Research & Coordination Group

Members (As of Apr. 2024)

Isamu Yagyu, Group Leader, Chief Researcher
Makoto Nomura, Deputy Group Leader, Chief Researcher
[Vacancy] Deputy Group Leader
Tetsuya Deguchi, Associate Chief Researcher
Yoshinori Aoki, Associate Chief Researcher
Jun-ichi Shimizu, Associate Chief Researcher
Kin-ichiro Kusunose, Associate Chief Researcher
Minehiro Takahashi, Manager
Noritaka Mochizuki, Planning Manager
Sou Kuranaka, Planning Manager
Yuka Matsugu, Vice Manager
Yuji Yamashita, Senior Researcher (concurrent)
Yumi Kobayashi, Senior Researcher
Natsuko Yasumoto, Senior Researcher
Hitoshi Nikaido, Senior Researcher
Miho Matsuoka, Vice Manager, Researcher
Nami Tatsumi, Chief
Michiyo Kubo
Mizuki Nagata

Research Efforts to Realize a Carbon-neutral Society

The Research & Coordination Group has four major functions to 1) explore new R&D topics while looking at domestic and overseas policies and technology trends, and propose and implement new research themes by taking advantage of the research potential of RITE; 2) support the government with regard to IPCC (Intergovernmental Panel on Climate Change), and facilitate collaboration with international organizations, such as ISO (International Organization for Standardization); 3) promote the dissemination of RITE's technologies and develop human resources for the future; and 4) promote the practical application of technologies through collaboration with the industry. We, together with research groups, have been actively working on policy support, technology development and the creation of innovation in order to pursue both global environment protection and economic development.[1)]

The following is an overview of the Japanese government's actions taken toward carbon neutrality in FY2023.

The Bill for the Act on Promotion of Smooth Transition to a Decarbonized Growth-Oriented Economic Structure (GX Promotion Act)[2)] approved by the Cabinet in February 2023 was passed into law in May 2023. Based on the GX Promotion Act, the Strategy for Promoting Structural Transition Based on Decarbonization (GX Promotion Strategy) was approved by the Cabinet in July 2023[3)]. In addition, the Carbon Management Subcommittee established under the Natural Resources and Fuel Committee of the Advisory Committee for Natural Resources and Energy started discussions on issues toward CCS commercialization in September 2023, and it prepared a summary entitled "What Institutional Measures Related to CCS Ought to Be"[4)] in January 2024. In February of the same year, the Bill for the Act on Carbon Dioxide Storage Businesses (CCS Business Act) was approved by the Cabinet[5)], and it was submitted to the 213th ordinary session of the Diet and passed into law.

1.1. GX Promotion Act

With investment competition toward green transformation (GX) being accelerated worldwide, Japan, in both the public and private sectors, needs to invest more than 150 trillion yen in GX over the next 10 years to fulfill its international pledges, including achieving carbon neutrality by 2050, strengthen its industrial competitiveness, and achieve economic growth. To

these ends, the GX Promotion Act requires the government to (1) formulate and implement a GX Promotion Strategy, (2) issue GX economy transition bonds, (3) introduce growth-oriented carbon pricing, (4) establish the GX Promotion Organization, and (5) conduct progress evaluation and necessary review.

(1) Formulation and implementation of the GX Promotion Strategy

The government formulates and implements a strategy to promote GX in a comprehensive and systematic manner.

(2) Issuance of GX economy transition bonds

The government issues GX Economy Transition Bonds, which was started from FY2023 for a 10-year period, to support upfront investment to realize the GX Promotion Strategy.

(3) Introduction of growth-oriented carbon pricing

Added value is provided to GX-related products and businesses by pricing CO_2 emissions. Starting in FY2028, the government will impose a fossil fuel levy on fossil fuel importers in accordance with the amount of CO_2 derived from fossil fuels that is imported. Starting in FY2033, the government will allocate CO_2 emission allowances to power generators for a partial fee and levy a specific business operator burden fee in accordance with the amount.

(4) Establishment of the GX Promotion Organization

The GX Promotion Organization has been established with the approval of the Minister of Economy, Trade and Industry. Major functions of the GX Promotion Organization are support for private companies' investment in GX (financial support (debt guarantee, etc.)), collection of fossil fuel levies and contributions from specific business operators, and the operation of an emission trading system (allocation of emission allowances for specific business operators, bidding, etc.).

(5) Progress evaluation and necessary review

Based on the implementation status of GX investment, etc. and economic trends related to CO_2 emissions in Japan and overseas, measures are examined and necessary review is conducted based on examination results. The detailed system design for the fossil fuel levy and the emissions trading system are reviewed, including concrete measures for the full-scale operation of the emissions quota trading system, and necessary legislative measures are taken within two years after the enforcement of this Act.

1.2. GX Promotion Strategy

In July 2023, the GX Promotion Strategy was approved by the Cabinet based on the GX Promotion Act. The following are the Strategy's two key pillars:

(1) For ensuring a stable energy supply, Japan will advance decarbonization efforts toward GX, including a shift to renewable energy, nuclear power and other decarbonized electric sources that contribute to increasing Japan's energy self-sufficiency, in addition to thorough energy savings.

(2) For achieving GX, Japan will implement “growth-oriented carbon pricing initiatives,” including support for bold upfront investment by using the GX economy transition bond, etc., incentives for upfront investment in GX by carbon pricing, and the use of new financial means.

1.3. CCS Business Act

To achieve carbon neutrality by 2050, it is an important challenge to achieve GX in areas where decarbonization is difficult. As a means to promote decarbonization after the use of fossil fuels and materials in such areas, it is indispensable to introduce CCS (carbon dioxide capture and storage), a technology that is used to capture and store CO_2 underground, as a solution.

