

Contents

1. Outline
2. Trends in carbon recycling
3. The importance of carbon recycling, the roles of the Carbon Recycling Fund Institute (CRF), and its progress to date
4. Advice for realizing a sustainable carbon recycling system
5. Summary

Attachment 1. CRF members' reports on activities

Attachment 2. Results of the questionnaire targeting CRF members

Attachment 3. Overview of the CRF

1. Outline

■ Trends in carbon recycling

World

- Nov. 30–Dec. 13, 2023 COP28 in Dubai, UAE
- Jul. 2023 Release of a draft for the End of Life Vehicle (ELV) Directive (European Commission)
- Apr. 2024 Intergovernmental Negotiating Committee on Plastic Pollution (INC) in Ottawa, Canada
- Compliance with the Corporate Sustainability Reporting Directive (CSRD) made mandatory from FY2024 reports

Japan

- May 2023 Enactment of the GX Promotion Act
- Jun. 2023: Revision of the Carbon Recycling Roadmap
- Dec. 2023 Foundation of the Circular Partners, an industry-government-academia partnership
- May 2024: Passing of the Bill for Promoting the Supply and Use of Low-Carbon Hydrogen and Other Resources for a Smooth Transition to a Decarbonized Growth-Oriented Economic Structure (Hydrogen Society Promotion Bill) and the Bill on Carbon Dioxide Storage Projects (CCS Project Bill)
- Jul. 2024 Launch of the GX Acceleration Agency

■ Roles of the Carbon Recycling Fund Institute (CRF) and its progress to date

* Roles of the Carbon Recycling Fund Institute (CRF):

This year marks the fifth anniversary of the Carbon Recycling Fund Institute (CRF) established in August 2019 with the mission of supporting the creation and social implementation of innovation that contributes to carbon recycling by carrying out public relations activities, providing research grants, issuing policy recommendations, and more. The aim is to address both the problems of global warming and global energy access.

* Progress of activities from 2023 to July 2024:

- **Research grant activities:** In FY2024, the CRF selected 14 projects (including three startup projects) from 104 applications. Over the five years from FY2020 to FY2024, the CRF has provided 430 million yen in grants.
- **Workshop for realizing a carbon recycling society**
 - FY2022 (1) Organized in Takehara, Hiroshima Prefecture.
 - FY2023 (2) Organized in Omuta, Fukuoka Prefecture.
 - (3) Started and currently continued in Sakata, Yamagata Prefecture.
- **Carbon Recycling University:** Seminars have been provided for personnel who will lead future carbon recycling in each member company since FY2021. In FY2023, 19 people attended.
- **Awareness-raising activities for the public:**
 - (1) Tale of Carbo and Risa (cartoon): Carbo and Risa, high school students in the year 2222, when sustainable carbon societies are commonplace, together with Sasuke the Ninja Owl, travel through time to around 2022 and learn about the efforts devoted to innovation and the passion of people involved in it. At the end of FY2023, the CRF released a story about general trading companies that

are focusing on supply chain creation, as well as **the English version** in July 2024 **for the English website**.

- (2) Event “Let’s learn about carbon dioxide by making bath bombs”：The CRF organized a spring vacation science class with the help of the Association for Technological Excellence Promoting Innovative Advances (TEPIA).

• **Messages from the CRF’s leaders**

- May 2023 Video speech by then-Chairperson, Mr. Fukuda, at the 8th STI Forum
- Oct. 2023 Speech by Chairperson, Mr. Mitsuoka, at the 5th International Conference on Carbon Recycling 2023
- Feb. 2024 Presentation titled “Vision and Challenges of Carbon Recycling to Realize a Carbon Recycling Society” by then-Vice-Chairperson, Mr. Koji Eguchi, during Smart Energy Week

• **Activity for CO₂ sinks**

The CRF started as a forestation activity in April 2023. In June 2023, a fast-growing paulownia plantation event took place in Saitama Prefecture. In FY2024, the CRF renamed this as the activity for CO₂ sinks. In FY2023, the CO₂ Sinks Study Group had three meetings ((1) green carbon, (2) blue carbon, and (3) biochar).

• **Creation of matchmaking opportunities with startups**

- May 2024 The CRF co-hosted a matchmaking event, “Create the Future with Carbon Cycle! Interdisciplinary Exchange for Open Innovation 2024” with Chubu TLO (Nagoya Industrial Science Research Institute) and the Carbon Value Research Center (Research Institute for Science and Technology, Organization for Research Promotion, Tokyo University of Science).

■ **Recommendations for realizing a carbon recycling society**

(1) Develop and promote innovation

The national government should provide solid and continuous support for private companies.

The CRF should engage in cross-industry coordination, including coordination with startups, and take full advantage of open innovation to achieve carbon neutrality by 2050.

(2) Create CO₂ value chains

The national government should promote measures across the ministries that provide incentives, such as offering premiums for products and services.

The CRF should establish the importance and roles of carbon recycling technologies and products through social implementation and promote the creation of CO₂ value chains that contribute to the valuation of CO₂. Both CO₂ suppliers and users should share exit strategies for CO₂-derived products.

(3) Integration with regional revitalization and expansion to the global market

The national government should strengthen support for creating examples of CO₂ value chains.

The CRF should consider local CO₂ recycling systems through collaboration with local governments. The main goal is to revitalize the agriculture, forestry, and fishing industries.

(4) Develop human resources

The national government should introduce carbon neutrality and carbon recycling in school education.

The CRF should make efforts to raise public awareness and deepen their understanding through public relations and other activities.

■ Summary

The importance of carbon recycling to use CO₂ as a resource is rising as Japan has started making steady progress towards achieving carbon neutrality by 2050, as exemplified by the launch of the GX Acceleration Agency in July 2024. To achieve carbon neutrality not only in Japan but also across the world, the CRF will continue to commit to industry-academia-government collaboration through efforts, including public relations activities, research grant activities, CO₂ sink activities, and social implementation workshops. At the same time, the CRF aims to play a main role in realizing a carbon recycling society with a view to international collaborations as well.

2. Trends in carbon recycling

The world is in the midst of an unpredictable situation as the end of the Russia-Ukrainian War is unforeseeable and Israel launched an incursion into the Gaza Strip controlled by Palestine in October 2023. As the risk of depending on certain countries or regions for energy resources is reaffirmed in this context, climate change remedies and movement towards carbon neutrality are continuing. In COP28 held in Dubai, UAE, from November 30 to December 13, 2023, the consensus document included accelerating the shift from fossil fuels in energy systems over the next 10 years to triple global renewable energy generation capacity by 2030 and enhancing efforts to phase out coal-fired plants without CO₂ reduction measures. It was also decided that a fund for global stocktaking and for dealing with loss and damage should be established to assess global progress. The Intergovernmental Negotiating Committee on Plastic Pollution (INC), which was established at the United Nations Environment Assembly in March 2022 and will have a legal binding power until the end of 2024, held its fourth meeting in Ottawa, Canada in April 2024.

