support is requested for the implementation of the system, as it needs to be adapted to the characteristics of the emission gas industry.
- ✓ Support for mechanisms that enable effective utilization of storage, methanation, etc., and transportation (e.g., priority allocation, subsidized transportation costs to CCS collection points outside of Japan, etc.)
- ✓ Clarification of acceptance criteria (e.g., concentration) at CCS collection point
- ✓ Support for cement plants located in inland areas, etc. (study of relay points between inland areas and CO2 shipping facilities, temporary storage facilities)
- ✓ Support response to reduced corporate competitiveness due to cost burden from CCS implementation and price competition with import products

Source: Compiled by Industry Research Department Mizuho Bank based on JCA (2022), ANRE (2023c)

【Emitter】Transition roadmap and location of major facilities in the cement sector

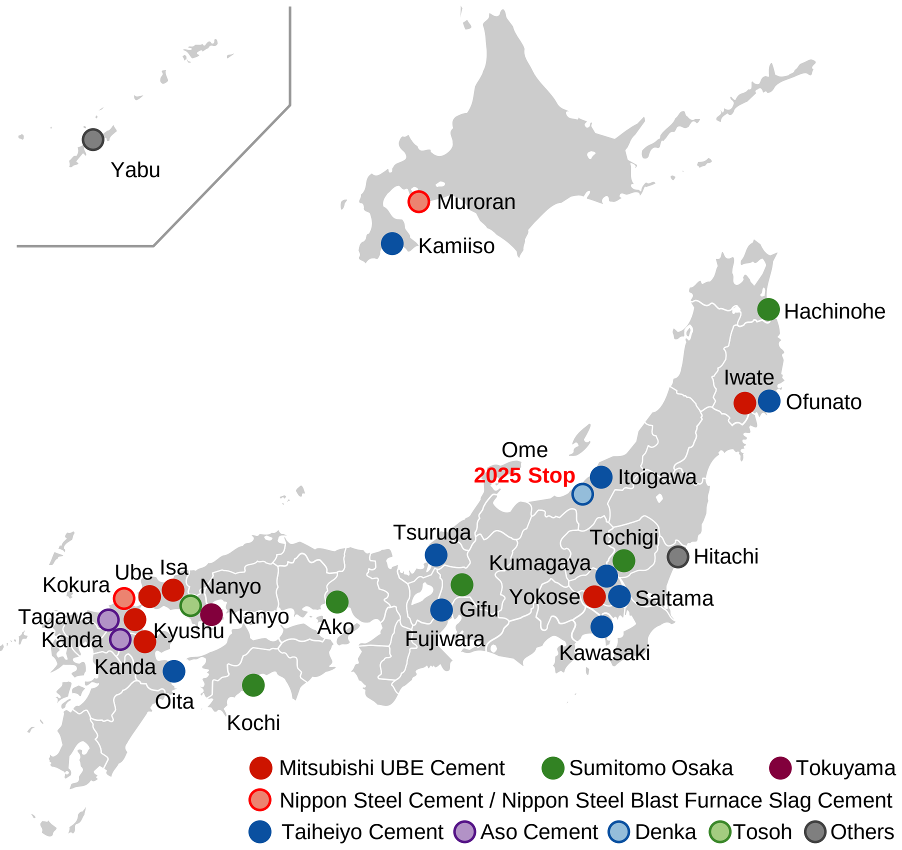
- CO2 capture from emissions to be practical in 2025, and CO2 capture production process in 2030
- Plants are also located inland and need to consider connecting to the CCS value chain or utilizing CCU

Transition roadmap for decarbonizing the cement sector



Source: Compiled by Industry Research Department Mizuho Bank based on ANRE (2022f)

Location of major cement plants



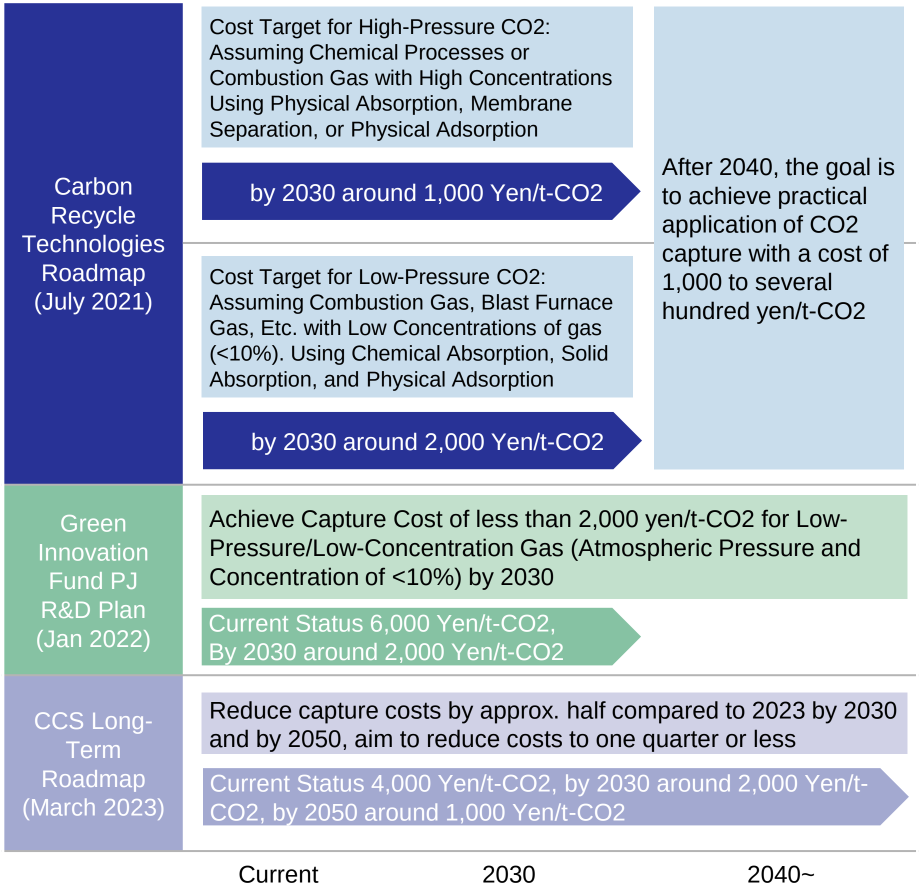
Note: As of April 2023

Source: Compiled by Industry Research Department Mizuho Bank based on JCA (2022), and various public materials

【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



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

by 2030 around 1,000 Yen/t-CO2

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

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

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

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 based on METI (2021, 2022), and ANRE (2023c)

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
	To Address the Technical Challenge: 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.
	To Address the Technical Challenge: To solve these challenges, the following strategies can be pursued: Amine absorption: Develop new solid materials that can absorb CO2 by reducing water enthalpy or latent and sensible heat. Physical Adsorption: Develop phase change materials that can be regenerated by pressure difference rather than heat. 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
	To Address the Technical Challenge: 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 based on METI (2022)

【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】 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 • Technology innovations for novel capture technologies • Learning by doing • Modularization and standardization	• Siting close to reservoirs to minimize distance • Economies of scale (e.g., increasing diameter and added compression) • Aggregation of various CO2 sources in a hub • Utilization of existing right-of ways	【Mizuho's View】 • Large-scale development, R&D and innovation of LCO2 Carriers • Standardization	• Siting on well-characterized site with existing infrastructure and good monitorability • Economies of scale, leveraging large reservoir capacities • Reduction of MMV (Measurement, Monitoring and Verification) costs by R&D and learning by doing

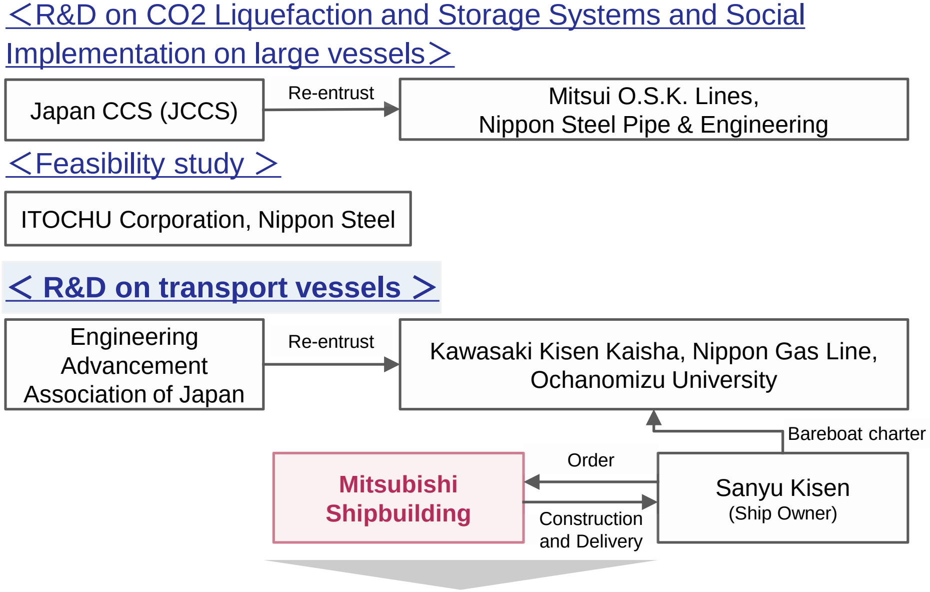
Source: Compiled by Industry Research Department Mizuho Bank based on U.S. Department of Energy (2023), etc.