Aiming to create a business environment in which private companies are able to launch CCS businesses in Japan by 2030, the government will establish a licensing system for storage business, etc. necessary for creating

the business environment while maintaining public safety and preserving the marine environment.

(1) Establishment of a licensing system for trial-drilling and storage business and the development of business regulations and safety regulations pertaining to storage businesses

① Establishment of a licensing system for trial-drilling and storage business

- The Minister of Economy, Trade and Industry designates an area where the reservoir may exist as a "specified zone," announces an open call for trial drilling and CO_2 storage projects in a specified zone, and grants permission to the most appropriate applicants.
- For those granted permission as stated above, a right is established for trial drilling (the right to excavate land to check whether the stratum is appropriate for a reservoir) and a storage business (the right to store CO_2 in the reservoir). To ensure the stable storage of CO_2, the rights for trial drilling and storage are a "deemed real right."
- A holder of digging right under the Mining Act may conduct trial drilling or a storage business with the permission from the Minister of Economy, Trade and Industry in areas (mining sites) other than specified zones as stated above.
- Conventionally, the storage of CO_2 in a sea area required the permission of the Minister of the Environment pursuant to the provisions of the Act for the Prevention of Marine Pollution and Maritime Disasters. Under the CCS Business Act, however, the procedures to obtain the permission are integrated so that the Minister of Economy, Trade and Industry may grant the permission after gaining consent from the Minister of the Environment through prior consultation. Accordingly, the licensing system for undersea storage of CO_2 emission under the Act for the Prevention of Marine Pollution and Maritime Disasters was abolished.

② Development of regulations for storage business operators

- A specific implementation plan for trial-drilling and storage projects requires the approval from the Minister of Economy, Trade and Industry.
- Business operators are obliged to monitor the temperature and pressure of the storage reservoir so that the leakage of stored CO_2 can be identified.
- To secure funding necessary for monitoring and other operations conducted after the stop of CO_2 injection, business operators are required to set aside reserves, etc.
- If certain requirements are met, such as stability of the stored CO_2, management of storage sites, including monitoring, can be transferred to the Japan Organization for Metals and Energy Security (JOGMEC). To secure funds for post-transfer management operations, storage business operators are obliged to contribute funds to JOGMEC.
- Storage business operators are prohibited from refusing CO_2 storage requests from CO_2 emitters without justification and from discriminatory treatment of certain CO_2 emitters, and they are required to provide notice of fees, etc.
- Safety and security regulations are imposed on storage business operators, including obligations to comply with technical standards, submit a work plan, and develop safety measures.
- If a third party suffers damage as a result of an event specific to a trial drilling or storage project, liability for damages (i.e., non-fault liability) is imposed on storage business operators, irrespective of intent or negligence, from the perspective of relief for victims.

(2) Development of business regulations and safety regulations pertaining to CO_2 pipeline transport operations

① Establishment of a notification system for pipeline transport operations

- Those who transport CO_2 via pipelines for the purpose

of storing CO_2 in a reservoir are required to submit notification to the Minister of Economy, Trade and Industry.

② Regulation imposed on pipeline transport operators

- Pipeline transport operators are prohibited from refusing requests for CO_2 transport from CO_2 emitters without justification and from discriminatory treatment of certain CO_2 emitters, and they are required to provide notice of fees, etc.

- Safety and security regulations are imposed on pipeline transport operators, including obligations to comply with technical standards, submit a work plan, and develop safety measures.

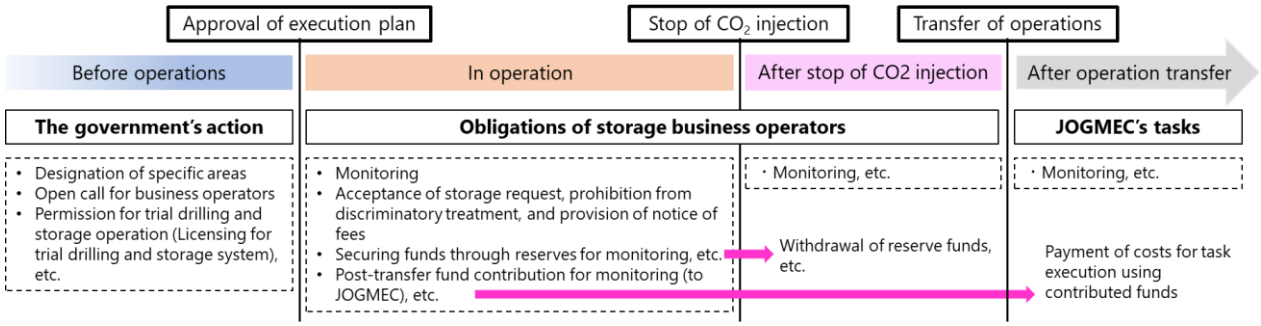

Figure 1 Flowchart for storage operations

2. Research study activities

In FY2023, we were entrusted with the " Study Project on Measures for Stable Fuel Supply (study on the improvement of the CCS business environment and the development of a CCS Action Plan with an eye toward achieving carbon neutrality by 2050)," a research project commissioned by the Ministry of Economy, Trade and Industry. To review the "CCS Action Plan" in the Final Summary by the CCS Long-term Roadmap Study Group[6], we conducted a study concerning cost targets and technology development guidelines.

Below is an outline of the CCS cost structure study conducted to discuss technology development policy (= cost reduction measures) to achieve cost targets.

Table 1 Policies discussed for formulation of the CCS Action Plan[6]

Items	Policies Discussed
Annual storage amount targets	**Elaborate the annual storage amount targets to be achieved by 2050 based on views and opinions from individual industrial sectors,** and make the targets more elaborate according to the progress of decarbonization efforts, including energy savings, electrification, and hydrogenization.
Cost targets / technology development guidelines	After reviewing CCS cost targets as needed, **develop technology development guidelines for achieving the targets set**, and make the guidelines more elaborate according to the progress of cost reductions.
Suitable site investigation plan	**Consider conducting investigation on the geological structure of coastal regions** while continuing to estimate the location of suitable sites for CO_2 storage in areas on which data exists. **Give further consideration to a method to evaluate risk from a geologic fault** in a geological structure investigation.