In Europe, compliance with the Corporate Sustainability Reporting Directive (CSRD) demanding large enterprises and listed companies to periodically report the risks of social challenges and environmental issues that they face and how their business activities impact society was made mandatory from FY2024 reports based on the EU law. The EU is also considering the revision of the Ecodesign for Sustainable Products Regulation (ESPR) for sustainable products to extend and replace the Ecodesign Directive established in 2009. The revised ESPR will apply to all products (except for automobiles, food, animal feed, medicine, etc.) in the EU market, in addition to energy products covered by the current directive, and will introduce a wide range of sustainability requirements.

The European Commission also released a proposal for the ELV Regulation in July 2023 to extend and replace the current End of Life Vehicle (ELV) Directive, targeting vehicles ahead of other industries. This proposal includes improving recyclability in terms of design, manufacturing, and disposal, employing design that is easy to reuse and recycle, and requiring a minimum inclusion of recycled materials to achieve EU climate environment goals and reduce dependence on resources outside the EU.

The GX Promotion Act (Act on the Promotion of a Smooth Transition to a Decarbonized Growth-Oriented Economic Structure) was enacted in Japan in May 2023. Policies for carbon neutrality such as clean energy strategies have been formulated and updated and businesses, municipalities, and academia are taking measures accordingly.

The Japanese government revised the Carbon Recycling Roadmap in June 2023. Carbon recycling is positioned as a key technology for reducing CO₂ emissions throughout the supply chain of products, etc. and

helping to realize a carbon-neutral society by 2050. The government changed its plan, bringing forward the start widespread use of carbon recycled products (general-purpose products) to around 2040, and estimated the potential of CO₂ recycling through carbon recycling to be about 100 to 200 million tons as of 2050 (equivalent to carbon recycled products used in Japan).

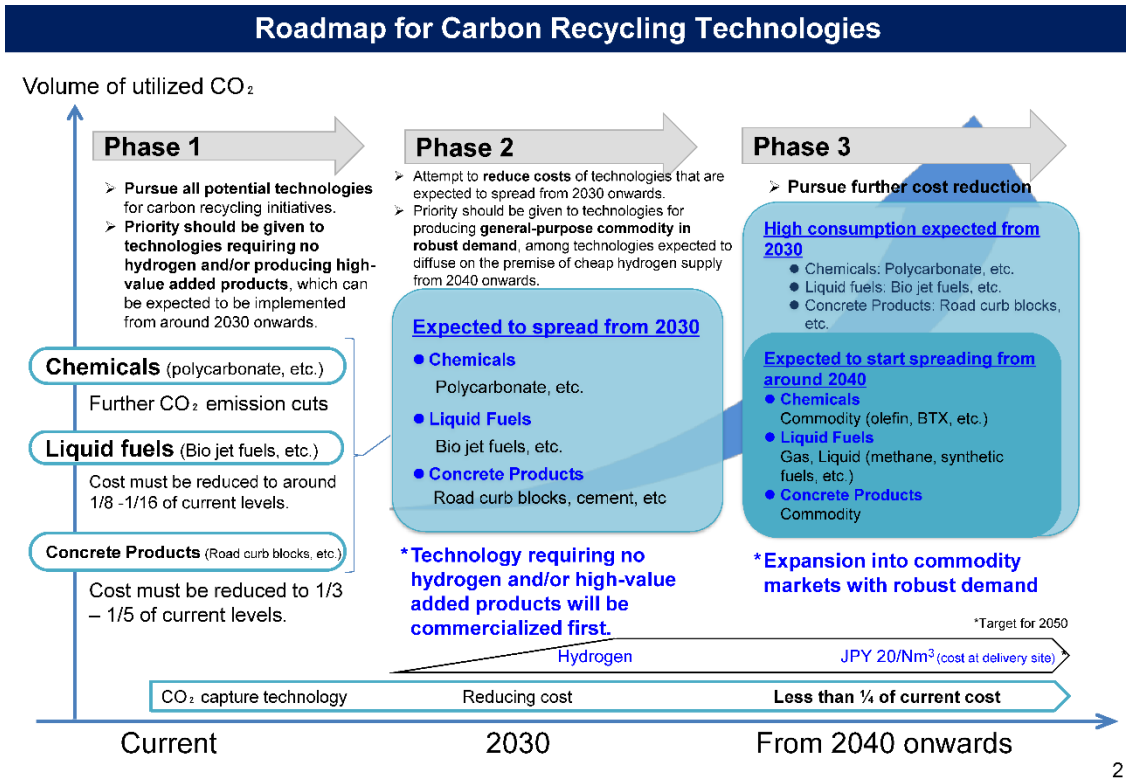


Figure 1. Ministry of Economy, Trade and Industry – Plan for expanding carbon recycling
Source: Ministry of Economy, Trade and Industry website

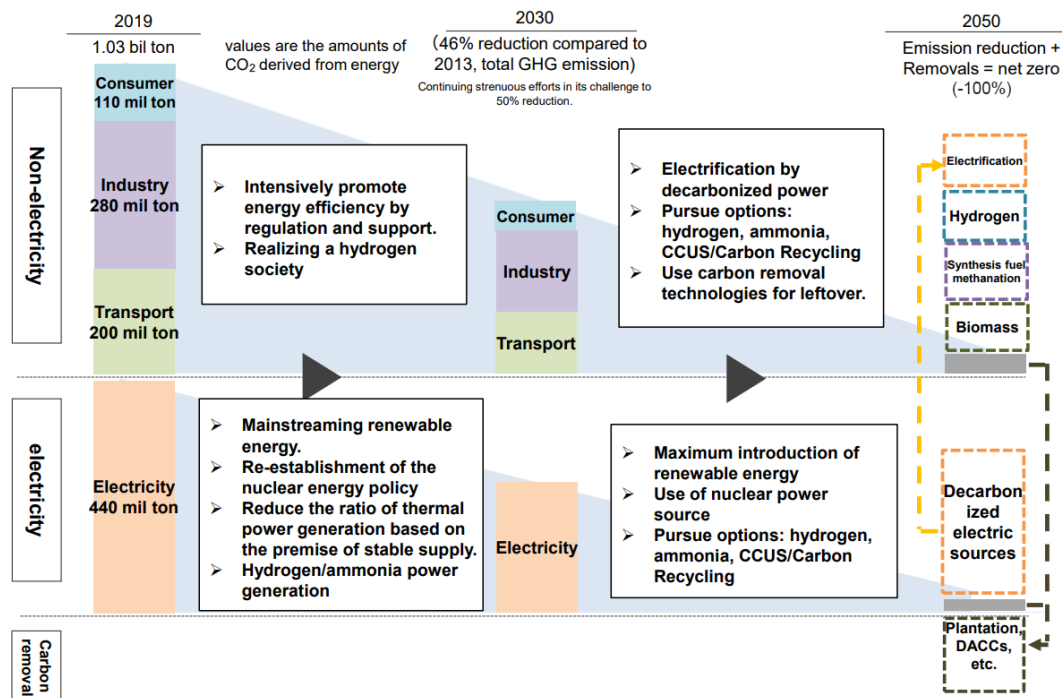


Figure 2. Ministry of Economy, Trade and Industry – Forecast of energy-derived CO₂ emissions
Source: Ministry of Economy, Trade and Industry website