【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

Mitsubishi Shipbuilding

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 based on NEDO, etc.

Direction of Development of LCO2 carriers by Mitsubishi Shipbuilding

	Initiatives to develop LCO2 carriers
①	**Development and commercialization of the first ship** — Development of First Ship for NEDO Demonstration
②	**Collaboration with global players to develop LCO2 carriers** — 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** — Aim to promote develop small to large vessels through joint development with NYK — 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** — 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 based on 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	2022	2023	2024	2025	2026
Mitsubishi Shipbuilding (Japan)	Sanyu Kisen (Japan)	1,450	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			Jul. 2023 →	→	→	Apr. 2026

small → large: 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. ✓ 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 based on 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 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 Mizuho Bank

【CO2 Storage】Promoting CCS in Japan and Asia

- To secure CO2 storage capacity, cooperation with Asia-Pacific region is important for Japan
  - It is required to establish the harmonized CCS systems and frameworks between Japan and Asia

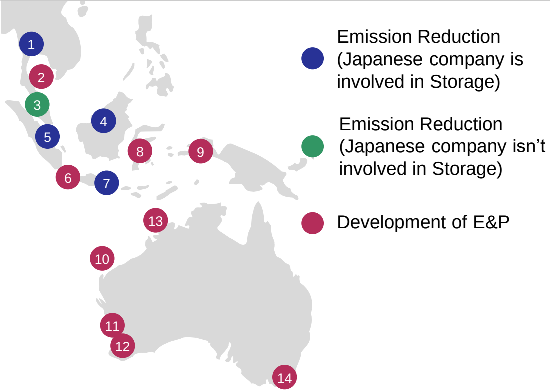
Key Milestones of Asia CCSUS Network

2020 ～ 2025	**Establish network and develop the CCUS** Training, information sharing, project promotion, Review regional potential and create roadmaps
2025 ～ 2030	**PJ development** Matching of emission sources and storage sites Developing CCUS operating environment within ASEAN region by creating common rules, etc.
2030 ～	**Decarbonizing Asia with CCUS** Expansion into the Indo-Pacific region Contributing to CO2 reduction targets Commercialization of CCUS projects in ASEAN Industry and R & D revitalization Asia Hub and Cluster Initiative

Necessity of developing the harmonized CCS system for CO2 transport and storage

- In 2009, the London Protocol was amended to allow for the export of CO2 for CCS if there is agreement between the CO2 exporting and importing countries. However, at present, more than two-thirds of the contracting parties to the protocol have not accepted the amendment, and it has not entered into force yet
- In 2019, Norway proposed new procedures for provisional application regarding cross-country projects in the North Sea, and a resolution was passed. Through the necessary procedures, CO2 imports and exports can be made possible by depositing declarations on interim application among related countries with IMO
- For a CO2 importing country that is a contracting party to the protocol (e.g., Australia), the related countries must agree on the CO2 import permit system for CCS in accordance with the protocol
- For a CO2 importing country that is not a contracting party to the protocol (e.g., Indonesia), the related countries must agree on the CO2 import permit system based on the protocol or the CO2 importing country must agree to apply the permit system in the CO2 exporting country
- As almost all countries in Southeast Asia (except the Philippines) are not contracting parties to the protocol, to transport and store CO2 from Japan, it is necessary to establish a permit system in a CO2 importing country or apply the permit system in Japan and the importing country

Major Asian CCS projects involving Japanese companies



1	Thailand	CCS Business FS in Thailand
2	Offshore Thailand	CCS Study of Arthiit Gas Field
3	Malaysia	FS for Liquefied CO2 Transport
4	Sarawak, Malaysia	CCS Joint Study at the Bintulu LNG Terminal
5	Sumatra, Indonesia	Feasibility Study for CCUS Value Chain
6	West Java , Indonesia	Feasibility Study for CO2EOR/CCS
7	Central Java, Indonesia	CCS/EGR Study at the Gundhi Gas Field
8	Central Sulawesi, Indonesia	Joint Study on CCS for Clean Ammonia
9	West Papua, Indonesia	CCS/EGR Study at the Tanguh Gas Field

10	North West Shelf, Australia	Government Approval for FS of CCS Project
11	Western Australia	Joint Study on CCS for Clean Ammonia Production
12	Western Australia	Blue Ammonia supply chain development survey
13	Northern Territory, Australia	Bonaparte CCS
14	Victoria, Australia	Feasibility Study of CCS business by Carbon Net

Source: Compiled by Industry Research Department Mizuho Bank based on ANRE (2023c, 2022b, 2022c)

【CO2 Storage】Developing CO2 Storage for Decarbonisation Solution

- Global leading companies actively develop CO2 storage capacity
  - Shell's strategies for the CCS business are as follow: to reduce CO2 emissions by utilizing its own business in the short term, to provide low-carbon products in the mid-term, and to develop the business as a decarbonization solution in the long-term

Shell: CCS Business Overview

	PJ Name	CO2 Source	Countries/ Region	Position	Share	Volume (mt/y)	Operator
Operation	Quest	Bitumen Reforming	Alberta, Canada	Technical developer, Operator, JV partner	10%	1	Yes
	Gorgon	Natural Gas	Australia	JV partner	25%	Up to 4	No
Construction	Technology Centre Mongstad test & research facility	Gas-Fired Power, Refineries, Chemicals	Norway	JV partner	8.7%	Test site	No
Pre-FID	Northern Lights (Phase 1)	Industry	Norway	JV partner	33.3%	1.5	No
	Acorn (initial)	Industry	Scotland	Technical developer, JV partner	30%	Approx.. 6	No
	Aramis (initial)	Industry	Netherland	JV partner	25%	5	No – transport Yes – storage
	Polaris	Refineries, Chemicals	Alberta, Canada	Operator	TBC	0.75	Yes
	Atlas	Refineries, Chemicals, Industry	Canada	Operator	TBC	10	Yes
	South Wales Industrial Cluster	Industry	Wales	Operator, JV partner	TBC	1.5	Yes
	Pernis CO2 capture (for transport & storage by the third-party Porthos PJ)	Refineries, Chemicals	Netherland	CO2 capture	100%	1.15	Yes – capture No – T&S
	Pernis SPeCCS CO2 capture expansion	Refineries, Chemicals	Netherland	CO2 capture	100%	0.5	TBC
	Asia-Pacific CCS hub	Refineries, Chemicals, Industry	Asia	-	TBC	-	-
	US Gulf Coast (Phase 1)	Refineries, Chemicals	U.S.A	Operator	100%	2	Yes
	Liberty (Phase 1)	Chemical Production	U.S.A	TBC	100%	1.7	TBC
	Daya Bay	Refineries, Chemicals	China	JV partner	TBC	10	TBC
	Northern Carnarvon (Angel)		Australia	JV partner	20%	5	TBC

【Mizuho's View】Shell Strategies

Low-carbon operations (2030 Scope 1 and 2 Net Emission - 50% from 2016)

Production of Low-carbon products (Low-Carbon Gas, Low-Carbon Hydrogen)

Delivering as a decarbonization solution, extending to DACCS/BECCS

Source: Compiled by Industry Research Department Mizuho Bank based on Shell Energy Transition Strategy, etc.