2.1. Understanding of CCS cost structure

2.1.1. Trial calculation (example)

Figure 2 shows an example of a trial calculation, in which a coal-fired power plant (CFPP) and a natural gas combined cycle power plant (NGCC)—for both of which there is a relatively large amount of cost data—are CO_2 emission sources. Other conditions set here are pipeline transport and liquefied CO_2 transfer by ship, as well as CO_2 injection for storage from a land area and injection in a sea area (grounding and floating).

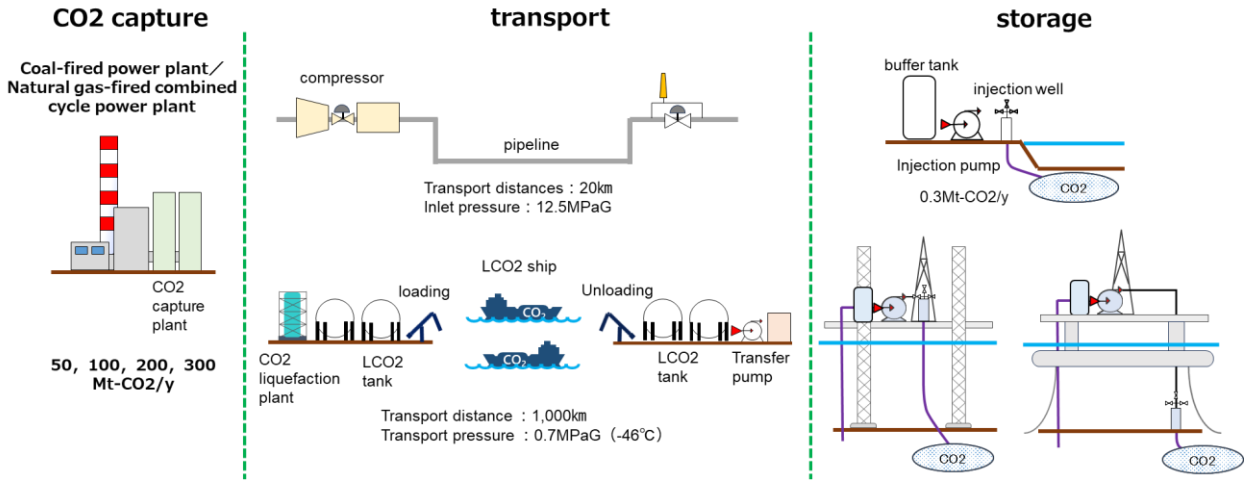

Figure 2 Example of trial calculation (a combination of separation & capture, transport, and storage)

2.1.2. Points to note regarding trial calculation and major preconditions

This time, a trial calculation was conducted, with the amount of CO_2 as a variable, under the preconditions set arbitrarily by RITE based on public data. It should be noted that this is not a cost estimate based on a specific site, piece of equipment, etc., and that in each of separation/capture, transport and storage, no consideration is given to constraints on land, land costs, reserve funds, or compensation costs.

Table 2 Major preconditions for trial calculation of CCS costs

Items	Description
Project period	Operation period (20 years) / post site closure management (20 years)
Trial calculation year, exchange rate, etc.	Cost base: 2023 Exchange rate: ¥139/US$ (average for the first half of 2023)[7)] Discount rate: 5% External electricity costs: ¥20/kWh Coal price: ¥26,000/t (Sept. 2023)[8)] LNG price: ¥88,000/t (Sept. 2023)[8)]
Emission sources	CFPP (CO_2 level: 12% - 13%) NGCC (CO_2 level: 3% - 4%) Capacity factor: 70%
Annual CO_2 recovery amount	0.5 million, 1 million, 2 million, 3 million ton CO_2/year
CO_2 separation and capture facilities	CO_2 recovery rate: 90% Chemical absorption method (amines) * Renovation costs for common facilities and existing facilities not

	included
Pipeline transport facilities	CO_2 transport pressure: 12.5 MPaG * Compression power (Calculated for two-stage compression)
Liquefied CO_2 transport facilities	Liquefaction equipment (directly cooled) * 0.7 MPaG, - 46°C
	Storage/loading equipment (land) * Pier not included
	Unloading/storage equipment (land) * Pier not included
	Boosting equipment for transfer to injection equipment
CO_2 carrier	Standard value: - 46°C (upper limit: - 43°C, lower limit: - 50°C) Design pressure: 1.0 MPaG * Type of ship: up to 50,000 ton class
Other	Renovation costs for existing facilities, reserve funds, general administration costs and miscellaneous costs NOT included

2.2. Outline of trial calculation results

2.2.1. CO_2 separation and capture costs (Figure 3, 4)

In both CFPP and NGCC, the percentage of capital expenditure becomes smaller with increasing CO_2 recovery amount. In terms of economies of scale, effects are higher in CFPP than in NGCC. In the case of CFPP, the percentage of capital expenditure is high, irrespective of the amount of CO_2 recovery, which is followed by absorbent/industrial water and renewable energy. In the case of NGCC, however, the percentage of capital expenditure becomes high when the CO_2 recovery amount is 0.5 million tons and 1 million tons, and in the case of other recovery amounts, the percentage of renewable energy costs is high. When the CO_2 recovery amount is the same, NGCC, whose emissions flow rate is higher, has a higher percentage of blower pump power than CFPP.