An urgent challenge is the transition to a circular economy to maximize the added value through resource recycling in the context of resource demand and geopolitical risks, in addition to environmental restrictions such as waste and climate change issues. The Ministry of Economy, Trade and Industry founded an industry-government-academia partnership called the Circular Partners in December 2023 based on a comprehensive policy package created in March 2023, “Economy Strategy for Growth-Oriented and Self-Sufficient Resources.” This partnership aims to create a vision and roadmap, launch an information platform, and establish a local recycling model to achieve a circular economy for 2030 and 2050.

Furthermore, the GX League also started full-fledged activities in FY2023, releasing emissions reduction goals for FY2025 and FY2030 and starting voluntary emissions trading. In February 2024, the first GX Economic Transition Bonds equivalent to 1.6 trillion yen in total were issued. There are plans to issue GX Economic Transition Bonds equivalent to 20 trillion yen for 10 years, which are expected to prompt decarbonization investments of 150 trillion yen in the public and private sectors. The GX Acceleration Agency was founded based on the GX Promotion Act enacted in February 2023 to financially support GX investments by private companies, collect fossil fuel tax, etc., and operate the emissions trading system (including the allocation of emission quotas and bidding) and was launched in July 2024.

In May 2024, the Bill for Promoting the Supply and Use of Low-Carbon Hydrogen and Other Resources for a Smooth Transition to a Decarbonized Growth-Oriented Economic Structure (Hydrogen Society Promotion Bill) and the Bill on Carbon Dioxide Storage Projects (CCS Project Bill) were approved by the Cabinet, which led to measures to expand the supply of hydrogen essential to carbon recycling and the establishment of regulations to set up a business environment for CCS businesses.

3. Roles of the Carbon Recycling Fund Institute (CRF) and progress to date

Many carbon compounds containing CO₂ are essential for maintaining the Earth’s systems, including life itself. For example, greenhouse gases, including CO₂, protect the Earth’s environment from the harsh cold of space. Plants use CO₂ to synthesize carbon compounds and provide them to nature; indeed, our own bodies are made up of carbon-based substances. The carbon cycle is a vital part of the atmosphere, land, and seas.

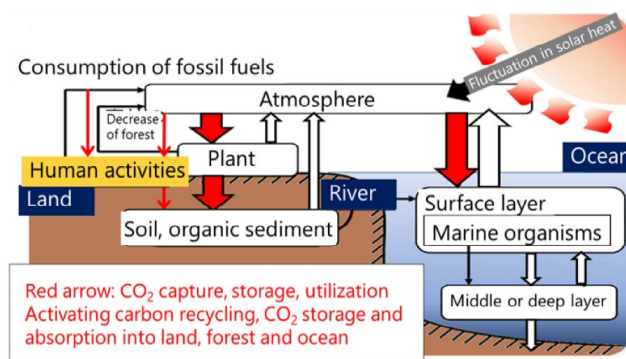


Figure 3. Model of the Earth’s carbon cycle

Source: Created by the Carbon Recycling Fund Institute based on materials from the National Institute for Environmental Studies, Center for Global Environmental Research

What we must aim to do is achieve the 1.5°C target and go beyond that to create truly sustainable socioeconomic systems. To do so, we must not look at CO₂ as an enemy but instead restore and maintain our planet’s health by creating carbon recycling societies that are based on the idea that CO₂ is a resource to be circulated and utilized. Based on this comprehensive approach, it is vital that we identify and capture CO₂ produced through social and economic activities. We need to make dramatic changes to our energy production and utilization, including developing and introducing renewable energy and transforming our lifestyles. We must switch to the use of value-added materials for the materials that are indispensable for our societies and economies, such as concrete and chemicals. Furthermore, we must harness the power of nature in industries such as agriculture, forestry, and fishing while fixing CO₂ and turning it into a resource by capturing and storing it. Transforming it into a value-added product and creating a market for it is crucial, which will require promoting integrated initiatives that take the entire CO₂ value chain, including CCS and hydrogen, into account.

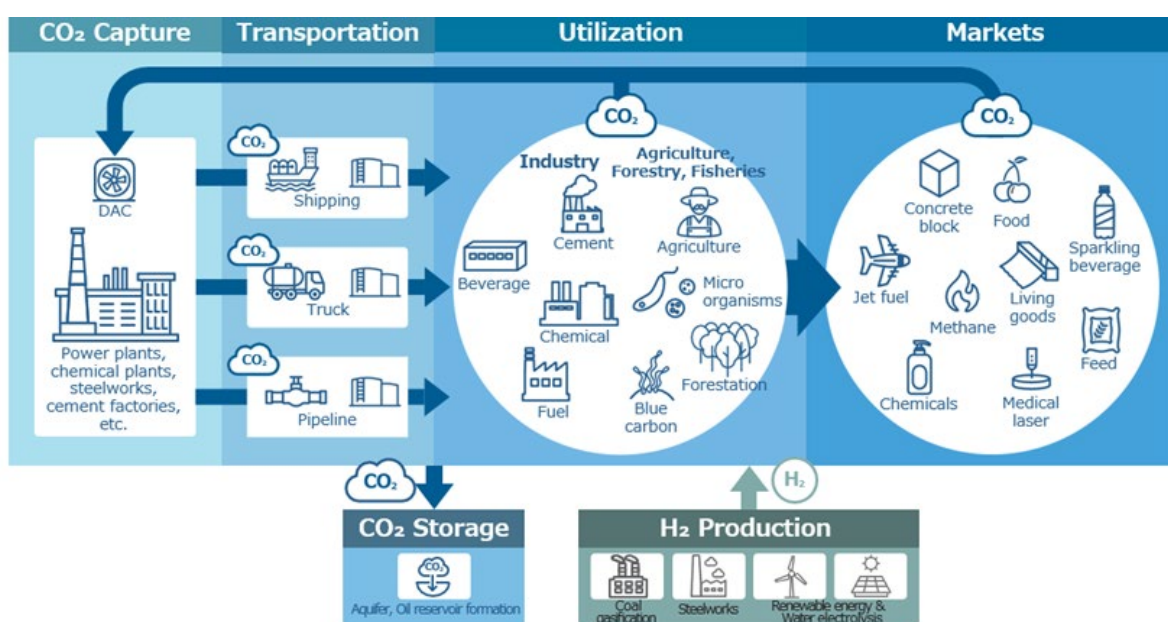


Figure 4. Conceptual image of the CO₂ value chain used in realizing carbon recycling societies
 Source: Carbon Recycling Fund Institute materials