(Ref) “Decarbonization as a Service” Value Chain

- To achieve decarbonization, companies need to develop effective roadmaps and implement a range of decarbonization solutions
- With increasing competition among decarbonization solutions, some leading companies start to pursue a “Decarbonization as a Service” business model to gain a competitive edge
  - “Decarbonization as a Service” model has the potential to increase revenue opportunities by leveraging synergies with various monetization points in its value chain

【Mizuho's View】“Decarburization as a Service” Business Value Chain & Monetization Points

Customer’s needs for decarbonization	“Decarburization as a Service” Business Value Chain & Monetization points		
Measurement & Visualization of GHG emissions	1	Support for the **measurement & visualization of GHG emissions**	Provide know-how for the measurement & visualization of customers’ emissions
Reduction of GHG emissions	2	Support for the **reduction** of GHG emissions	Support customers’ reduction of GHG emissions by aiding them in the formulation of emission reduction strategies, and providing renewable energy
Offset by utilizing carbon credits	3	**Creation** of credits	Get involve in business that creates values from emissions reduction such as carbon credits
	4	**Certification** of credits	Acquire certification for the created values, such as carbon credits, from emissions reduction
	5	**Trade management** for credits	Get involve in the exchange marketplace of credits
	6	**Supply** of credits	Provide credits to the end consumers

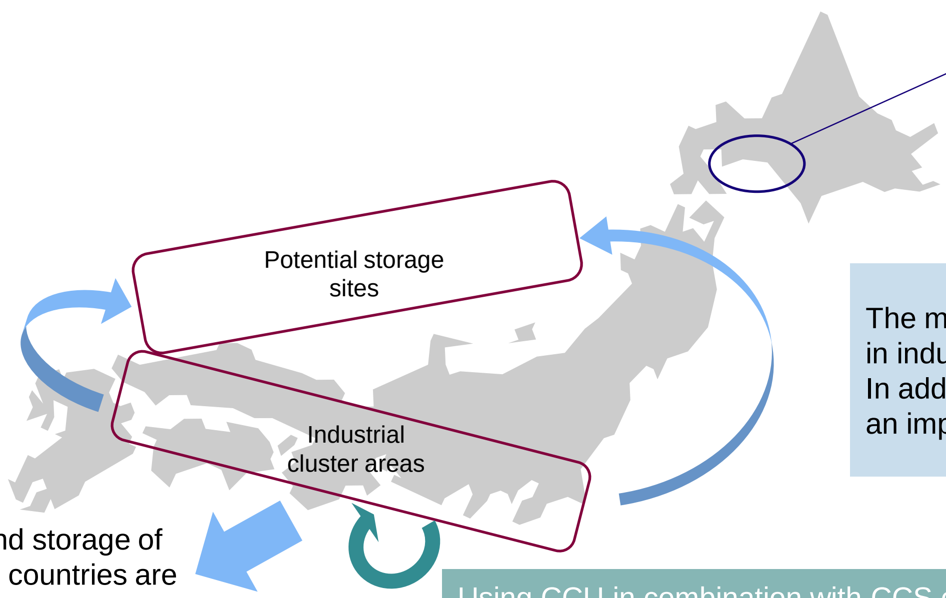
Source: Compiled by Industry Research Department Mizuho Bank

3. The Future of CCS in Japan

【Mizuho’s View】Regional Hub & Cluster CCS Model in Japan

- CCS related players are considering to establish regional hub & cluster CCS model
  - — From a cost efficiency perspective, industrial clusters play an important role in CCS value chains
  - — The consortium consisting of companies with CO2-intensive facilities, companies specializing in CO2 capture, players in CO2 transportation and storage, and representatives from local governments is critical for driving the development of the first CCS project

【Mizuho's View】Regional Hub & Cluster CCS Model in Japan



The Tomakomai CCS demonstration project is a rare case where the distance between the CO2 source and the storage site is close, and it has also succeeded in cultivating public acceptance in the region

The movement to establish a CCS consortium is accelerating in industrial cluster regions and potential CCS storage sites. In addition to companies, involving local governments is also an important option for cultivating public acceptance

Transport and storage of CO2 in Asian countries are also being considered

Using CCU in combination with CCS can enable local carbon reduction action and carbon recycling

Source: Compiled by Industry Research Department Mizuho Bank

【Mizuho's View】The ecosystem of CCS business

- Establishing effective business models for CCS and expand government support, especially for CO2-intensive sectors that face high concentration of costs, is necessary

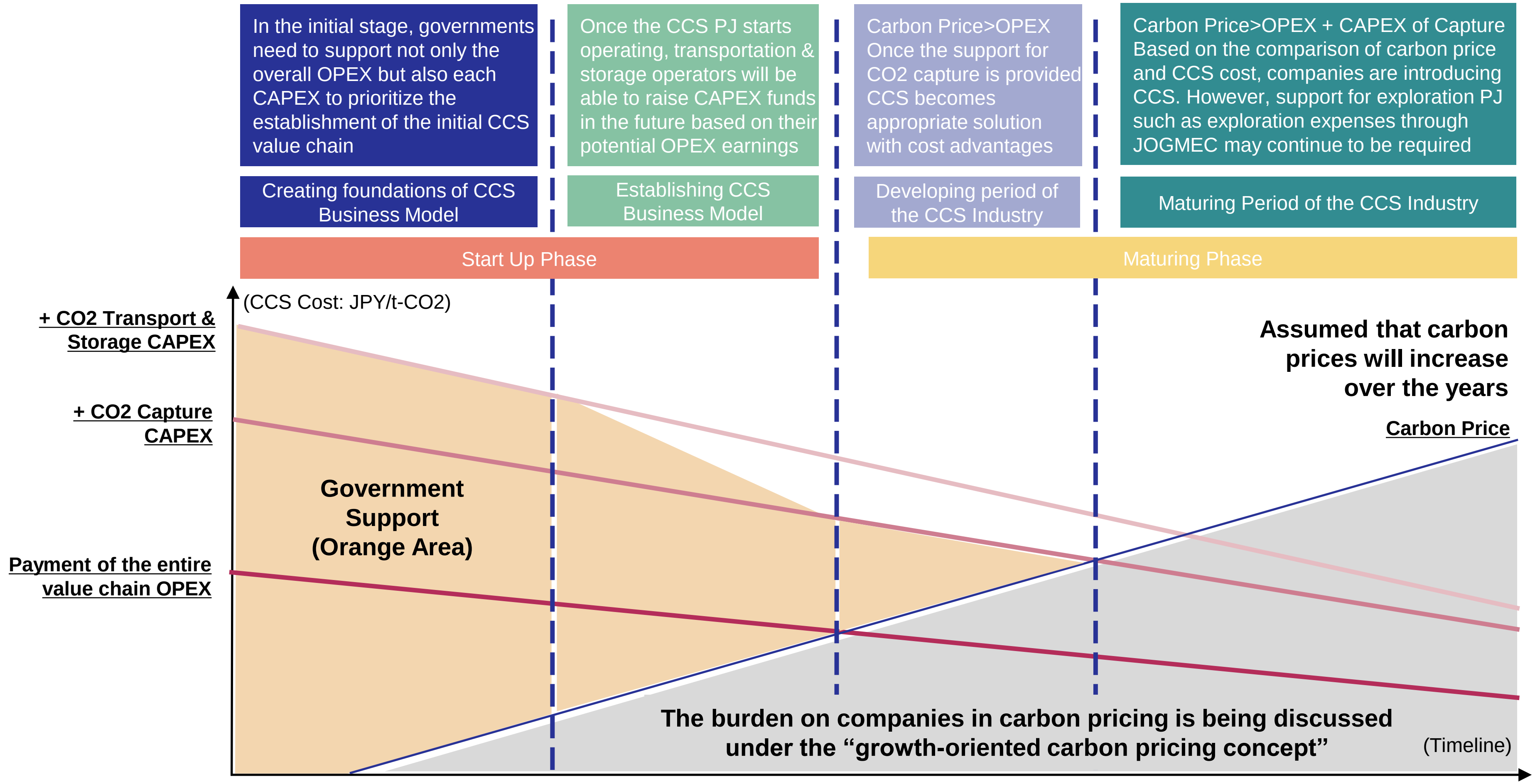
Company	Type	CCS Value Chain						Function of Government	Note
		CO2 Capture		CO2 Transportation		CO2 Storage			
CO2-Intensive Companies (Emitters)	CAPEX	—	Paying CAPEX for CO2 Capture Facilities					Support to ensure effective functioning of each stakeholder (e.g. Shaping appropriate fund flows and support of creditworthiness of stakeholders) Appropriate redistribution of CCS costs and providing subsidies that align with the importance of project. Optimization of CCS business model in Japan through integration of processes and stakeholder functions	Since the CO2 capture CAPEX and the payment of the entire value chain OPEX will be concentrated on the emitters, policy support is necessary for the effective activation of CCS value chain
	OPEX	—	Paying OPEX for CO2 Capture Facilities (e.g. Energy Cost)	—	Paying OPEX for LCO2 carrier	—	Paying OPEX for CO2 Storage site		
CO2 Transport Related Companies	CAPEX			—	Paying CAPEX for LCO2 carrier				If the OPEX for LCO2 carrier or CO2 Storage site become stable long-term income cash flows, there are possibility of financing for CAPEX payment. However, in the early stages of CCS project development, support for CAPEX is needed to launch the value chain quickly
	OPEX			+	Receiving OPEX for LCO2 carrier				
CO2 Storage Related Companies	CAPEX					—	Paying CAPEX for CO2 Storage site		
	OPEX					+	Receiving OPEX for CO2 Storage		
Others	CAPEX	+	**Engineering Companies** Receiving CAPEX for CO2 Capture	+	**Shipyard Companies** Receiving CAPEX for LCO2 carrier	+	**Engineering Companies** Receiving CAPEX for CO2 Storage		—
	OPEX	+	**Energy Companies** Receiving OPEX for CO2 Capture						