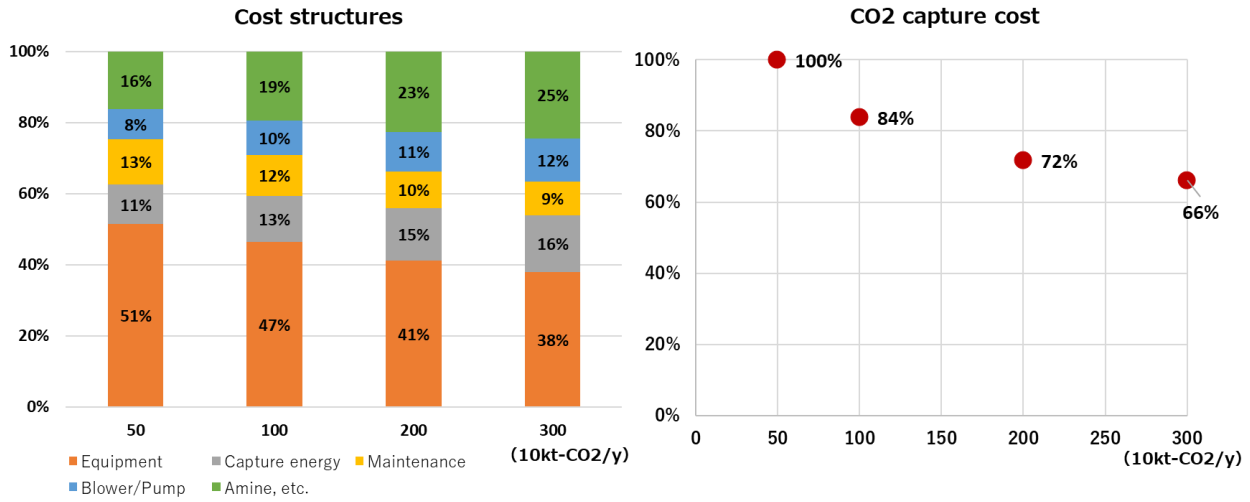

Figure 3 CO_2 capture (Cost structures) ※coal-fired thermal power plant

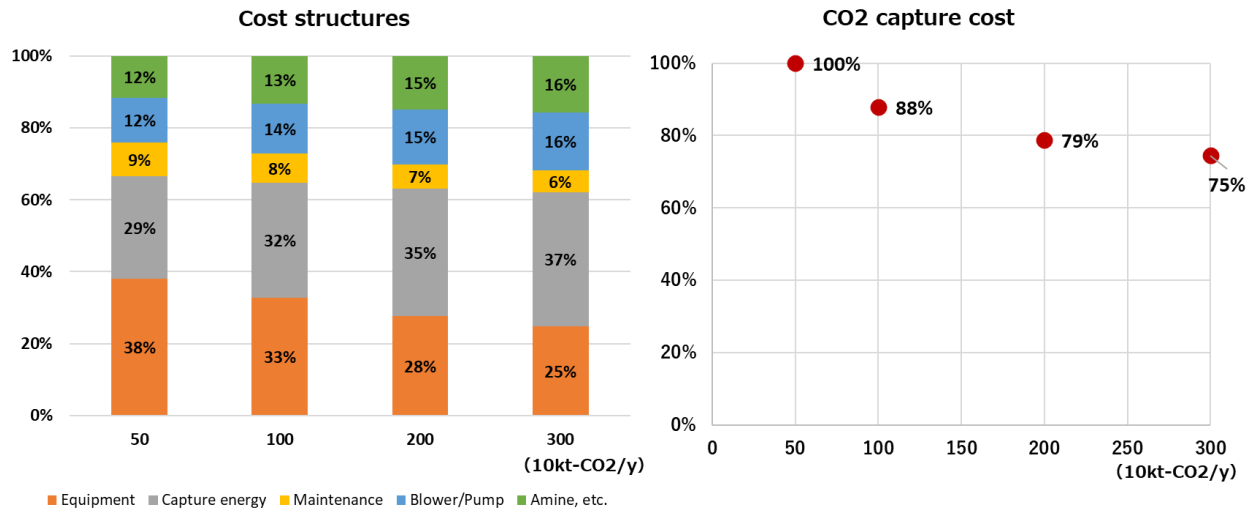

Figure 4 CO_2 capture(Cost structures) ※Natural gas-fired combined cycle power plant

2.2.2. Transport costs (Figure 5, 6)

In both pipeline transport and liquefied CO_2 transport by ship, the percentage of capital expenditure becomes smaller with an increasing CO_2 transport amount. In terms of economies of scale resulting from expanded transport scale, pipeline transport and liquefied CO_2 transport by ship showed about the same results.

In pipeline transport, the percentage of electricity costs for compressor (compression power) is high, irrespective of the amount of transport, with about 70% for 3 million tons of transport.

In liquefied CO_2 transport by ship, the percentage of electricity costs for liquefaction is high, irrespective of the amount of transport. With external electricity costs of ¥20/kWh set as a precondition, each energy cost became high.