In August 2019, members from 15 corporations established the Carbon Recycling Fund Institute (CRF) with a mission of supporting the creation and social implementation of innovation that contributes to carbon recycling by carrying out public relations activities, providing research grants, issuing policy recommendations, and more. The aim is to address both the problems of global warming and global energy access. The purpose of the CRF is to serve as a platform through which stakeholders can work to achieve carbon neutrality and create carbon recycling societies (sustainable carbon systems), led by the key concept of carbon recycling, and to facilitate related activities.

Now, five years since its establishment, the CRF has 214 members who support its goals and participate in its activities (143 corporate members, 19 local governments, 28 academic members, and 30 individuals, as of October 2024). The CRF serves as the foundation through which the private sector will implement carbon recycling policies, the heart of the Green Growth Strategy Through Achieving Carbon Neutrality by 2050 announced by the Japanese government.

■ [Example of progress: research grant activities]

Through its research grant activities, the CRF supports research and development on carbon recycling by academia, established businesses, and startups that are both unique and innovative, and measures that contribute to the steps that lie beyond this: verification testing and actual implementation in society. Specifically, research grants are provided to both individual researchers and research teams in a broad range of fields related to carbon recycling, such as CO₂ separation and capture, conversion to fuels and chemicals, mineralization, social science-related research, research related to CO₂ sinks (soil, forests, blue carbon, biological use, agriculture, forestry, and fishing industries), hydrogen creation, geoengineering, functional materials, medical fields, and more.

	Features
Eligibility	Researchers or teams affiliated with companies, universities, etc. A startup support framework newly established in FY2022
Research targets	Research on carbon recycling that uses CO ₂ (or carbon atoms) as a resource, related technologies, and social science to solve social issues <Expected Fields> 1. CO ₂ fixation by mineralization (materials such as concrete) 2. Conversion to fuels 3. Conversion to chemicals 4. Separation and recovery (including direct-air capture) 5. Social science 6. Utilization of CO ₂ sinks (soil, forests, blue carbon, biologics, agriculture, forestry and fisheries) 7. Other (H ₂ production, geo-engineering, functional materials, medical fields, etc.)
Evaluation points	Creativity, innovativeness, superiority over conventional technologies, method to determine issues, and social realization potential through collaboration with companies
Grant scale	Approx. 10 million yen per case (average: approx. 7 million yen per case)
Number of applications and accepted cases	FY2020~FY2022 : (total) 165 applications → 40 accepted FY2023: 56 applications → 15 accepted and 31 applications for startup support → 2 accepted FY2024: 78 applications → 13 accepted and 26 applications for startup support → 1 accepted
Attribution of research results	Research results basically belong to researchers

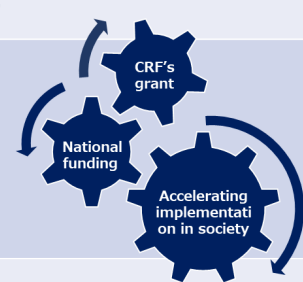


Figure 5. Overview of the Carbon Recycling Fund Institute’s research grant activities
 Source: Carbon Recycling Fund Institute materials

The CRF selected 40 (including three startup projects) from a total of 165 applications for the three years from FY2020 to FY2022; 17 (including three startup projects) out of 87 applications in FY2023; and 17 (including three startup projects) out of 104 applications in FY2024. Over the five years from FY2020 to FY2024, the CRF has provided 430 million yen in grants.

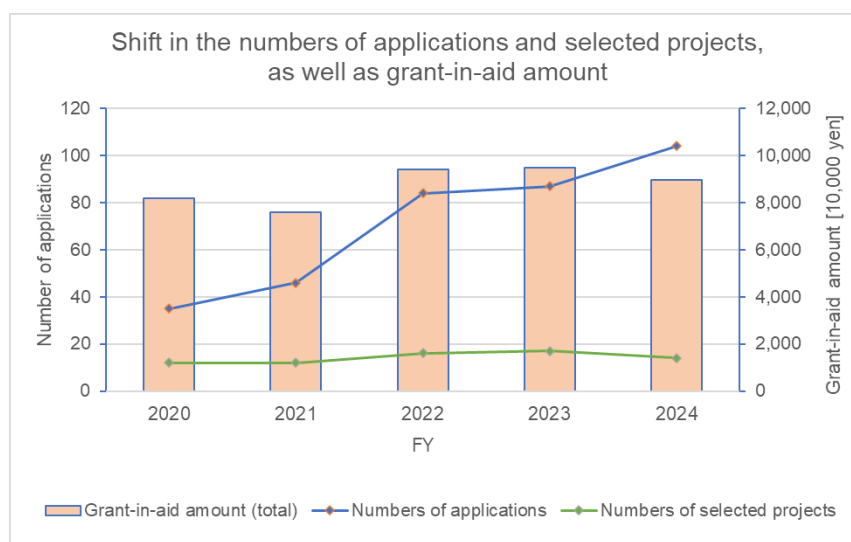


Figure 6. Shift in the numbers of research grant applications and selected projects as well as grant-in-aid amount

