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Research Efforts to Realize a Carbon-neutral Society

The Research and Coordination Group aims to i) searching for new research topics that enhance the research potential of RITE, proposing and implementing new research themes, ii) government support for the relation with international organizations such as IPCC (Intergovernmental Panel on Climate Change), ISO (International Standard Organization), iii) dissemination of RITE's technologies and Human development of the future generation iv) practical application of technology through industrial collaborative R&D, together with the research groups. These efforts lead to a creation of new policy implementation, R&D and innovation aiming at the global environment and the economy[1].

The office for EXPO 2025 Osaka, Kansai is founded in April, 2023 in order to introduce the carbon neutral technologies such as DAC, CCS as the innovative environmental ones that RITE has been implementing the Research and Development for many years. The staffs comprise the Research and Coordination Group, Chemical research group and CO2 Storage Research Group to communicate with the Japan Association for the 2025 World Ex-position and so on.

In 2022, the Clean Energy Strategy[2] was summarized in May, 2022 and showed the feasible paths to reduce greenhouse gas emissions by 46% in FY 2030 from its FY 2013 levels and realize a carbon-neutral, decarbonized society by 2050. Also, the Cabinet approved the

Basic Policy for the Realization of GX (Green Transformation)[3], so it is outlined at first.

1.1. Clean energy strategy

In May 2022, Advisory Panel of Experts of the Clean Energy Strategy summarized the interim report of the Clean Energy Strategy. The Chapter 1, based on Ukraine Crisis and electric stringency of energy supply and demand, summarizes the policy to secure the energy security and also accelerate the decarburization. The chapter 2 summarizes ①the industrial GX connecting to the decarbonization with the economy growth and development, ② the concrete approach of energy transform of industry, ③the concrete approach of the decarbonization of the area and life, and ④the policy to realize the GX.

This transformation for the carbon-neutral society is to transform economy, society and industrial structure consisted of fossil fuel since the Industrial Revolution to the center of clean energy. The in-vestment for the carbon neutral of 2050 is estimated with about 17 trillion yen in 2030, and about 150 trillion yen in the next ten years under the constant supposition (Table 1, Table 2).

Table 1 Investment amount for decarbonization

Investment amount for decarbonization

● Calucalated under certain assumptions about the investment amounts in major areas, the investment amount required for CN in 2050 will be approximately 17 trillion yen in 2030 alone and approximately 150 trillion yen in the next 10 years

Decarbonization-related investment	About 17 trillion yen per year	→ About 150 trillion yen in 10 years	
"Power source decarbonization / fuel conversion"	About 5 trillion yen	✓Renewable Energy	About 2 trillion yen
		✓Hydrogen/ammonia	About 0.3 trillion yen
		✓Manufacture of storage batteries	About 0.6 trillion yen
Decarbonization of manufacturing processes, etc.	About 2 trillion yen	✓Energy saving and decarbonization of manufacturing processes	About 1.4 trillion yen
		✓Introduction of industrial heat pumps, cogeneration equipment, etc.	About 0.5 trillion yen
end- use	About 4 trillion yen	✓Introduction of houses and buildings with high energy-saving performance	About 1.8 trillion yen
		✓Introduction of next-generation vehicles	About 1.8 trillion yen
infrastructure development	About 4 trillion yen	✓System enhancement cost	About 0.5 trillion yen
		✓ Infrastructure development for electric vehicles	About 0.2 trillion yen
		✓ Response to digital society	About 3.5 trillion yen
Research and development, etc.	About 2 trillion yen	✓Carbon recycling	About 0.5 trillion yen
		✓ Development of manufacturing processes that contribute to carbon neutrality	About 0.1 trillion yen
		✓Nuclear	About 0.1 trillion yen
		✓ Implementation of advanced CCS projects	About 0.6 trillion yen

Table 2 Step-by-step development of the GX League

GX League plan

GX League (supported by 440 companies)	Carbon credit market
✓ **Efforts in the GX League** ① Discuss and create a carbon-neutral sustainable future image for 2050 ② Discuss market creation and rule-making in the carbon-neutral era (example: certification system for zero-CO2 products, etc.) ③ Conduct voluntary emissions trading to achieve the goals set for carbon neutrality	✓ **Corporate origin** Value Credits reduced by GX League Participating Companies ✓ **Derived from the project** J-Credit JCM High-quality overseas volunteers credit (international standard credit), etc.