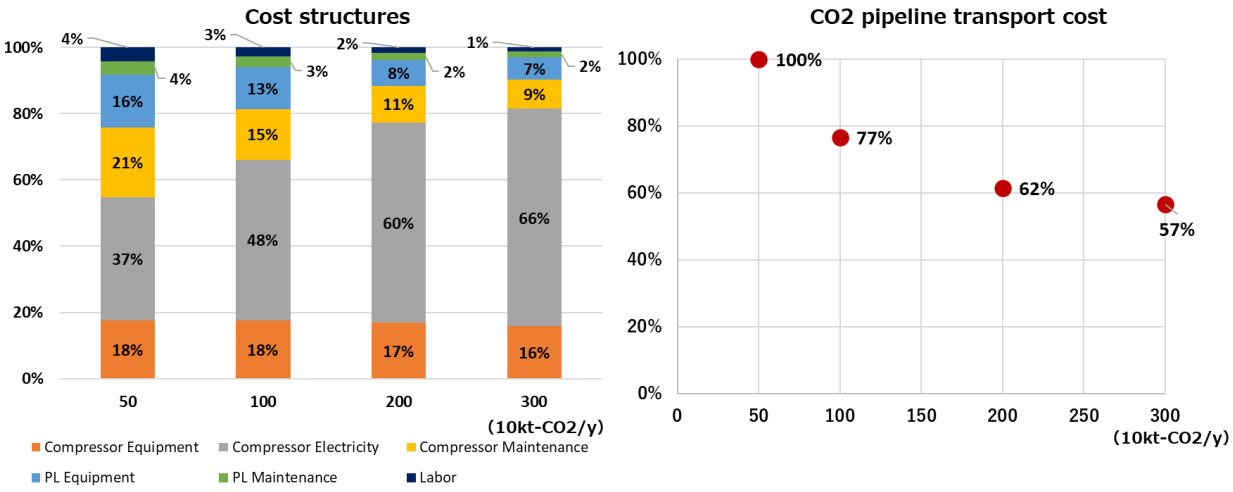

Figure 5 CO_2 Pipeline transport(Cost structures)

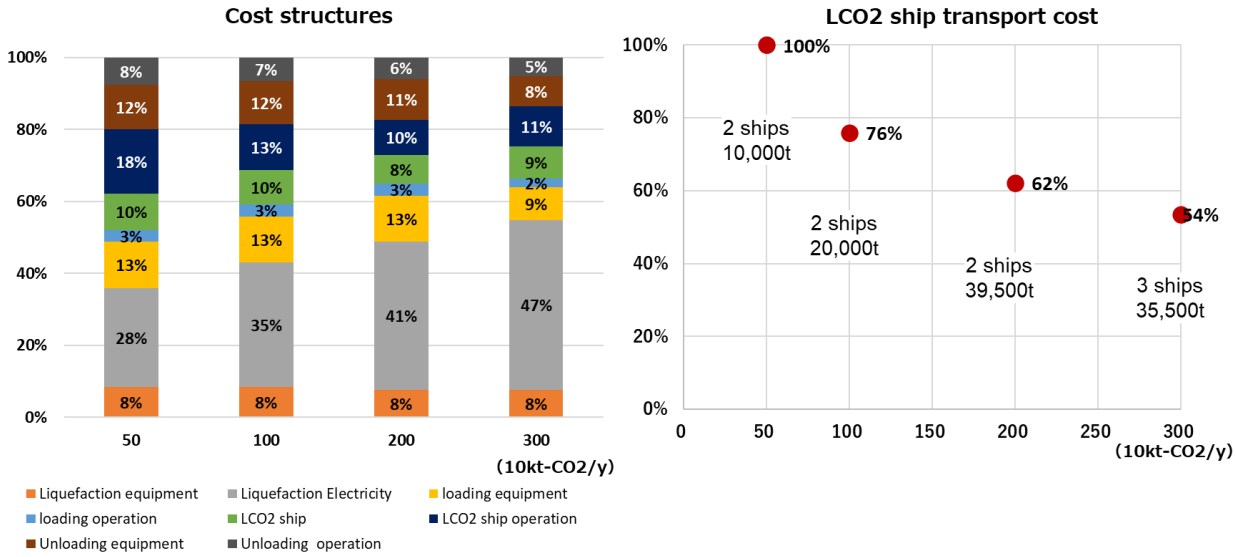

Figure 6 LCO_2 Ship Transport(Cost structures)

2.2.3. Storage and monitoring costs (Figure 7, 8, 9)

The percentage of drilling costs in any area of land, sea (grounding), and sea (floating).

In the case of land area, the percentage of injection monitoring costs is second highest, behind drilling costs. For the sea area (grounding and floating), the percentage of costs for grounding base and floating base is high.

For the sea area (grounding), the third highest is injection monitoring costs, but for the sea area (floating), it is costs for undersea equipment. The percentage of capital expenditure (CAPEX) is relatively higher than separation/capture and transport.