Source: Compiled by Industry Research Department Mizuho Bank

【Mizuho’s View】The Path for the Development of CCS in Japan

- It is necessary to change the form and volume of government supports in line with the development of CCS industries, decrease in CCS-related costs due to technological innovations and changes of the carbon price

【Mizuho's View】The Path for the Development of CCS in Japan



In the initial stage, governments need to support not only the overall OPEX but also each CAPEX to prioritize the establishment of the initial CCS value chain

Once the CCS PJ starts operating, transportation & storage operators will be able to raise CAPEX funds in the future based on their potential OPEX earnings

Carbon Price>OPEX
Once the support for CO2 capture is provided CCS becomes appropriate solution with cost advantages

Carbon Price>OPEX + CAPEX of Capture
Based on the comparison of carbon price and CCS cost, companies are introducing CCS. However, support for exploration PJ such as exploration expenses through JOGMEC may continue to be required

Creating foundations of CCS Business Model

Establishing CCS Business Model

Developing period of the CCS Industry

Maturing Period of the CCS Industry

Start Up Phase

Maturing Phase

The burden on companies in carbon pricing is being discussed under the “growth-oriented carbon pricing concept”

Source: Compiled by Industry Research Department Mizuho Bank

【Mizuho's View】The Path for the Development of CCS in Japan

	Creating foundations of CCS Business Model	Establishing CCS Business Model	Developing period of the CCS Industry	Maturing Period of the CCS Industry
	Start Up Phase		Maturing Phase	
Assumption	Initial Stage of the CCS industry. Governments need to support not only total operating expenses of CCS, but also CAPEX costs for each stage to construct the initial value chain	"Advanced CCS Projects" are started based on government support. Once the CCS PJ starts operating, transportation & storage operators will be able to raise CAPEX funds in the future based on their potential OPEX earnings	CAPEX support for CO2 transport & storage are gradually decreased. If partial policy support is provided for CO2 capture facilities, cost advantages can be obtained by using CCS, compared to carbon prices	Based on the comparison of carbon price and CCS cost, companies are introducing CCS. However, support for exploration PJ such as exploration expenses through JOGMEC may continue to be required
Trigger for transition from previous stage	—	Improving predictability and stability of future cash flows of CO2 transport and storage	Carbon Price>OPEX	Carbon Price>OPEX + CAPEX of Capture
Government Support	The entire value chain OPEX + CAPEX for Carbon Capture + CAPEX for Transport & Storage	The entire value chain OPEX + CAPEX for Carbon Capture Decreasing the support for CAPEX for Transport & Storage	CAPEX for Carbon Capture	No Support (support for exploration PJ such as exploration expenses through JOGMEC may continue to be required)
For CO2-Intensive Companies (Emitters)	Receive the support for the entire value chain OPEX + CAPEX for Carbon Capture costs from government by directly or indirectly	Receive the support for the entire value chain OPEX + CAPEX for Carbon Capture costs from government by directly or indirectly	Receive the support for CAPEX for Carbon Capture costs from government by directly or indirectly	No Support
For CO2 Transport Related Companies	Receive the support for the CAPEX for LCO2 carrier from Government and OPEX for LCO2 carrier from customers	Decreasing the support for CAPEX for Transport	No Support	No Support
For CO2 Storage Related Companies	Receive the support for the CAPEX for Storage site from Government and OPEX for LCO2 carrier from customers	Decreasing the support for CAPEX for Storage	No Support	No Support

Source: Compiled by Industry Research Department Mizuho Bank

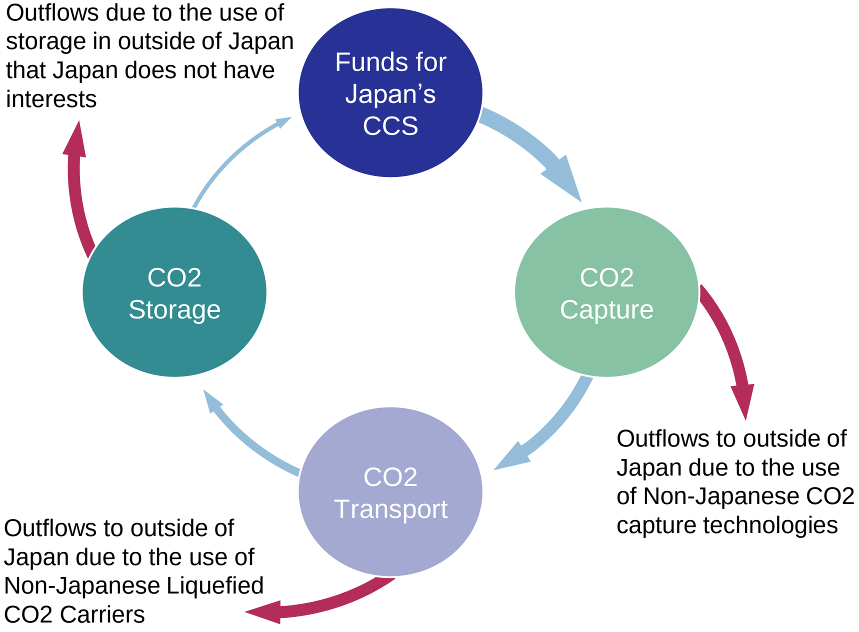
The future of CCS in Japan: The horror story and the goal

- 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

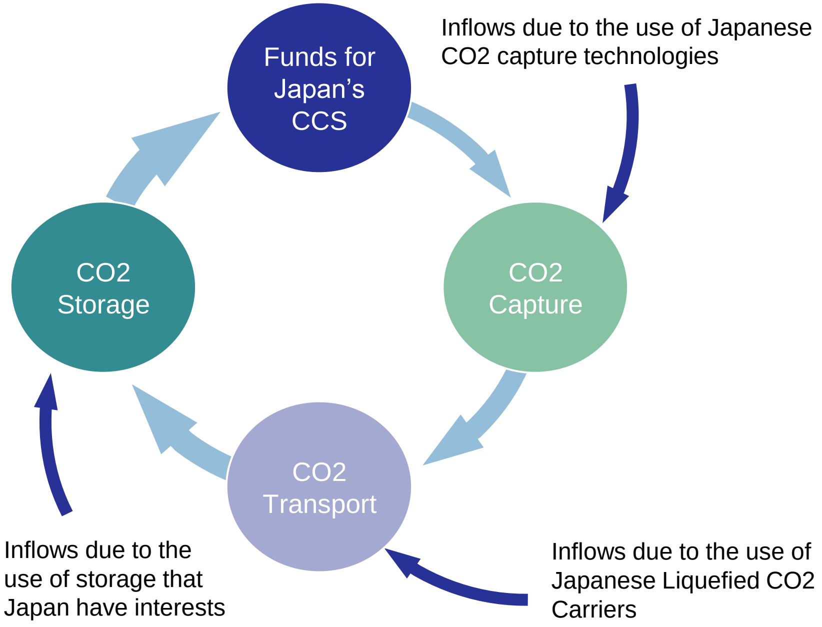
【 The future of CCS in Japan: The horror story in 2050 】

- 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

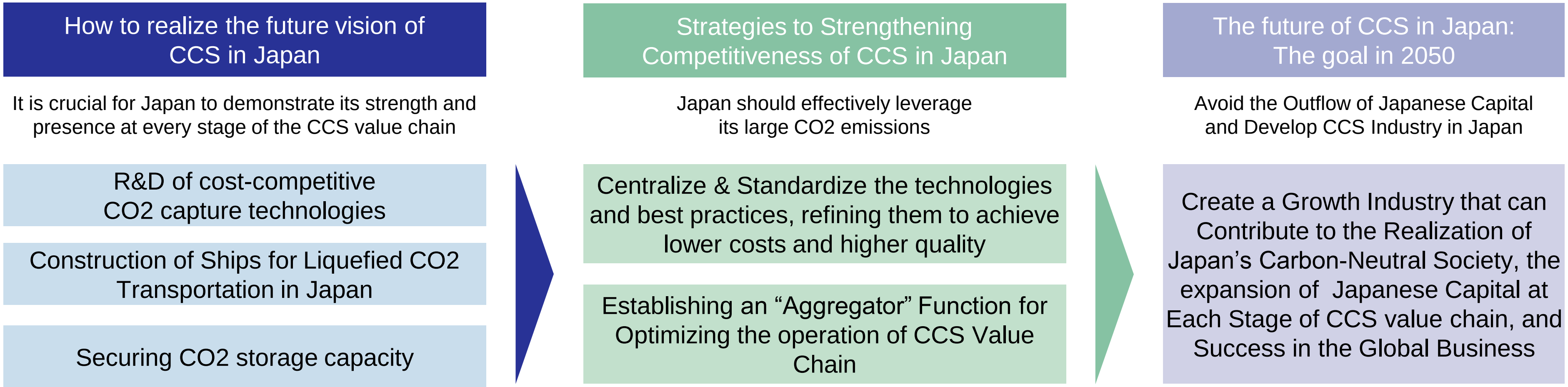


Source: Compiled by Industry Research Department Mizuho Bank

【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

It is crucial for Japan to demonstrate its strength and presence at every stage of the CCS value chain