Issues for the gradual development of the GX League (example)

- How to implement emissions trading
- Mechanisms to further expand the number of supporters, including businesses with high emissions
- Setting more ambitious reduction targets and mechanisms to attract more investment to reduce emissions
- Mechanisms for GC market creation (initial demand, etc.)
- Increase the depth of transactions, expand the creation of absorption/removal credits, and appropriately respond to discussions on international carbon pricing and carbon credit trends overseas.

1.2. The basic policy for the realization of GX

In May, 2023, " Basic Policy for the Realization of GX - the roadmap of the next ten years -" was approved by the Cabinet. Advisory Panel of Experts of GX summarized the policy of the approach in the next ten year through GX implementation, to realize the achievement of greenhouse gas 46% reduction in FY 2030 and the international promise of the carbon neutral in 2050, to implement the trans-formation of the energy supply and demand structure to be connected for stable, cheap energy supply, to revolutionize industry and social structure of our country, and to realize the society which all nations including the generation can live with hope in the future.

Specifically, it is summarized as follows.

(1) Approach of GX to secure the energy steady supply

① Thorough Energy Efficiency Promotion

- The foundation of the Energy Efficiency subsidy which can support investment project of plural years
- For 5 main types of industry, the government shows the indication of the non-fossil energy transformation

② Main Power Supply of the renewable Energy

③ Nuclear Energy utilization

- Implementing the next-generation innovation nuclear furnace in the site to decommission the nuclear power plant

④ Other important matters

- Toward production and supply network construction of hydrogen / ammonia, the introduction of the support system based on the price differences of existing fuel

(2) Realization and implementation of such as "a growth-oriented carbon pricing"

① The forward investment support utilizing GX economy shift bonds

・GX economy shift bonds were founded and the forward investment of the 20 trillion yen scale for the next ten years was supported.

② GX investment incentive by the growth-oriented carbon pricing (CP)

③ Application of new finance technique

・the risk supplement plan (debt guarantees, etc.) in the social implementation stage of the GX technology.

④ International strategy, fair transformation, GX of small and medium Enterprises

・Realizing the implementation of "Asian Zero-Emission Community"

(3) A progress evaluation and necessary review

2. Research activities

In FY2021 and FY2022 (continuing project), the research project commissioned by the Ministry of Economy, Trade and Industry "Survey project on measures for stable fuel supply (Survey project on improving the CCS business environment and implementation roadmap toward carbon neutrality in 2050)" [4], and conducted a survey report at the "CCS Long-term Roadmap Review Committee" in FY2022, so the outline will be introduced in the below.

2.1. Hydrogen/Ammonia and trial calculation of thermal power plant cost with CCS[5]

In order to understand the positioning of CCS, we calculated the power plant cost when using decarbonized fuels (hydrogen (H_2), ammonia (NH_3)) produced by introducing CCS and the power plant cost when CCS is introduced into thermal power plant. The cost of power plant using H_2 and NH_3 was calculated by the Central Research Institute of Electric Power Industry based mainly on the results of literature research. The cost of thermal power plant with CCS was calculated by RITE based on the specifications of the Power Plant Cost WG[6] published in September 2021, in the case of transportation costs using a liquefied CO_2 transport ship. The Central Research Institute of Electric Power Industry is in charge of summarizing the results of these trial calculations. It should be noted that the prospects for technological progress and preconditions required for the cost estimation are arbitrarily set based on existing literature, etc., so it should be noted that the results of the estimation may change depending on future technological progress.

2.1.1. Trial calculation

Figures 1 and 2 show the images of the 10 cases calculated. The case of importing raw materials as fossil fuels such as natural gas and coal and using them in thermal power plants with CCS, the case where H_2 and NH_3 are produced overseas from natural gas and coal respectively, imported, and used in thermal power plants, and the case where H_2 is produced from domestically produced natural gas and used in a thermal power plant are calculated.