Source: Carbon Recycling Fund Institute materials

14 Projects Adopted in FY2024

Field	Research title	Name of Research Representative (Organization)
CO2 separation and capture	Development of DAC system with high CO2 concentration by zeolite-based pressure swing	Kenta IYOKI (Planet Savers Inc.)
	Investigation of Ion-gel Membranes for Direct Air Capture	Yu KANASAKI (AIST)
CO2 storage	R&D on CO2 fixation technology into the goaf of a closed coal mine	Shohei TAKEUCHI (Mikasa City, Hokkaido)
Conversion to fuels or chemicals	Methanol production by electrolytic CO2 reduction using 1 nanometer copper cluster	Tokuhsa KAWAWAKI (Tokyo University of Science)
	Closing the carbon cycle by using ammonia energy to produce olefins from CO2	Martin KELLER (AIST)
	Development of a Chemical Reactor to Produce Synthetic Hydrocarbon Fuels from CO2 Using an Internal Combustion Engine	Tadanori YANAI (Shizuoka Institute of Science and Technology)
Social sciences	Lifestyle measures to promote lower carbon emission and higher birth rate	Hidenori KOMATSU (Central Research Institute of Electric Power Industry)
Circulation of carbon resources	Resource Recovery of Waste Plastics through Photoreforming	Haruki NAGAKAWA (Ibaraki University)
	[Startup support framework] Catalytic plastic depolymerization and organic waste decomposition into hydrogen	Tadashi KUBO (AC Biode)
Utilization of CO2 sinks	Sugar production on both land and sea by sugar corn, sugar sorghum and sugar eelgrass	Ryushiro KASAHARA (Nagoya University)
	Elucidating the mechanisms and quantifying carbon capture in next generation seaweed farms	Gregory N. NISHIHARA (Nagasaki University)
	Cultivation of biofuel plants for revegetation of abandoned coal mine sites	Shin OKAZAKI (Tokyo University of Agriculture and Technology)
	Development of a forest DX management system that contributes to judgment criteria for logging and planting that can realize a sustainable carbon cycle	Tohru NAKAJIMA (the University of Tokyo)
CO2 usage for agriculture	Development of A Next-Generation Horticulture System Utilizing Atmospheric CO2	Naomi TANGA (ARCS LLC.)

17 Projects Adopted in FY2023

Field	Study title	Name of Research Representative (Organization)
CO2 separation and capture	Development of Defect-Free MOF Ultrathin Membranes for CO2 Capture	Shunsuke TANAKA (Kansai University)
	Room temperature and atmospheric pressure CR technology using innovative separation adsorbent and photocatalyst	Hideki TANAKA (Shinshu University)
CO2 separation and capture (Direct Air Capture)	Highly efficient atmospheric CO2 capture featuring with a new CO2 emission system	Fuyuhiko INAGAKI (Kobe Gakuin University)
	[Startup support framework] DAC System with Innovative Separation Membrane and Photoresponsive Absorbent	Tatsushi IMAHORI (Tokyo University of Science)
Conversion to fuels	Development of Direct Air Capture (DAC) system using zeolites	Kei IKEGAMI (Planet Savers Inc.)
	Development of novel on-demand laser driven chemical process	Akira KUWAHARA (Nagoya University)
Conversion to chemicals	Development of highly effective cathode catalysts for electrochemical CO2 reduction	Yoshikazu ITO (University of Tsukuba)
	Development of Fluidized Bed Plasma Reactor for Innovative Direct Methanol Production from CO2	Nobusuke KOBAYASHI (Gifu University)
	Development of Reaction System for Selective Conversion of CO2 to Chemicals with Waste Silicon as a Reducing Agent	Ken MOTOKURA (Yokohama National University)
Conversion to chemicals (Using organisms)	Development of technology to convert CO2 into useful chemicals using electrochemical dehydration reactions	Katsuhiko TAKEUCHI (National Institute of Advanced Industrial Science and Technology)
	Development of fatty alcohol production from CO2 using microorganisms	Kosuke NISHIO (Utilization of Carbon Dioxide Institute Co., Ltd.)
Social sciences	Regime Change for Carbon-Neutral Agriculture, Forestry, and Fisheries	Ayu WASHIZU (Waseda University)
Conversion to high value-added materials	Development of Direct Coating Process of Carbon Nanotube Films from Carbon Dioxide	Yuta SUZUKI (Doshisha University)
	Green sustainable transformation using CO2 as a carbon source	Toshiyuki MORIUCHI (Osaka Metropolitan University)
Technologies related to the use of bio-energy	Development of a novel electrochemical device for effective utilization of unused carbon resources	Akifumi IDO (Central Research Institute of Electric Power Industry)
	[Startup support framework] A New Bio-Energy with Carbon Capture & Storage	Atsushi Alex MAZAWA (Kyoto University Innovation Capital)
Direct use of CO2	CO2 hydrate storage and discharge system	Shin'ya OBARA (Kitami Institute of Technology)

Figure 6. List of research projects selected for grants by the CRF
FY2024 (upper list) and FY2023 (lower list)

Source: Carbon Recycling Fund Institute materials

Among the applications chosen to receive grants from the CRF, eight projects have been selected and are currently receiving NEDO research grants or national project grants such as Green Innovation Fund grants, while three projects have led to joint research with private companies. Two projects were also selected by an independent grant system of Hiroshima Prefecture, “HIROSHIMA CARBON CIRCULAR PROJECT,” started in FY2022. In some cases, startups were founded based on research outcomes.

Research field	Grantee	Research project name (grant fiscal year)	Principal investigator name (affiliated institution)
Technologies for CO ₂ fixation	Joint research with companies (verification testing)	Development of a novel CO ₂ immobilization technology using microbial fuel cells (FY 2022)	Daisuke SANO (Tohoku University)
	NEDO and MOE	Development of a novel CO ₂ mineralization method using for waste seawater using biogenic amines (FY 2021)	Ko YASUMOTO (Kitasato University)
Technologies for conversion to fuels	JST/OPERA	Breeding to eliminate bottlenecks against practical application of microseaweed-derived biofuel (FY 2021)	Shigeaki HARAYAMA (Chuo University)
Technologies for conversion to chemicals	Green Innovation Fund	Development of super-efficient polyurethane material production method using CO ₂ : (FY 2021)	Katsuhiko TAKEUCHI (National Institute of Advanced Industrial Science and Technology)
	Joint research with companies, etc.	Development of technology for synthesizing lactic acid and polylactic acid from carbon dioxide (FY 2021)	Hajime KAWANAMI (National Institute of Advanced Industrial Science and Technology)
	Joint research with companies	Adaptive research on new low-temperature methanol synthesis catalyst to IGCC+CCS (FY 2020)	Noritatsu TSUBAKI (University of Toyama)
Technologies related to CO ₂ separation and capture	JST/JST-Mirai	Development of CO ₂ absorber for low-cost CO ₂ -free hydrogen production (FY 2021)	Kei INUMARU (Hiroshima University)
	Joint research with companies, etc.	Development of highly efficient DAC technology using CO ₂ absorbing and releasing agents that separate even water (FY 2021)	Fuyuhiko INAGAKI (Kobe Gakuin University)
Social sciences	MOE	Research on the Realization of Setouchi Carbon Recycling Complex (FY 2020)	Takayuki ICHIKAWA (Hiroshima University)
	ERCA (Environment Research and Technology Development Fund)	Regime Change for Carbon-Neutral Agriculture, Forestry, and Fisheries (FY 2023)	Ayu WASHIZU (Waseda University)
Circulation of carbon resources	Launching a startup	Highly-Efficient Conversion of CO ₂ Utilizing Biomass, Brown Coal and Metal Ion Media (FY 2020)	Ryuichi ASHIDA (Kyoto University)
Utilization of CO ₂ sinks	JST/A-STEP (tryout) Launching a startup	Development of a compact horticultural system with atmospheric CO ₂ enrichment by membrane separation (FY 2021)	Shigenori FUJIKAWA (Kyushu University)
	JSPS (grants-in-aid for scientific research)	Enhancement of plant CO ₂ uptake using a chemical compound (FY 2022)	Yohei TAKAHASHI (Nagoya University)