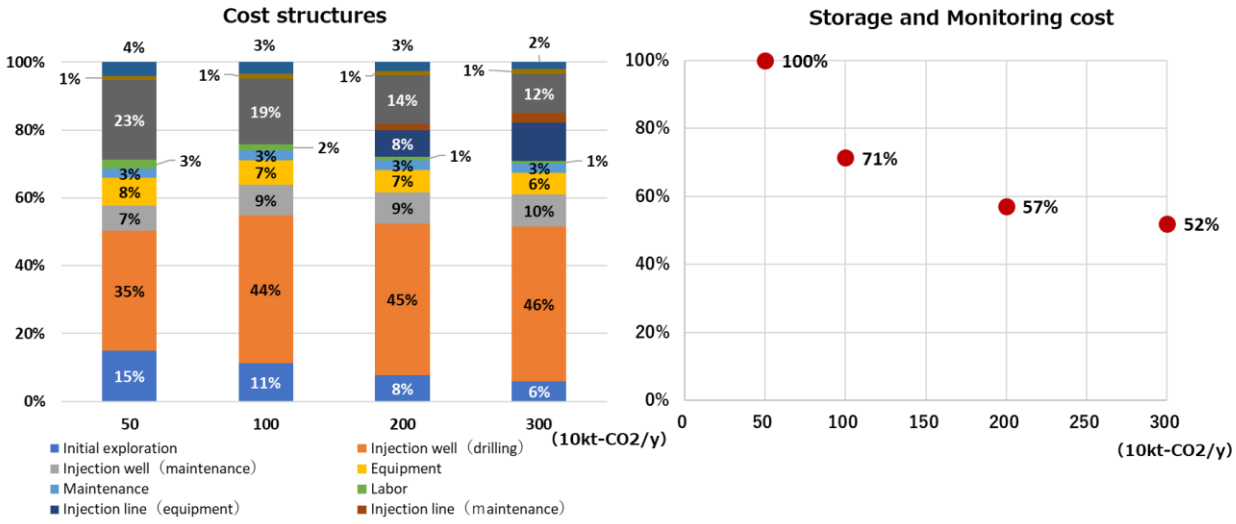

Figure 7 Storage and Monitoring(Cost structures)※Onshore

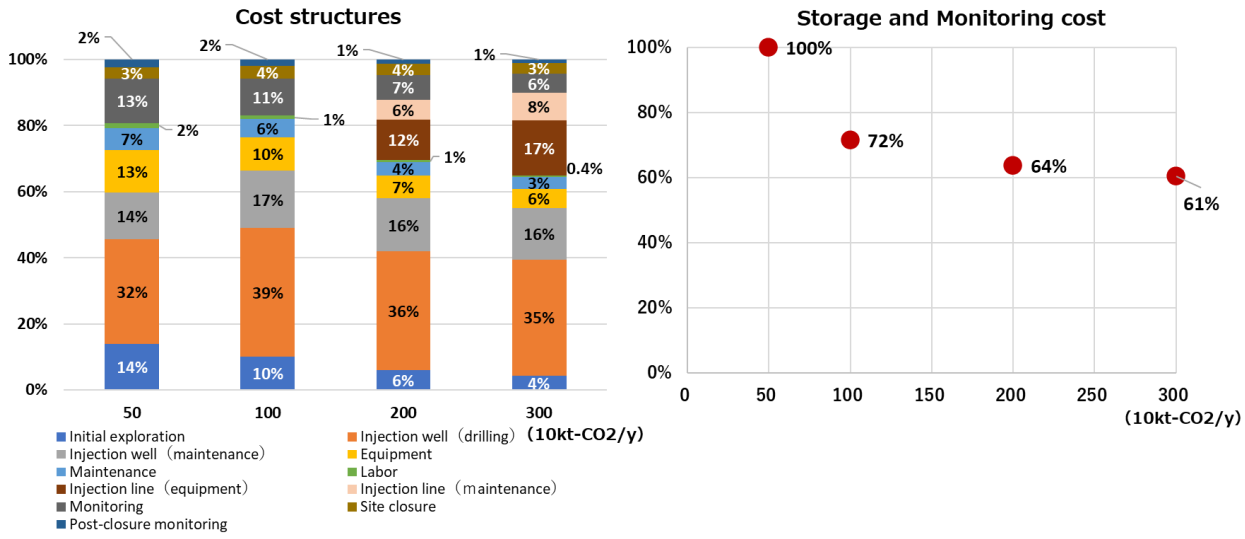

Figure 8 Storage and Monitoring（Cost structures）※Jack-Up

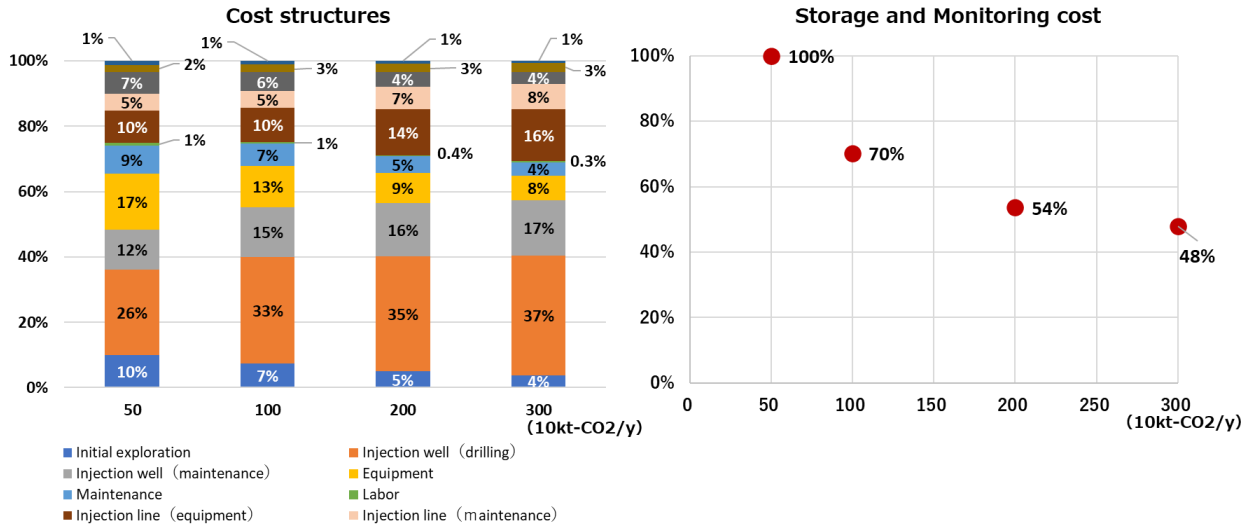

Figure 9 Storage and Monitoring（Cost structures）※Semi-sub

2.3. Summary

For CCS in Japan, operating expenditure (electricity and fuel costs, etc.) for CO_2 separation and capture and transport is relatively high. So, it is an effective way to develop energy-saving equipment and a technology to utilize waste heat. With regard to storage, the percentage of CAPEX (drilling costs, platform, undersea equipment, etc.) is relatively high. So, it is important to discuss cost reduction measures for CAPEX.

This time, the trial calculation of CCS costs was conducted for a project that is implemented in an integrated manner—from separation/capture to transport and storage. However, when a CCS project is expanded to the several hundred million yen level, the optimization of a CCS project as a whole needs to be considered in order to reduce costs.