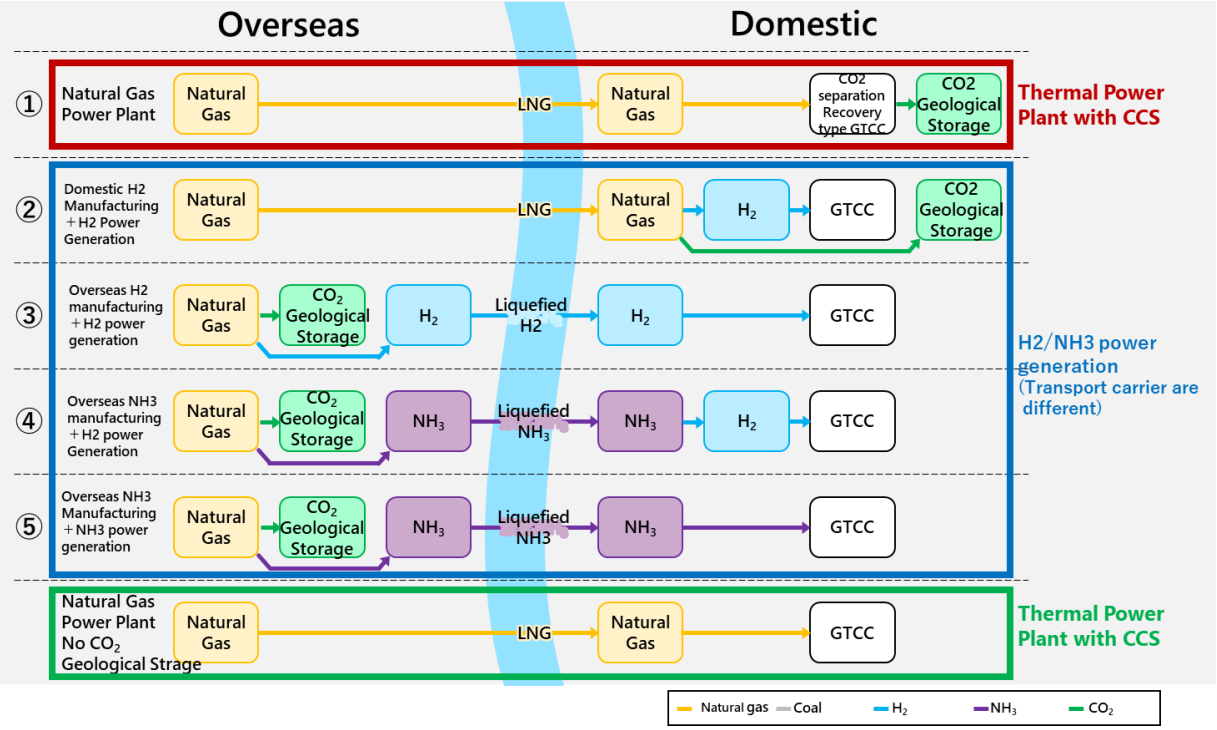

Fig.1 Trial calculation case of overseas natural gas + CO_2 underground storage[5)]