Figure 7. Examples of achievements from CRF research grant activities

Source: Carbon Recycling Fund Institute materials

■ [Example of progress: Workshop for realizing a carbon recycling society]

The CRF has promoted working group activities to connect CO₂ emitters and potential CO₂ users, and seeks opportunities to perform social pilot testing of carbon recycling and then deploy it in society by leveraging the strengths of local communities.

In FY2022, the CRF organized a workshop in Takehara, Hiroshima Prefecture. In addition to member companies that have offices in Takehara or other cities in Hiroshima Prefecture, local companies and officials have also participated in the workshop and discussed the creation of the Takehara Model. According to reports, CRF members and local companies discovered one another in this workshop and started projects, which were selected for the subsidy to support the research and development of technologies related to carbon recycling granted by the Hiroshima prefectural government.

The CRF has held similar workshops, deploying this model in other regions. In FY2023, the CRF organized social implementation workshops in Omuta, Fukuoka Prefecture, and Sakata, Yamagata Prefecture, to implement actual carbon recycling technologies in society.

In Omuta, CRF members, local companies, and officials discussed the possibility of spreading CCU in the city. Attendees compared the current CO₂ emissions (supply potential) in Omuta and the CO₂

emissions when fuels, etc., used in the city and its suburbs are replaced with carbon recycling products (demand potential). They also shared and discussed the regional characteristics of Omuta and other topics and selected applicable carbon recycling technologies as the conclusion of the workshop.

In Sakata, the CRF started a workshop in November 2023. The first meeting was held to deepen the understanding of local companies and the municipality about carbon recycling, raise their awareness, and present the industrial and regional characteristics of Sakata to CRF members to encourage mutual understanding. At the second meeting, the CRF introduced the potential to use CO₂ based on CO₂ emissions in Sakata with the aim of developing a specific vision and ideas for carbon recycling. This workshop will continue to consider establishing a framework to create a more specific carbon recycling model.

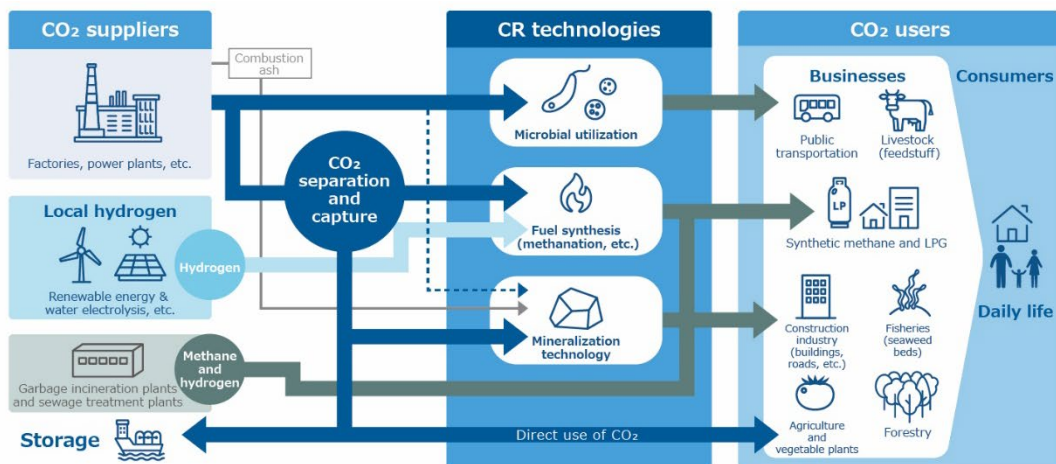


Figure 8. Overview of the CO₂ value-chain creation workshop

Source: Carbon Recycling Fund Institute materials



Figure 9. Second workshop and excursion in Sakata

- [Example of progress: Carbon Recycling University—Program to nurture the next generation of people who will be involved in realizing a carbon recycling society]

Carbon neutrality-oriented R&D and commercialization require not only technology development but also promoters for the social implementation of new technologies. That is why it is essential that the people involved in the process see the social challenges as ones that they face themselves and for which they take a proactive approach while drawing in those around them, expanding their circle of collaboration. In FY2021 the CRF started Carbon Recycling University courses for employees who are expected to become core members of their companies in the future. In these courses, participants develop the skills and mindsets that are important when implementing ideas in collaboration with organizations and people with various ideas and values. These skills and mindsets are cultivated through discussions with management personnel from promising startups and colleagues.

In FY2023, the third year of the courses, 19 young people from member companies and other organizations visited a biofuel production demonstration plant of Euglena Co., Ltd. and learned the facts of carbon recycling with their own eyes and ears. The participants were then divided into teams, each of which was assisted by a venture company. Fueled by their own passion and that of the team, they set goals, repeatedly obtained primary information by leveraging the ability to draw in those around them that they have learned, and gave a presentation to gain new peers as the climax of the workshop. The themes selected by the teams are: “Carbon Cycle Model Project in a Specific Area,” “Consideration of a Circulation Model Started from Households Using Existing Infrastructure,” “Adopting DAC in Unexplored Fields,” and “Marine Commercialization.” In addition, this year’s attendees made a specific business plan based on the theme they discussed with their team after attending the CR University and returning to their own company, and presented a poster to external parties at an event hosted by the Carbon Recycling Fund Institute.



Figure 10. The Carbon Recycling University in the third year (left figure: Euglena biofuel demonstration plant tour, right figure: lecture given by a venture company and team presentation)

Source: Carbon Recycling Fund Institute materials



Figure 11. The Carbon Recycling University in the third year (top figure: team presentation, bottom figure: group photo after the completion of the course and completion certificate ceremony)

Source: Carbon Recycling Fund Institute materials

- [Example of progress: Awareness-raising activities for the public (1) The Tale of Carbo and Risa – Digital content and (2) TEPIA]

Due to the importance of reaching the younger generation, the CRF created “The Tale of Carbo and Risa,” which is digital content for the general public. The fascinating story introduces examples of carbon recycling. The CRF is now working on turning it into a series. Carbo and Risa, high school students in the year 2222, when sustainable carbon societies are commonplace, together with Sasuke the Ninja Owl, travel through time to around 2022 and learn about the efforts devoted to innovation and the passion of people involved in it. It is available for viewing on the CRF website. Sasuke also plays an active part in PR activities as the CRF’s mascot. At the end of FY2023, the CRF released a story about general trading companies that are focusing on supply chain creation , as well as the English version in July 2024 for the English website.