R&D of cost-competitive CO2 capture technologies

Construction of Ships for Liquefied CO2 Transportation in Japan

Securing CO2 storage capacity

Strategies to Strengthening Competitiveness of CCS in Japan

Japan should effectively leverage its large CO2 emissions

Centralize & Standardize the technologies and best practices, refining them to achieve lower costs and higher quality

Establishing an “Aggregator” Function for Optimizing the operation of CCS Value Chain

The future of CCS in Japan: The goal in 2050

Avoid the Outflow of Japanese Capital and Develop CCS Industry in Japan

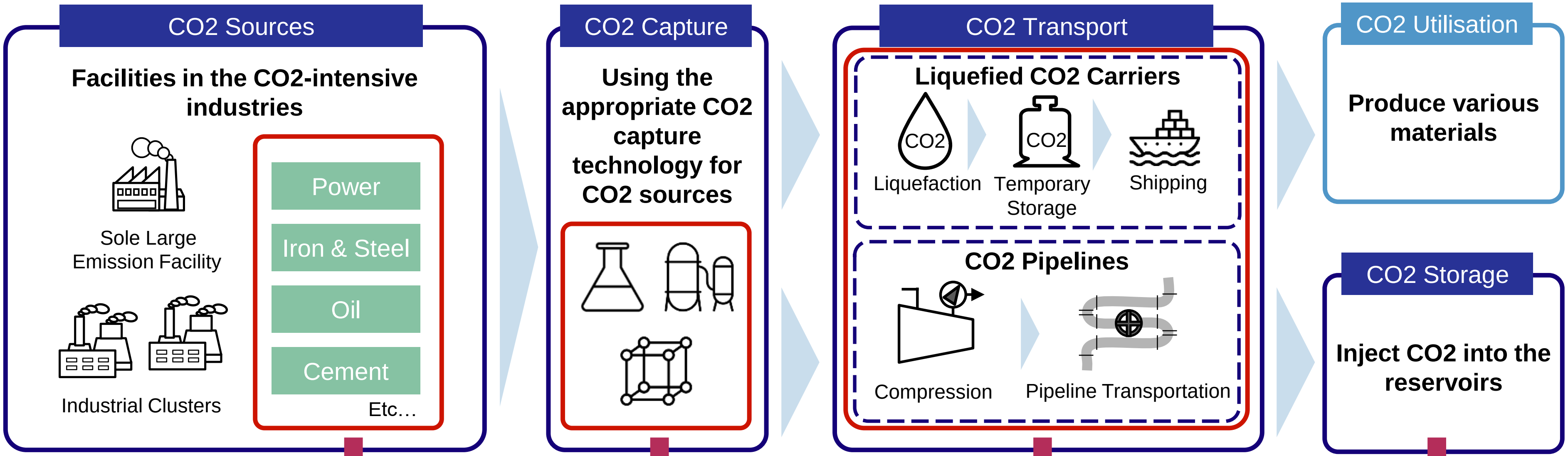
Create a Growth Industry that can Contribute to the Realization of Japan’s Carbon-Neutral Society, the expansion of Japanese Capital at Each Stage of CCS value chain, and Success in the Global Business

Source: Compiled by Industry Research Department 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



CO2 Sources

Facilities in the CO2-intensive industries

Sole Large Emission Facility

Industrial Clusters

Power

Iron & Steel

Oil

Cement

Etc…

CO2 Capture

Using the appropriate CO2 capture technology for CO2 sources

CO2 Transport

Liquefied CO2 Carriers

Liquefaction

Temporary Storage

Shipping

CO2 Pipelines

Compression

Pipeline Transportation

CO2 Utilisation

Produce various materials

CO2 Storage

Inject CO2 into the reservoirs

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

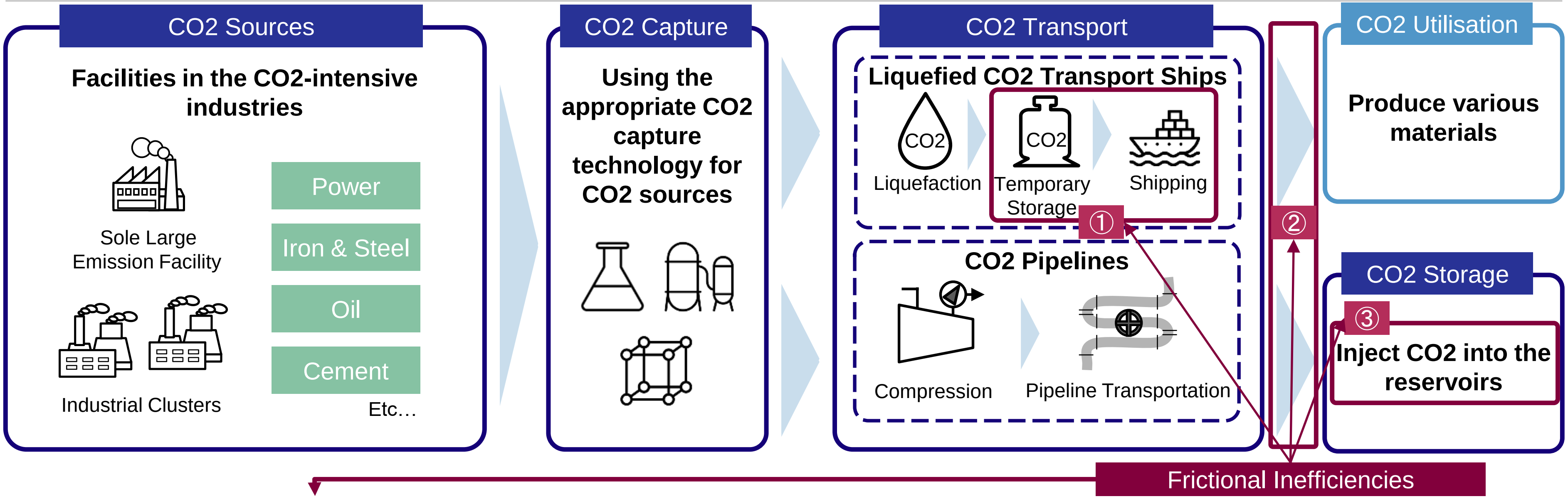
Expansion of technologies for global

Source: Compiled by Industry Research Department Mizuho Bank

Establishing an “Aggregator” Function for Optimizing the operation

- When the trade volume of CO2 increases in the future, frictional inefficiency in the CCS will push up the cost
  - If Japan can establish an “aggregator” that performs optimization functions to minimize cost inefficiencies, Japan can use it as an advantage in acquiring CCS business on a global basis

【Mizuho's View】Optimization function and “aggregator” image required for the smooth operation of the CCS value chain



CO2 Sources

Facilities in the CO2-intensive industries

Sole Large Emission Facility

Industrial Clusters

Power

Iron & Steel

Oil

Cement

Etc…

CO2 Capture

Using the appropriate CO2 capture technology for CO2 sources

CO2 Transport

Liquefied CO2 Transport Ships

Liquefaction

Temporary Storage

Shipping

①

CO2 Pipelines

Compression

Pipeline Transportation

②

CO2 Utilisation

Produce various materials

CO2 Storage

③

Inject CO2 into the reservoirs

Frictional Inefficiencies

	Frictional Inefficiencies	Required optimization function	“Aggregator”
①	Temporary CO2 storages are necessary for large-scale ship transportation. There is a potential for inefficiencies in operations from storage to ship	Managing the storage capacity and shipping schedule for optimization	The player mainly conducting optimization in the CCS that traders perform in commodity. Due to the nature of CCS, the main purpose of the aggregation should be “minimized social costs through inefficiency” rather than “profit through arbitrage trading”
②	If both CCS and CCU scale are expanded, the operational inefficiency may occur depending on the allocation of CO2	Balancing supply & demand imbalances between CCS & CCU for optimization	
③	If the CO2 trade flow become large and various, the fixed transportation operations & routes from CO2 sources to storage sites become inefficient	Being involved in large amounts of trade flow and enables minimize costs through cargo swaps, etc.	

Source: Compiled by Industry Research Department Mizuho Bank based on Trafigura (2019), etc.