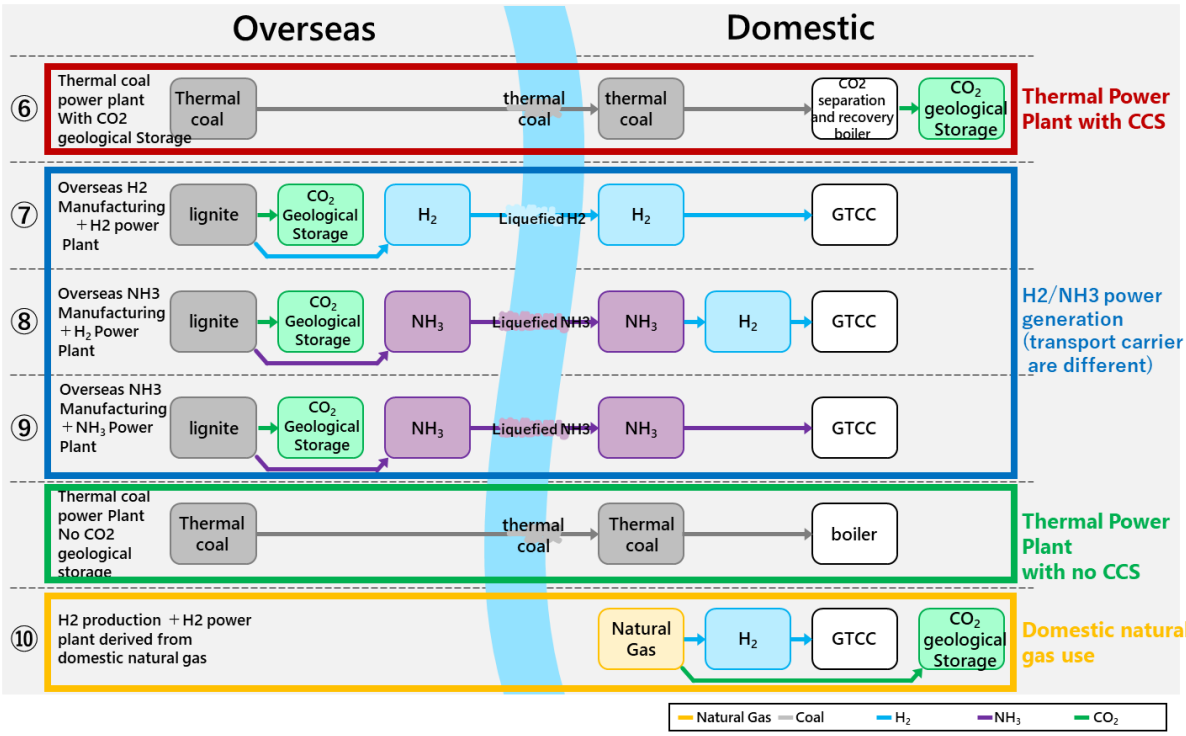

Fig.2 Trial calculation case of overseas coal, domestic natural gas + CO_2 underground storage[5)]

2.1.2. Trial calculation result

The trial calculation results are sorted by capital cost, operation and maintenance cost, fuel cost, social cost and policy cost. Social costs are CO_2 transportation and underground storage costs in Japan and overseas, including CO_2 transportation and underground storage

costs during H_2/NH_3 production. Policy costs are costs covered by taxes, etc. required for each type of power source, such as the budget for technology development.

Regarding the results of this trial calculation, the power plant cost of thermal power plant with CCS (natural gas; ①, coal; ⑥) is cheaper than that of H_2/NH_3 power plant (natural gas; ②～⑤, ⑩, coal; ⑦～⑨). The reason is that under the conditions set this time, the transportation cost of natural gas and coal is cheaper than the transportation cost of liquefied H_2 and liquefied NH_3, and the cost of producing H_2 and NH_3 from natural gas/coal (energy loss, etc.) is higher than the CCS cost added to thermal power plant.

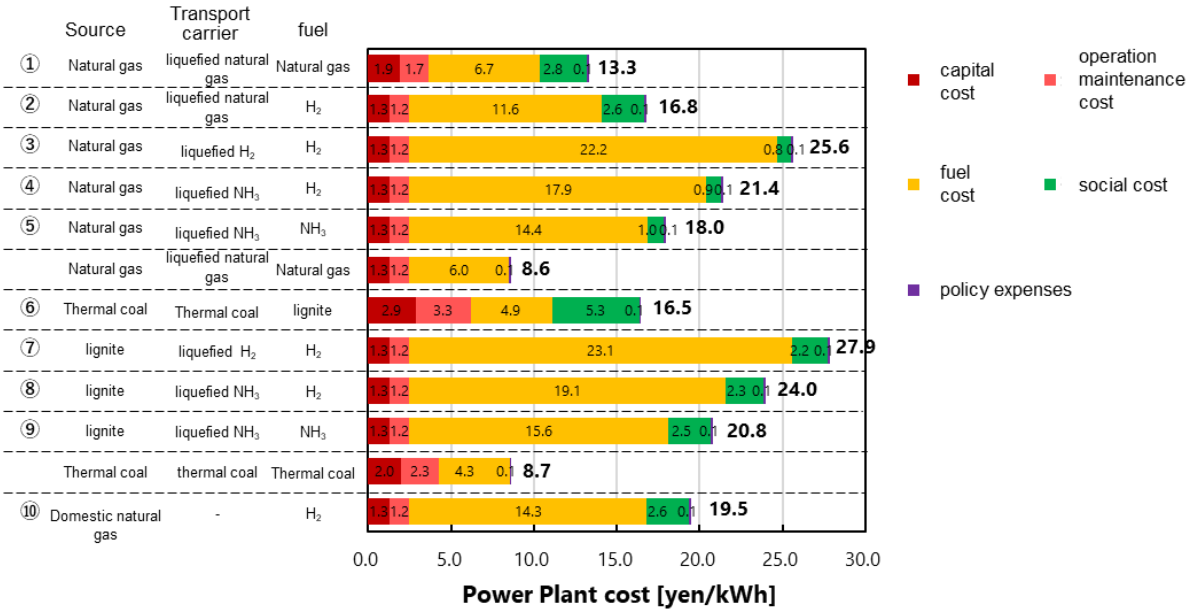

Fig.3 Trial calculation case of Power Plant Cost[5)]