Figure 12. Sample content from the Tale of Carbo and Risa and Sasuke
Source: Carbon Recycling Fund Institute materials

The CRF also organized a TEPIA spring vacation science class event to experience making bath bombs to promote the understanding of carbon recycling and raise awareness in TEPIA Advanced Technology Gallery with the help of the Association for Technological Excellence Promoting Innovative Advances (TEPIA). The title of this event was “Let’s learn about carbon dioxide by making bath bombs.” Elementary school students who participated in the event learned that carbon dioxide is used in familiar products such as bath bombs through the experiment.



Figure 13. Spring vacation science class “Let’s learn about carbon dioxide by making bath bombs”
Source: Carbon Recycling Fund Institute materials

■ [Activity progress: Messages from the CRF’s leaders]

Senior leaders from the CRF explain the importance of carbon recycling and call for collaboration at international symposia and exhibitions. Mr. Fukuda, the CRF Chairperson at the time, gave a three-minute video speech as a high-level government respondent at the 8th UN Science, Technology, and Innovation (STI) Forum held at the UN headquarters in May 2023. In response to his speech on the significance of building a sustainable carbon system that leverages the Earth’s inherent functions to address climate change and solve challenges such as sustainable procurement of resources, energy, and food, the moderator suggested that carbon recycling is a crucial technology. In addition, Mr. Tsugio Mitsuoka, CRF Chairperson, gave a speech in the opening session at the 5th International Conference on Carbon Recycling 2023 (October 2023) hosted by the Ministry of Economy, Trade and Industry and NEDO, and then-Vice-Chairperson, Mr. Koji Eguchi, gave a presentation titled “Vision and Challenges of Carbon Recycling to Realize a Carbon Recycling Society” during Smart Energy Week 2024 (February) and received many responses.



Figure 14. Then-Vice-Chairperson Mr. Eguchi giving a presentation and Chairperson Mr. Mitsuoka standing on the stage (rightmost)

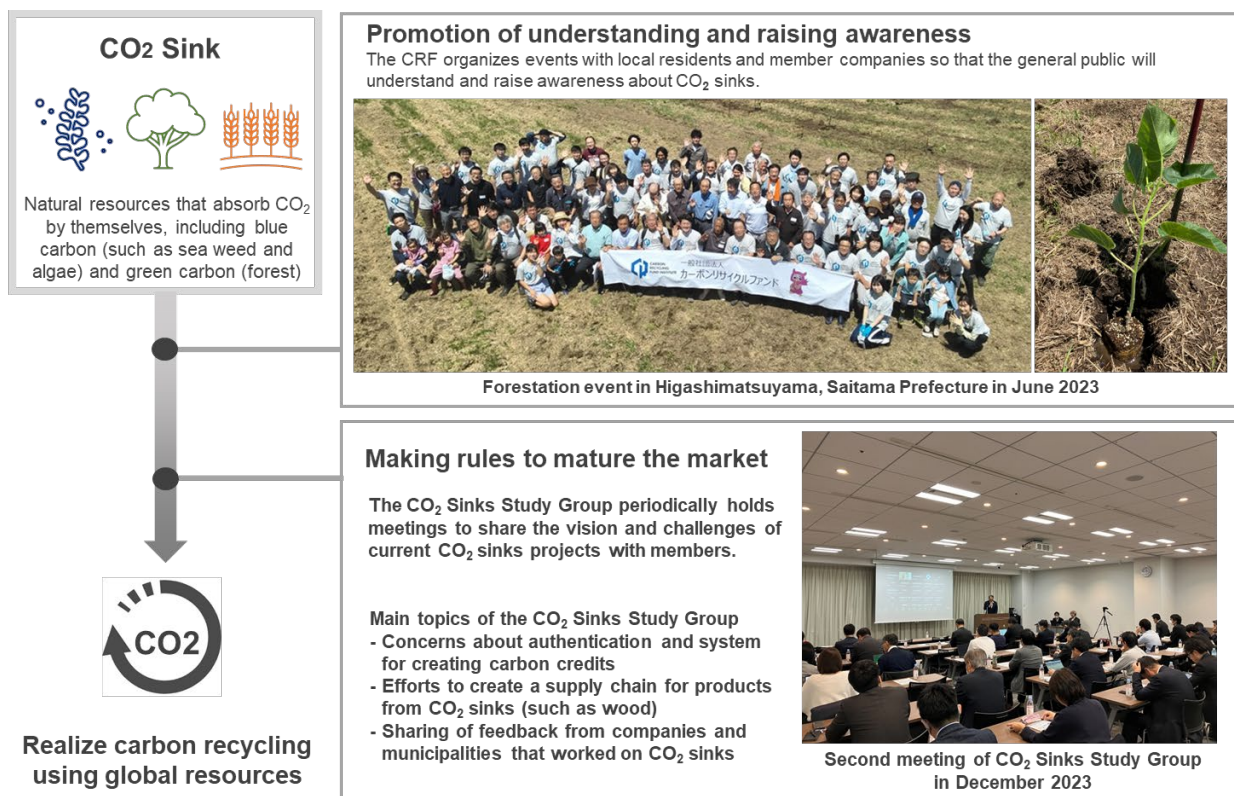
Source: Carbon Recycling Fund Institute materials

■ [Activity progress: Activity for CO₂ sinks: Understanding and raising awareness about supply chain creation, including CO₂ sinks]

CO₂ sinks such as green carbon and blue carbon play an important role in building a carbon recycling society on a global scale. The importance of green carbon and blue carbon is recently increasing in line with the maturing of the carbon credit market. However, in reality, there remain many challenges. Specifically, the exit strategies for supply chain creation (biomass resources and diversification of wood applications), J-Credit, and the design of overseas voluntary and other systems have not been completed. Amidst this background, the CRF launched an activity for CO₂ sinks in April 2023. Initially operated for forestation, it was renamed as the activity for CO₂ sinks in FY2024 to address CO₂ sinks in a wider sense. This activity is broken down into two purposes, for which the CRF has organized events and study groups.