Appendix. Carbon Credit Trends for CCS

Overview of Carbon Pricing and Voluntary Carbon Credit (VCC)

- Voluntary carbon credit (VCC) are categorized as a type of “Baseline & Credit”
  - It is a different framework from “Cap & Trade”, in which emission quotas are set by regulatory authorities

Overview of Carbon Pricing and Voluntary Carbon Credit (VCC)

<table>
<tr>
<td rowspan="4">Carbon Pricing
(In Broad Definition)</td>
<td rowspan="2">Carbon Pricing
(In Narrow Definition)</td>
<td colspan="2">Carbon Tax</td>
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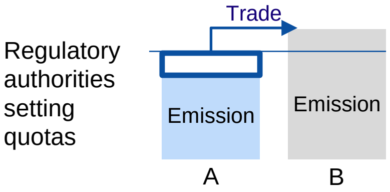
<tr>
<td>Cap & Trade
(Emission Trading)



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<td>

- EU-ETS(EU-Emission Trading System)
- UK-ETS(UK-Emission Trading System)
- RGGI(Regional Greenhouse Gas Initiative, Eastern United States)
- California
- China
- Tokyo etc…

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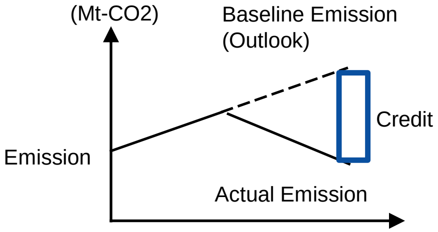
<tr>
<td>Baseline & Credit</td>
<td>Carbon Credit



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- CDM (Clean Development Mechanism, Creating CER (Certified Emission Reduction))
- JI (Joint Implementation, Creating ERU (Emission Reduction Unites))
- J-Credit
- JCM (Joint Crediting Mechanism)
- **Voluntary Carbon Credit (Based on the standard (e.g. Verified Carbon Standard)** etc…

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<tr>
<td>Guarantee of Origin</td>
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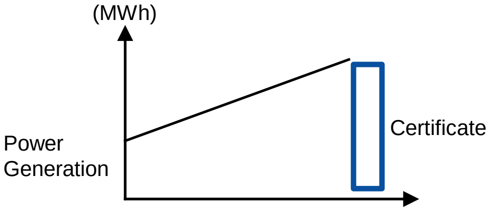

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- REC (Renewable Energy Certificate)
- GO (Guarantee of Origin)
- IREC (International Renewable Energy Certificate)
- Green Power Certificate
- Non-Fossil Certificate etc…

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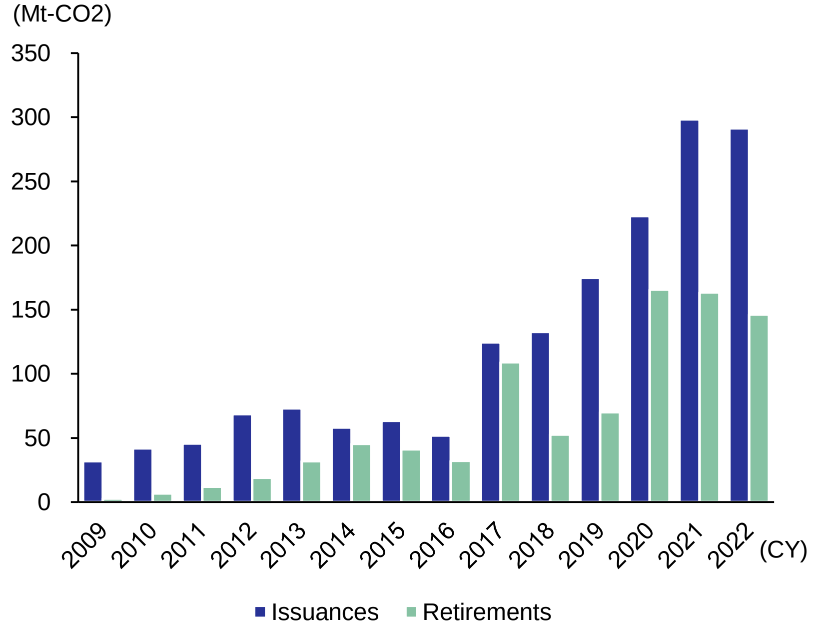
</table>

Source: Compiled by Industry Research Department Mizuho Bank based on Mizuho Financial Group (2023), etc.

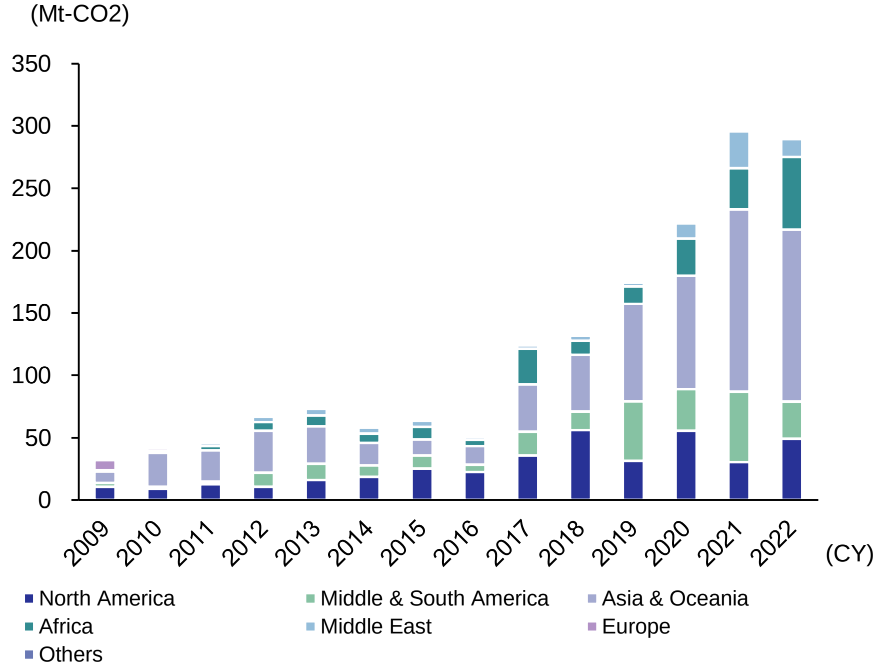
Trends of VCC issuances and retirements

- The use of VCC has been active in recent years due to factors such as the increasing number of products with added carbon credits and the establishment of emission trading framework in the aviation industry (CORSIA)
- According to Verra, the number of PJ registrations & verification applications in 2022 increased from 2021
  - However, the capacity for review and verification seemed to be a bottleneck
  - As for 2022, the number of PJ registration applications increased by 243% compared to the previous year, and verification applications increased by 90%

Trends of VCC issuances and retirements



Trends of VCC issuances by Region



Note: Total amount from VCS, Gold Standard, ACR, CAR

Source: Compiled by Industry Research Department Mizuho Bank based on The Berkeley Carbon Trading Project, etc.

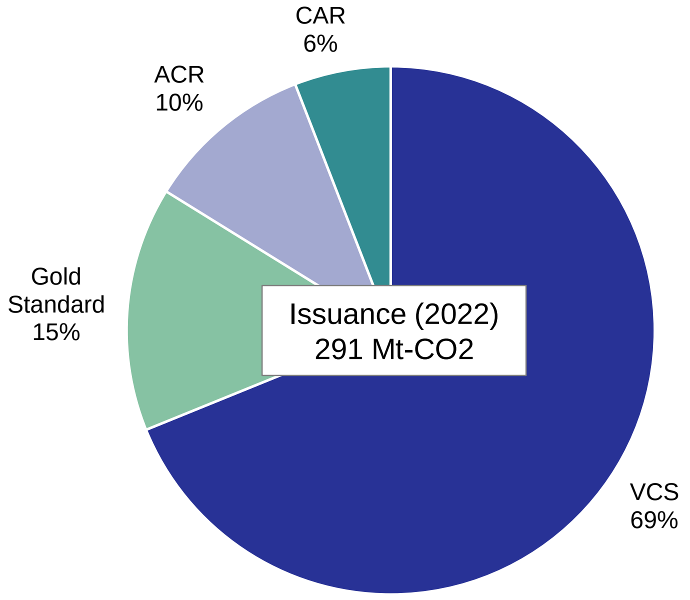
Issuance of VCCs by Standards

- VCCs can be obtained through various schemes, including credits operated by private organizations (such as VCS), the CDM operated by the United Nations, and so on
  - The largest share of credits come from private organizations and, in particular, VCS is the largest provider

Overview of VCC Standards

Standard	Operators	Start Year	Overview
Verified Carbon Standard (VCS)	Joint Operation by VERRA, The Climate Group, IETA, WEF, and WBCSD	2005	The world's largest credit standard. Managing various projects such as forest and land use projects. Recently, public consultation on CCS methodology was implemented
Gold Standard	Joint Operation by World Wide Fund for Nature, South South South, and Helico International	2003	Gold Standard was started as a standard to guarantee the quality of the Kyoto Mechanism (CDM/JI). In addition to issuing credits themselves, efforts to certify PJs deemed to have co-benefits such as contributions to local communities within the CDM have also been implemented
American Carbon Registry (ACR)	American Carbon Registry	1996	The world's first private credit standard. Formulated methodology for 21 credit targets (Forest management, waste, soil improvement, etc.)
Climate Action Reserve (CAR)	Climate Action Reserve	2001	Standard initiated to utilize the California Emissions Trading System

Issuance of VCCs by Standards (2022)



Source: Compiled by Industry Research Department Mizuho Bank based on Mizuho Financial Group (2023), The Berkeley Carbon Trading Project etc.