3. Promotion of international partnership

3.1. IPCC (Intergovernmental Panel on Climate Change)

The IPCC has been established in 1988 with a view to conducting a comprehensive assessment from scientific, technical, and socio-economic perspectives on climate change, impact, adaptation and mitigation measures by anthropogenic sources, jointly by the United Nations Environment Program (UNEP) and by the World Meteorological Organization (WMO). The IPCC examines scientific knowledge on global warming and makes the reports prepared by three WGs, - Physical Science Basis (WG1), Impacts and Adaptation, and Vulnerability (WG2), and Mitigation Measures (WG3).

In the IPCC, the experts chosen among each country make the reports, based on the literature or the scientific observation data and evaluate / examine the scientific analysis, social economic influence and countermeasures to control climate change. This outcome is to have a high influence on international negotiations since the scientific basis is also given to the policies of each country.

RITE plays the central role of domestic support secretariat of mitigation measures (WG 3) (Figure 10). The IPCC launched a new structure for the Seventh Assessment Cycle (AR7) in July 2023, and decided to provide the Working Group reports, a Special Report on Climate Change and Cities, a Methodology Report on Short-Lived Climate Forcers (SLCF), and a Methodology Report on Carbon Dioxide Removal Technologies (CDR) and Carbon Capture Utilization and Storage (CCUS), and has begun its work. RITE has also been supporting METI through information gathering, analysis, report, advise, etc.

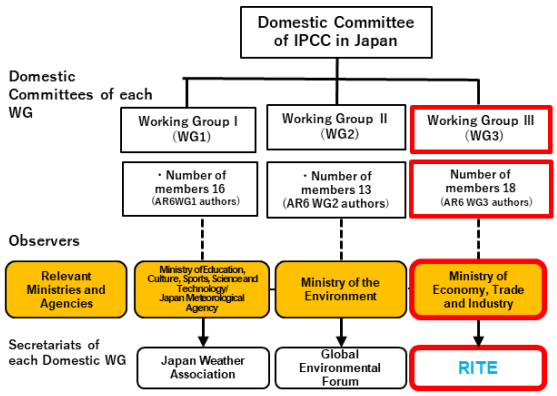

Figure 10 Committee structure and RITE

3.2. ISO

ISO (International Standard Organization) is an organization composed of 170 standardization bodies of various countries that gives the common standards and promotes global trade. It can provide safe, reliable, and high-quality products/service by utilizing ISO standards.

In the world, a number of CCS verification projects on a commercial scale are implemented, and inter-national collaboration is under way. International standardization of CCS can contribute to the wide-spread of safe and appropriate CCS as it can ensure internationally agreed knowledge on safety and environmental aspects.

RITE is a domestic deliberation organization on ISO / TC 265 (Carbon dioxide capture, transportation, and geological storage) and is in charge of a secretariat of WG 1 (capture). Through these activities, we are actively involved in the international standardization on design, construction, operation, environmental planning and management, risk management, quantification, monitoring and verification, and related activities in the CCS field (Figure 11).

As of the end of March, 2024, thirteen standards related to the CCS have been published from ISO / TC265 and eight documents are currently under development. The launch of a new project is also being considered, and TC265 has become more active in recent years. In

particular, CO_2 ship transportation is attracting attention as a powerful means of transportation from emission sources to CO_2 storage site. Development of Technical report related to CO_2 ship transportation began in 2022, and it is currently in the final stage.

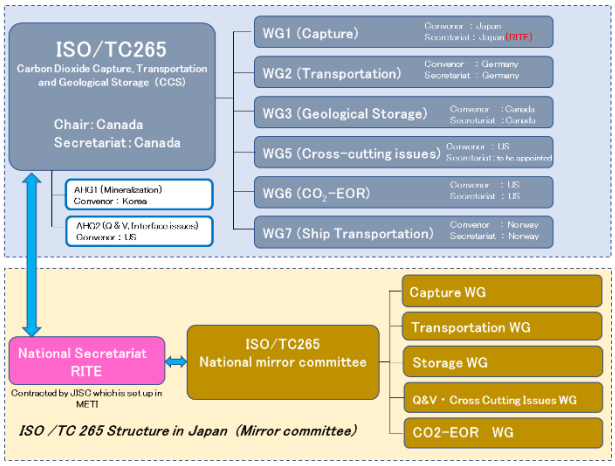

Figure 11 ISO/TC265 structure

4. Human development and industry collaboration

4.1. Human development

RITE conducts various human resource development activities to foster the next generation of re-searchers. Here, human resource development activities are explained separately for elementary, junior high and high school students and universi-ty/graduate school students.

<Elementary, junior and high school students>

It is important to educate the next generation about the issue of global warming. At RITE, we are: i) accepting field trips for elementary, junior and high school students using research facilities; we are working to respond to class requests. In 2023, 133 students from 6 schools visited RITE. In the class, CCS technology will be picked up from the research conducted by RITE, and the mechanism of global warming will be explained as knowledge, and the possibility of leakage through the clay layer (shielding layer) even if CO_2, which is the main greenhouse gas, is stored underground. In addition, activities are based on a learning cycle, such as deepening understanding through consideration and exchange of opinions (Figure 12).