2.2. Overseas examples of frameworks for the spread of CCS[7)]

We investigated overseas cases to consider the introduction of CCS in Japan.

In many cases, the spread of CCS requires incentive measures that can ensure the predictability of the business. In particular, when CO_2 storage is aquifer storage, unlike enhanced oil recovery (EOR), business profits cannot be expected, so sufficient incentive measures are essential.

2.2.1. Overseas examples of incentive measures and regulations

Regarding incentive policies and regulations for overseas commercial CCS projects, as a result of re-searching projects in Norway, Alberta, Canada, Saskatchewan, the United States, Australia, the United Kingdom, and the Netherlands, direct subsidies to CAPEX and OPEX mainly consist on combine support. Regarding OPEX support, except for the United States, which has introduced tax credits, many nations have introduced that emission credits are exempted or granted, and carbon taxes are exempted, but not direct subsidy. Since all of these aids are intended for pre-ceding projects, they are generous subsidies, and the subsidy rate is estimated to be around 100%.

Table 3 Overseas cases of regulations and incentives[7)]

	CAPEX Support	Operational Support	Subsidy Rate
Norway Longship	・Direct Subsidy	・10-years Direct Subsidy ・Emission credit exemption or provision	Direct Subsidy 67% + Emission credit exemption・grant20%
Canada Alberta Quest	・Direct Subsidy	・10-years Direct Subsidy ・Carbon Tax Exemption ・Double Offset Credit of CO2 Storage	100%
USA	・Direct Subsidy (under consideration) ・Low-interest loans for pipelines (under consideration) ・Investment tax credit for clean coal ・Obligation guarantee for fossil fuel CCS	・Tax credit according to storage amount (or use amount)	unknown
Australia Moomba	・Direct Subsidy (small amount)	・Carbon credit exemption ・Granting carbon credits for 25 years	>100% (25 years)
England Hub&Cluster	・ Direct Subsidy for transport/storage and industrial CCS, and thermal power CCS	・Various subsidies. 15 years for industry ・Emission credit exemption ・Transportation/storage: Collection of usage fees	100% + α (15 years)
Netherland Porthos	・Direct Subsidy in EC (Equivalent amount reduced from SDE++)	・Fixed-price purchase for 15 years ・Emission credit exemption ・Transportation/storage: Collection of usage fees	100% + α (15 years)
Canada Saskatchewan BD3	・Federal Direct Subsidy ・Public funding by state governments	・Transfer to electricity charges	100%

Table 4 Features of Overseas regulations and incentives[7)]

Scheme	Analysis	Remarks
CAPEX Support	Direct subsidies are basically for advanced projects.	Invest in businesses with high ripple effects.
	The government faces the risk of non-operation. Early recovery of investment for businesses.	In Quest, Alberta, to avoid non-operating riskImplement CAPEX payment in 8 stages.
	For investment tax reduction, the amount of tax paid must be greater than or equal to the amount of tax reduction. Investment tax cuts are unfavorable to start-up companies.	
Operational Support	High compatibility with existing schemes.	
	Direct subsidies are basically for advanced projects.	Invest in businesses with high ripple effects.
	Retained tax credit must be taxable amount ≥ tax reduction amount.	In the 45th quarter of the United States, there was a movement to subsidize unspent credits.
	Tax credits reduce revenue.Emission credit exemption and carbon tax exemption do not increase or decrease revenue.	US EOR is $70/bbl due to royalty and corporate tax increases Excess revenue.
	Price drop risk for emission credits.	If carbon prices fall below a certain level in the UK and the Netherlands,Introduce a carbon tax.
Financing assistance	Only advantages for business operators. Large operational burden on the administrative side.	The U.S. DOE has a department specializing in debt guarantees.