Issuance volume trend by category and type of VCC

- VCCs have two broad categories: Avoidance/Reduction (e.g. measuring emissions reduction volume compared to baseline), and Removal/Sequestration (e.g. measuring carbon removal from the atmosphere).
- Currently, the only major supply is avoidance/reduction type, and VCC market is supported mainly by renewable energy and forest conservation credit supply

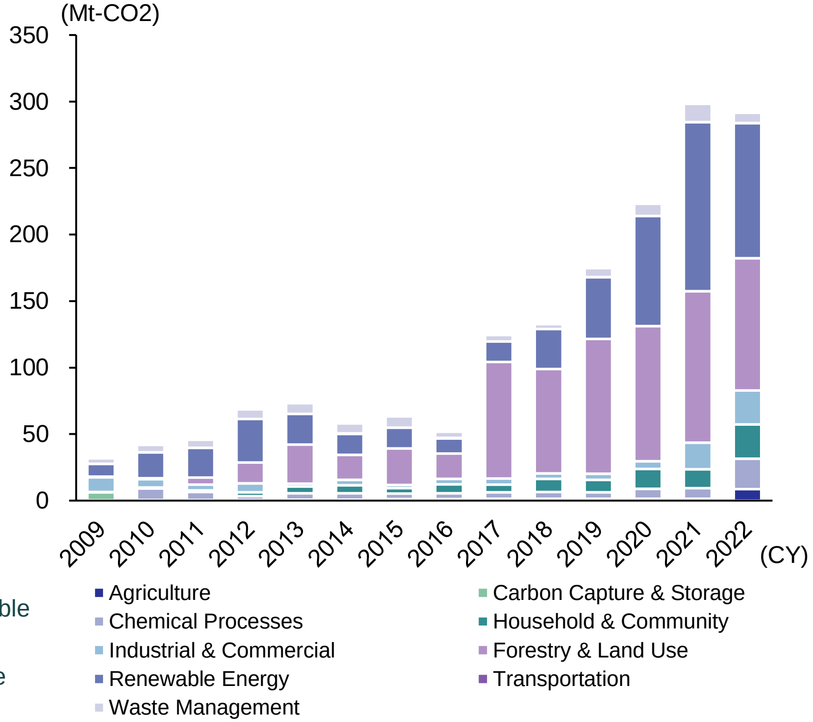
The issuance volume trend by category and type of VCC

Credit Type	Nature /Tech	Category	2022 (mt)	
			Issuance	Inventory
Avoidance/ Reduction	Nature Basis	Agriculture	9	11
		Forestry & Land Use	31	72
		REDD+	60	206
	Tech Basis	Chemical & Industrial Process	48	95
		Carbon Capture & Storage	0	7
		Household & Community	7	19
		Cookstoves	19	28
		Renewable Energy	102	255
		Others	8	33
Removal/ Sequestration	Nature Basis	Afforestation/ Reforestation	8	28
	Tech Basis	DACCS	-	-
		BECCS	-	-

Categories that support current market supply

Currently available

Expanded in the future



Note: Total amount from VCS, Gold Standard, ACR, CAR. REDD+: Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries

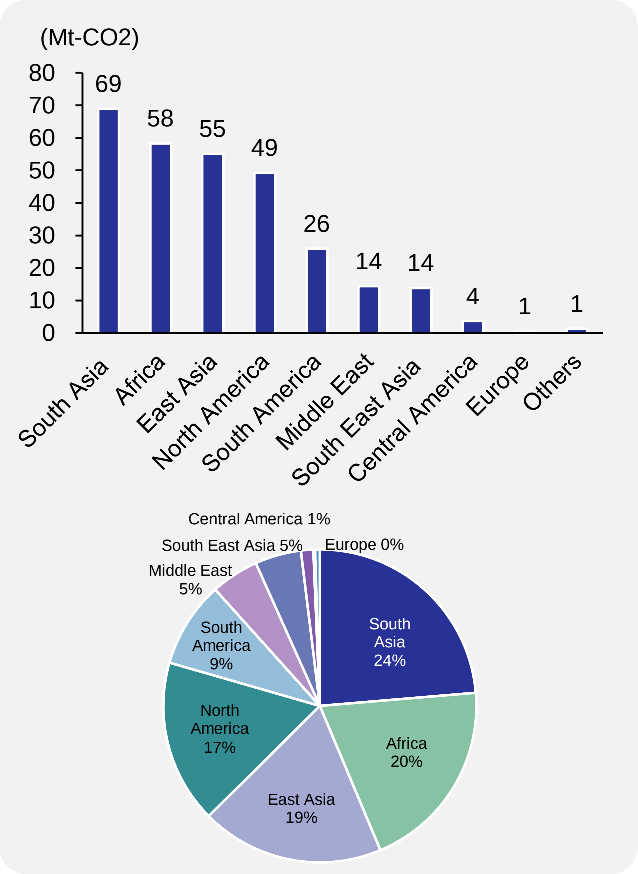
Source: Compiled by Industry Research Department Mizuho Bank based on The Berkeley Carbon Trading Project, etc.

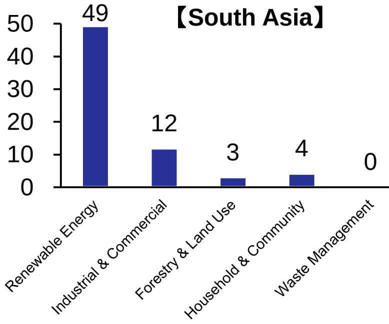
(Ref) Issuance volume by Region and Credit Type

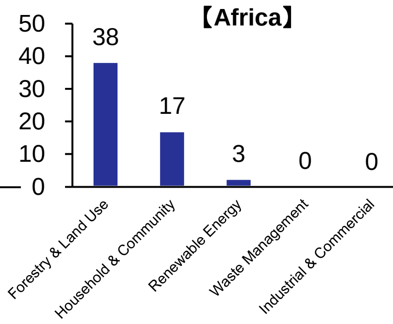
- South Asia/East Asia/Middle East are dominated by renewable energy, Africa/South America/Southeast Asia are dominated by forests, and North America is dominated by chemical processes and forests

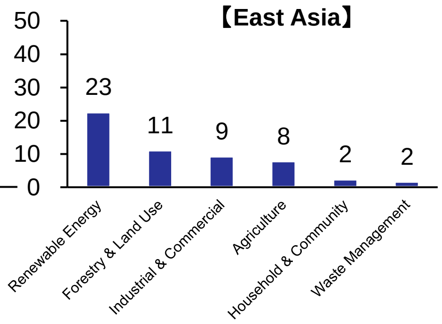
Issuance volume (Mt-CO2) by Region and Credit Type (2022)

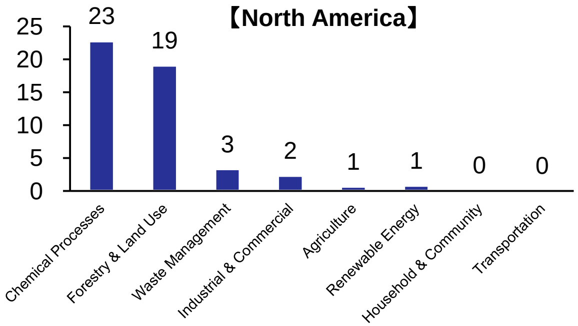
【Issuance volume in Global and Region】

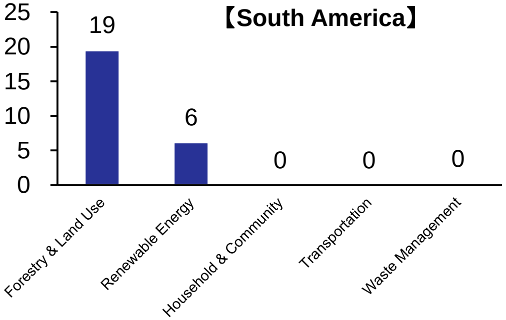


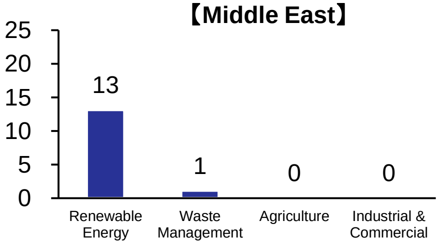

【South Asia】

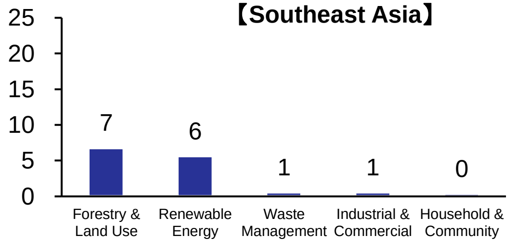

【Africa】


【East Asia】


【North America】


【South America】


【Middle East】


【Southeast Asia】

Note: Total amount from VCS, Gold Standard, ACR, CAR
Source: Compiled by Industry Research Department Mizuho Bank based on The Berkeley Carbon Trading Project, etc.