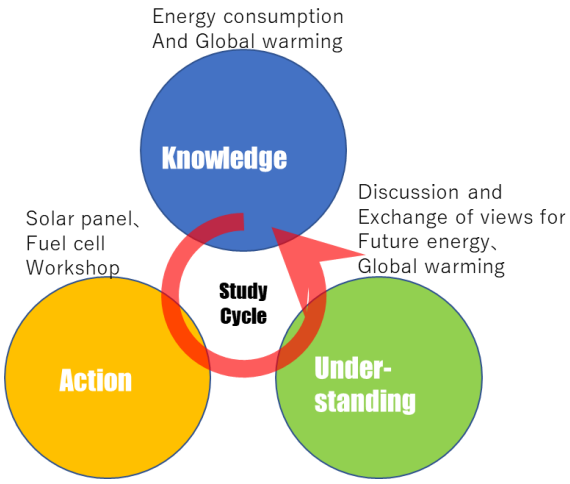

Figure 12 Human resource development by RITE
(Elementary, Junior and high school students)

<University & Postgraduate student>

As part of efforts to develop human resources who will support next-generation research and technology, RITE promotes educational partner-ships with universities and graduate schools. We are developing education at universities and re-search guidance at research institutes (Figure 13). For example, Nara Institute of Science and Technology (NAIST) has set up a university-collaborated laboratory in the bio-science field at RITE. We are promoting research and education aimed at realizing are cycling-oriented and low-carbon society using renewable resources. In addition, we have established a collaborative laboratory with the materials creation science area of the NAIST, and are promoting research and education on CO_2 separation and recovery technology.

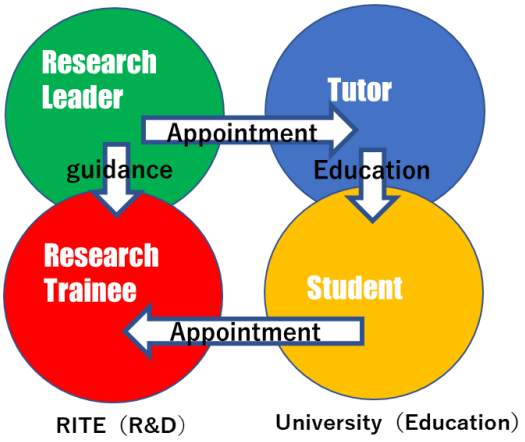

Figure 13 Human resource development by RITE (University & Post graduate students)

4.2. Intellectual property and industry collaboration

RITE strategically and efficiently acquires and manages intellectual property rights such as pa-tents and know-how regarding the results of re-search and development, etc., and actively utilizes them for the public interest. The aim is to advance and improve industrial technology that contributes to the conservation of the global environment.

The acquisition of such research results as intellectual property creates opportunities for industrial collaboration with companies, etc., and through joint research and joint applications, further intellectual property is generated through a virtuous cycle that contributes to society. At RITE, we focus on the di-verse functions of intellectual property rights and strategically promote intellectual property activities while taking into consideration the market and other research and development trends.

As part of the promotion of intellectual property strategies, the "Patent Deliberation Committee" was established with RITE executives as members and the public relations and industry collaboration team as the secretariat. The main agenda is the acquisition and management of intellectual property such as patent applications and examination requests, patent right maintenance, and intellectual property strategies such as approval of license agreements.

As of the end of March 2024, of the patents for which RITE is the sole or joint applicant, 16 domestic applications and 18 foreign applications are pending patent applications, and the registered rights are maintained. It holds 71 domestic patents (including 7 under license to companies) and 49 foreign patents (7 of which are licensed to companies).

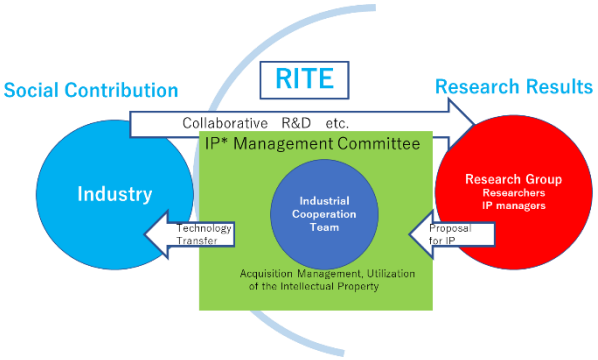

Figure 14 Strategic IP management and industrial collaboration

5. Conclusion

Toward the realization of carbon neutrality by 2050, the government has started the issuance of GX economy transition bonds and various GX promotion measures. With the enactment of the CCS Business Act, in addition, efforts have just been commenced to develop a business environment in which private companies are able to launch CCS business by around 2030. However, it is never easy to achieve carbon neutrality. To achieve this, RITE is required to play an active role in the social implementation of innovative environmental technologies. For practical application of CCS and other new technologies, it is essential to enhance public understanding. Taking advantage of the opportunity to display its DACCS (Direct Air Capture and Storage) technology at Expo 2025 Osaka, Kansai, Japan, RITE will make active efforts to enhance public understanding of

the need to achieve carbon neutrality and the importance of CCS.

We at the Research & Coordination Group will also actively collect information on domestic and overseas policies and technology trends. With an eye toward realizing carbon neutrality by 2050, we, together with research groups, will actively implement and promote technology development and PR activities as well as industry-university cooperation activities. We believe that through RITE's concerted efforts to promote the social implementation of innovative environmental technologies, we will be able to contribute to carrying out RITE's mission: "to achieve the balance between the global environmental protection and economic growth."

Reference

1) RITE, "The Role of RITE" (https://www.rite.or.jp/en/about/)
2) The Bill for the Act on Promotion of Smooth Transition to a Decarbonized Growth-Oriented Economic Structure (GX Promotion Act)
3) The Strategy for Promoting Structural Transition Based on Decarbonization (GX Promotion Strategy) (Cabinet approval on July 28, 2023)
4) Interim summary on "What Institutional Measures Related to CCS Ought to Be"
5) The Bill for the Act on Carbon Dioxide Storage Businesses (Cabinet approval on February 13, 2024) (https://www.meti.go.jp/english/press/2024/0213_003.html)
6) Final Summary by the CCS Long-Term Roadmap Study Group, Agency for Natural Resources and Energy (March 2024)
7) Mitsubishi UFJ Research and Consulting, Exchange Quotations, "Daily Exchange Quotations – since 1990," Checked in February 2024
8) Trade Statistics of Japan published by the Ministry of Finance, Exports and Imports Values by Commodity, World Monthly (Import), Checked in February 2024