2.2.2. Toward the introduction of CCS in Japan

Many of the commercial CCS in operation overseas are injected into oil fields (locations with a lot of underground information) for the purpose of EOR from emission sources that separate high concentrations of CO_2 in existing processes[8)]. Based on this situation, it is thought that the total investment amount will be reduced by combining CCS implemented in Japan with less additional cost for separation and recovery and storage site development, making CCS more acceptable. CCS with such a combination can be a powerful candidate, especially in the early days of its spread.

However, the emission source that separates CO_2 at

high concentration in the existing process is considered to be relatively small (scale of tens of thousands of tons per year), which is assumed to be higher than CCS from a large emission source (scale of several million tons per year). CCS is an external diseconomy and cost reduction is essential. Therefore, in order to aim for the widespread spread of CCS in the future, it is necessary to consider a hub and cluster that accumulates CO_2 emitted from multiple emission sources, transports and injects it as a shared infrastructure. By adopting a hub and cluster, we can expect cost reductions through economies of scale, and we can also expect to reduce cross-chain risk*1 because multiple businesses participate.

Whether introducing small-scale emission sources or introducing large-scale emission sources, in any case, for the spread of CCS, it is necessary to develop incentive measures for business operators working on CCS to be able to decide investment.

*1 Cross-chain risk: The risk that the suspension of operation of any of the collection, transportation, or storage chains will force the suspension of all chains.

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) (Fig. 4). The IPCC released the WG1 contribution to the Sixth Assessment Report in August 2021, followed by the release of the WG2 and WG3 Report in February and April 2022 respectively, and the Synthesis Report was released in March 2023. The Seventh Assessment cycle will start, beginning with the IPCC session scheduled to be held in July. RITE has also been supporting METI through information gathering, analysis, report, advise, etc.

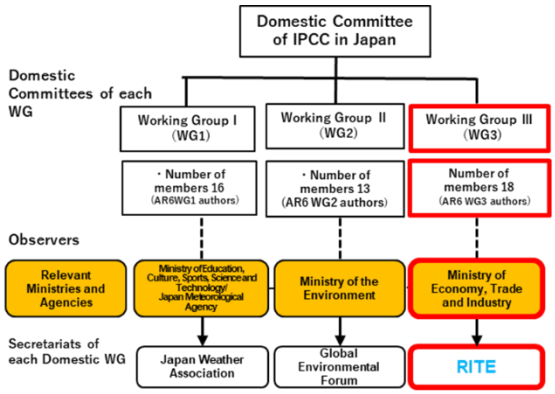

Fig.4 Committee structure and RITE

3.2. ISO

ISO (International Standard Organization) is an organization composed of 168 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 international

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 (capture, transportation, and geo-logical storage of CO_2) 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 (Fig. 5).

As of the end of March, 2023, twelve standards related to the CCS have been published from ISO / TC265. Currently TC265 as a whole are becoming more active as seven documents are under development including three new projects started in 2022 and two systematic review projects. In particular, CO_2 ship transportation is attracting attention as a powerful means of transportation from emission sources to CO_2 storage site. WG7 has been newly established to deal with issues specific to CO_2 ship transportation, and the development of standards has been started.

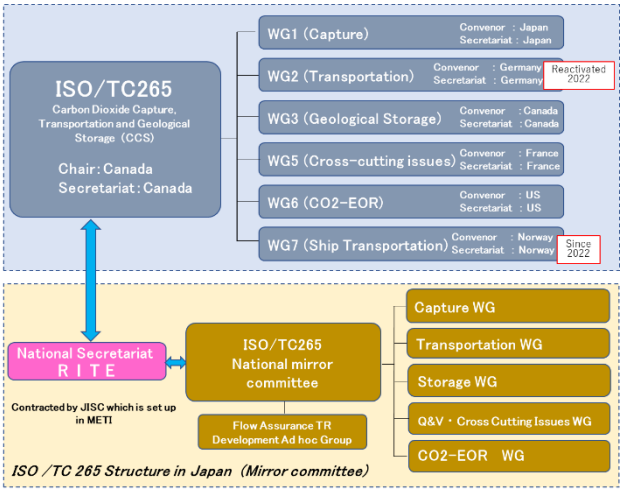

Fig.5 ISO/TC265 structure

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 university/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 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 (Fig. 6).