Recent progress of CCS Carbon Credits

- In June 2021, the CCS+ initiative was launched with the aim of establishing a carbon credit methodology to enhance cash flow through the CCS business and to support CCS technology R&D
  - Public consultation on methodology for carbon credit of CCS developed at VCS in 2023
- In March 2023, JOGMEC published a handbook that summarized the contents of lectures given at an international workshop in January 2023

Overview of CCS+ Initiative

Purpose of the initiative	The CCS+ Initiative aims to leverage carbon markets and to scale up global decarbonization and carbon removal efforts through enabling much needed financial incentives to make technologies economically such as carbon capture and storage viable and robust
Members	The CCS+ Initiative will be set-up as a joint and open alliance where industry leaders bring their projects to the initiative and together with internationally renowned methodological experts co-create the needed methodologies and tools. Additional members are most welcome to join the CCS+ Initiative at any time to bring their interests and projects to this effort, collaborate on methodological development and share learnings Currently, more than 40 companies and JVs participate. From Japan, INPEX, JAPEX, JOGMEC, JX Nippon Oil & Gas Exploration, Kajima and Mitsubishi Corporation are participating. Other Oil & Gas, CCU related companies, DAC related companies are also participate

Source: Compiled by Industry Research Department Mizuho Bank based on CCS + Initiative HP

Overview of Handbook for CCS Carbon Credits

Release	March 2023
Published by	JOGMEC, Mitsubishi Research Institute, Inc.
Overview	This handbook is based on the contents and results of the international workshop on "Global Carbon Markets and CCS: Towards ASEAN decarbonization" hosted by the Ministry of Economy, Trade and Industry of Japan; Japan Organization for Metals and Energy Security (JOGMEC); and International Emission Trading Association (IETA) held in January 2023 Table of Contents 1. Introduction 2. Carbon Market and CCS 3. CCS credit schemes around the world 4. Introduction of finance case 5. Prospect for CCS in Carbon Market 6. Discussion

Source: Compiled by Industry Research Department Mizuho Bank based on JOGMEC (2023)

Overview of CCS credit schemes in Global

- Several credit schemes have baseline and credit type methodologies for CCS
  - VCS held a public consultation on CCS methodology in June 2023

Overview of CCS credit schemes in Global

	American Carbon Registry (ACR)	Alberta Emissions Offset Scheme (AEOS)	Emissions Reduction Fund (ERF)	Puro.earth	Verified Carbon Standard (VCS)
Country/Region	United States	Canada Alberta	Australia	Global	Global
Purpose of using credit	Use in the compliance market (ETS in California) and voluntary initiatives	Offsets in the Alberta regulations (Technology, Innovation and Emissions Reduction Regulation, TIER)	Government regulations (offsets under the safeguard mechanism) and voluntary initiatives	Voluntary initiatives	Voluntary initiatives
CCS methodology approved year	2015	2015	2021	2022	Plans for 2023 – 2024
Target Project Type	CCS, CO2-EOR	CCS, CO2-EOR	CCS	DACCS and BECCS with EOR+	Plans for CCS, DACCS, and BECCS
Number of Project	5 PJ	1 CCS PJ (Quest) 1 CO2-EOR PJ (MEglobal)	1 CCS PJ (Moomba)	AspiraDAC BECCS Norway	-

Source: Compiled by Industry Research Department Mizuho Bank based on JOGMEC (2023)

(Ref: Leading Company Case Study) Occidental's Strategy for Achieving Net Zero

- Occidental announced ambitious targets for its net zero emissions and its plans for business transformation
  - Occidental targets include achieving net zero for Scope 1, 2 emissions by 2040 (Ambitious target: 2035), and achieving net zero for Scope 1, 2, and 3 emissions by 2050.
- Occidental aims to transform its business model by leveraging its "Carbon Management" expertise
  - Business plan does not only focus on expanding CCS but also aims to incorporate carbon credit business
  - Occidental is involved in Xpansiv, which aims to provide a digital marketplace platform that enables the trading of ESG commodities such as carbon credits with high transparency

Overview of Occidental's Pathway to Net-Zero and Action Plan

	2020~2025	2025~2030	2030~2040	2040~2050
Phase	Activation	Expansion	Broad Deployment	Global Market Development
Target	Achieve Net-Zero for scope 1 & 2 emissions before 2040, with the ambition to accomplish before 2035			Ambition to achieve Net-Zero for scope 1,2&3 emissions before 2050
Action	• World's 1st commercial scale Direct Air Capture (DAC) facility comes online • 1st CO2 storage site receives human-made CO2 • Emissions-free power facility to support carbon capture • Operational efficiencies at Occidental facilities • CO2 industrial capture project expansion • Continued methane emissions reduction activities	• Multiple large volume CO2 storage sites operational • DAC expansion • Routine flaring ended • Strategic CO2 pipeline buildout to support broader capture and use • Increase renewable energy deployment • Increase emissions-free power deployment • Unconventional CO2 storage development • Industrial 'Clean Campus'	• Natural CO2 replaced with humanmade CO2 in all EOR operations • Growth of non-EOR CO2 utilization • Expansion of CO2 storage sites • Broader DAC deployment in U.S. with expansion pilots internationally • Expanding low-carbon fuel products • Use of CO2 as a chemical feedstock	• Large-scale national and international deployment of DAC and CCUS technologies • Occidental's domestic oil and gas production is carbon neutral • CO2 feedstock utilized in domestic manufacturing • Widespread deployment of industrial capture applications

Source: Compiled by Industry Research Department Mizuho Bank based on Occidental IR, etc.

【Mizuho's View】For further Expansion of the utilization of CCS carbon credits

- Carbon crediting of CCS is a meaningful initiative for promoting the development of the CCS industry. For further expansion of the utilization, it's important to consider the following points:
  - 1) Developing strategies for increasing the demand for CCS credits classified as emission avoidance/reduction credits, and
  - 2) Establishing systems for transferring the contribution of outside of Japan CCS emission reductions to Japan

【Mizuho's View】For further Expansion of the utilization of CCS carbon credits

1) Developing strategies for increasing the demand for CCS credits classified as emission avoidance/reduction credits

- The price of carbon credits has a wide range, and emission avoidance/reduction credits are generally priced below US$10/t-CO2. On the other hand, the cost of CCS in Japan is estimated to be around JPY13,000-20,000/t-CO2, indicating a significant deviation between the value of CO2 emission reductions in the carbon credit market and the cost of CCS projects
- To ensure that the CCS carbon credits will be accepted by the demand side and used as a means to strengthen project financing flows, it's important to consider the unique merits and attractiveness of CCS credits that differentiate them from other carbon credits. For example, in the case of forest conservation projects in emerging countries, in addition to their contribution to CO2 reduction, they are evaluated for their value-added contributions (Co-benefits) to local communities and biodiversity. This can lead to increased demand
- In addition to enhancing the promotion of the merits and attractiveness of CCS carbon credits, the use of carbon credits from a policy-backed CCS system such as Canada's can also be considered as a proposal for promoting demand expansion

2) Establishing systems for transferring the contribution of outside of Japan CCS emission reductions to Japan

- To account for CO2 reduction achievements outside of Japan as carbon credits in Japan, it is necessary to establish a system called "Corresponding Adjustment" between Japan and the host country of the implemented project. A joint-credit mechanism (JCM) agreement that incorporates the handling of emissions reduction achievements in bilateral relationships has great potential for utilization
- However, while the JCM has already been signed with emerging countries, it has not been established with countries such as Australia, where there is a possibility of LCO2 transportation and storage of CO2 from Japan. Thus, further consideration is necessary to establish a more extensive framework to promote the utilization and expansion in the CCS field

Source: Compiled by Industry Research Department Mizuho Bank

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Industry Research Department	Natural Resources & Energy Team	Ryo Yamasaki	
		Yoichiro Ikoma	youichirou.ikoma@mizuho-bk.co.jp
		Kohei Shimamura	kouhei.shimamura@mizuho-bk.co.jp
	Transportation Technologies & Machinery Team	Daiki Matsuo	daiki.matsuo@mizuho-bk.co.jp
	Primary Materials Team	Taichi Kawase	taichi.kawase@mizuho-bk.co.jp
		Akiko Mizukami	akiko.mizukami@mizuho-bk.co.jp

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1-3-3 Marunouchi, Chiyoda-ku, Tokyo ird.info@mizuho-bk.co.jp