However, in 2022, as in 2021, the number of students remained at 58 due to the impact of the new coronavirus (54 in 2021), but classes and workshops have resumed, and we plan to actively respond in the future.

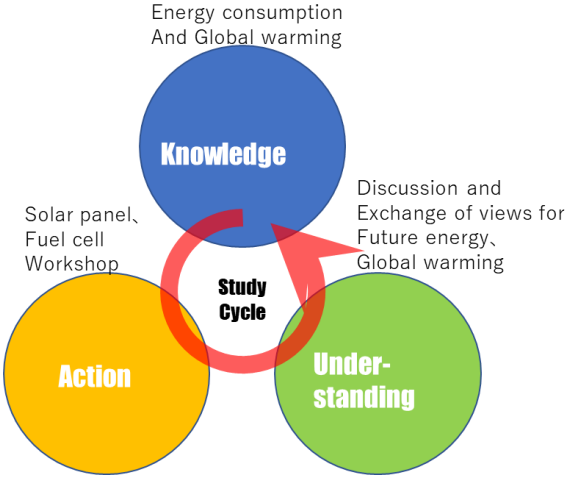

Fig.6 Human resource development by RITE
(Elementary, Junior and high school students)

<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 (Fig. 7). For example, Nara Institute of Science and Technology (Nara Institute of Science and Technology) 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, and are promoting research and education on CO_2 separation and recovery technology.

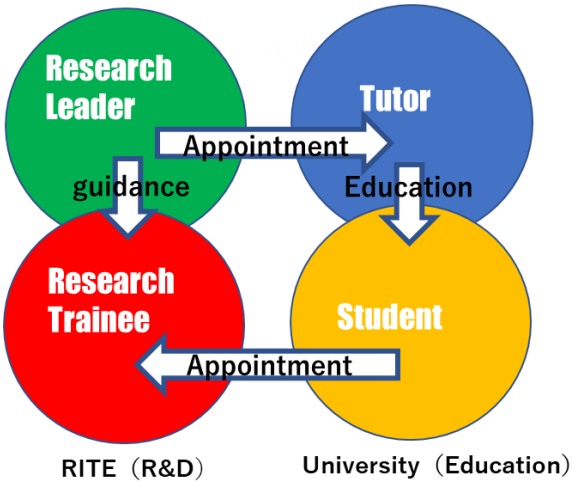

Fig.7 Human resource development by RITE (University & Post graduate students)

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 diverse 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 2022, of the patents for which RITE is the sole or joint applicant, 17 domestic applications and 16 foreign applications are pending patent applications, and the registered rights are maintained. It holds 72 domestic patents (including 8 under license to companies) and 52 foreign patents (12 of which are licensed to companies).

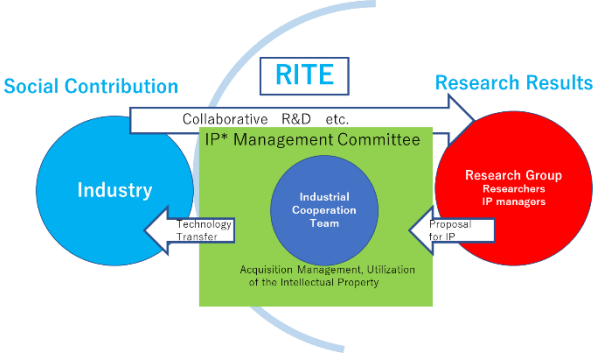

Fig.8 Strategic IP management and industrial collaboration

5. Conclusion

In April 2023, RITE established the office for Expo 2025 Osaka Kansai, and is considering exhibiting negative emission technology (Direct Air Carbon Capture and Storage: DACCS) at EXPO 2025 Osaka Kansai.

To realize 2050 Carbon neutrality is almost im-possible with ordinary efforts, and RITE needs to make maximum efforts to spread carbon neutral technologies. In December 2021, RITE conducted the recognition survey of DACCS, and found that nearly 70% said they did not know anything about DACCS. RITE would like to make maximum efforts to increase the public recognition of DACCS technologies at EXPO 2025 Osaka Kansai.

The Research and Coordination Group not only collects domestic & foreign policy and technology information, but promotes the technology development in order to aim the social implementation in 2050 with Research Group. Thereby, RITE can contribute to the achievement of "a balance be-tween the global environmental protection and economic growth".

Reference

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