The first purpose is to promote understanding and raise awareness. For this purpose, the CRF organized an event to deepen the understanding of CRF members and the general public about CO₂ sinks. In June 2023, the CRF organized an event to plant fast-growing paulownia, which mature in about five to six years, in the town of Higashimatsuyama, Saitama Prefecture. Through this event, participants experienced forestation with CRF members and local residents to learn an overview of forestation and deepen their understanding of its co-benefits (such as disaster control and biodiversity) in addition to CO₂ absorption.

The second purpose is to make rules to mature the market of CO₂ sinks. To achieve this purpose, the CO₂ Sinks Study Group periodically holds meetings. This study group is intended to share challenges and vision in using carbon credits in relation to CO₂ sinks and creating supply chains. The group had three meetings in FY2023 and discussed green carbon in the first meeting, blue carbon in the second meeting, and biochar in the third meeting. For example, in the second discussion, participants pointed out the following: (1) Although blue carbon provides many co-benefits, including the improvement of fishery resources, promotion of fisheries, and creation of tourism resources, in addition to CO₂ absorption and credit creation, (2) one of the major challenges in promoting blue carbon in the future is improving the efficiency of CO₂ absorption measurement for credit creation, because current measurement methods using divers or drones are costly, leading to a low profitability in some cases even though credits can be created.



- [Activity progress: Creation of matchmaking opportunities between members and between members and researchers or startups]

To achieve carbon neutrality, the creation of CO₂ value chains from the source of CO₂, which includes capturing, transporting, using, and storing it, is important and inter-industry collaboration is essential. It is also critical to connect researchers and startups that make innovations with well-financed companies to implement carbon recycling technologies in society. The CRF periodically organizes a carbon recycling salon to provide matchmaking opportunities for member companies to share carbon recycling information and promote networking. The CRF also holds a debrief meeting for research grant activities every September, providing opportunities for researchers and member companies to mingle.



Figure 15. Lecture session in a debrief meeting (left) and poster exhibition (right)

Source: Carbon Recycling Fund Institute materials

In May 2024, the CRF co-hosted “Create the Future with Carbon Cycle! Interdisciplinary Exchange for Open Innovation 2024” with Chubu TLO (Nagoya Industrial Science Research Institute) and the Carbon Value Research Center (Research Institute for Science and Technology, Organization for Research Promotion, Tokyo University of Science). This was a matchmaking event between researchers or startups and accelerators such as VCs. Twenty researchers and startups attended the event in which 10 accelerators and over 170 visitors participated. The CRF will continue to actively provide similar matchmaking opportunities to promote the social implementation of innovation in the future.



Figure 16. Invited lecture at the matchmaking event (left) and exhibits by startups (right)
Source: Carbon Recycling Fund Institute materials

4. Recommendations for realizing a carbon recycling society

The CRF takes the initiative in the development and social implementation of carbon recycling technologies to continue to make innovations with its member and aims to realize a carbon recycling society in the near future. The CRF believes that the following four activities are important to achieve this goal.

Develop and promote innovation

- The national government should enhance acceleration measures, including additional support to help and accelerate GX initiatives in the industry, and assist high-spirited leading private companies strongly and continuously.
- The CRF and its members should formulate and implement growth strategies to achieve carbon neutrality by 2050. They should also develop carbon recycling technologies and products, verify these technologies and products, deploy them in the real world at a faster pace, and expand investment in them. To help achieve these goals, the CRF should engage in cross-industry coordination, including coordination with startups, and take full advantage of open innovation. The CRF should also leverage government-led support to implement measures such as a “Basic GX Policy.”

Create CO₂ value chains

- The national government should promote measures across the ministries that provide incentives, such as offering premiums for products and services that use CO₂ value chains to maintain and enhance Japan’s international competitiveness. Specific examples are as follows.
 - (1) Quantitative evaluation of obtained and accumulated data regarding CO₂ separation, capture, and utilization should be promoted, as should the visualization of CO₂ flow based on LCA. Furthermore, efforts should be made to further the overall optimization of the effects and impact of introducing carbon recycling.

- (2) Discussion on matters that would have major impacts on and consequently transform the social structure, such as emission trading, carbon taxes, and carbon pricing, should be promoted. Unified systems that ensure fairness between industries should be prepared and implemented without delay. Incentives (such as tax benefits like 45Q and price difference compensation), policies to increase predictability for investment decisions (fair public financial burden and supply chain creation), and incentives for the demand side (such as the CR mark) should be implemented.
- (3) CO₂ sinks such as oceans and vegetation should be evaluated, and international rules should be actively deployed. Support should be provided for small-scale voluntary credit frameworks that serve as their base.
- The CRF and its members should establish the importance and roles of carbon recycling technologies and products through social implementation. They also should promote the understanding about carbon recycling technologies and products, spread them, and promote the creation of CO₂ value chains that contribute to the valuation of CO₂. Efforts around the key technology for these activities, CO₂ separation and capture, should be enhanced while both CO₂ suppliers and users share exit strategies for CO₂-derived products.

Integration with regional revitalization and expansion to the global market

- The national government should strengthen support for creating examples of CO₂ value chains, including CCS and hydrogen supply, through collaboration between the private sector and local communities.
- The CRF and its members should consider local CO₂ recycling systems that leverage regional strength and features through collaboration with local governments. In particular, the agriculture, forestry, and fishing industries should be revitalized as they contribute to CO₂ sinks. Examples include planting fast-growing trees and building fish reefs made of CO₂ concrete. They should also seek to expand efforts to the global market, including the licensing business. Particularly for Asian countries, carbon-neutrality technologies should be introduced to nurture carbon recycling into one of Japan's growth industries, contributing to carbon neutrality throughout Asia.

Develop human resources

- The national government should introduce carbon neutrality and carbon recycling in school education between 2030 and 2050 to develop personnel who can implement carbon-neutrality measures and carbon recycling.
- The CRF also makes efforts with its members to foster deeper understanding of carbon neutrality and carbon recycling among the general public in order to promote greater adoption by society through the CR University by mainly targeting young people, public relations activities, etc.

5. Summary

The importance of carbon recycling to use CO₂ as a resource is rising as Japan has started making steady progress towards achieving carbon neutrality by 2050. For example, the GX Acceleration Agency was approved in April 2024 and launched in July to realize GX investments of over 150 trillion yen in the public and private sectors for the next 10 years. In May, the Hydrogen Society Promotion Bill and the CCS Project Bill were approved by the Cabinet. To achieve carbon neutrality not only in Japan but also across the world, the CRF will continue to commit to industry-academia-government collaboration through efforts, including public relations activities, research grant activities, CO₂ sink activities, and social implementation workshops. At the same time, the CRF aims to play a main role in realizing a carbon recycling society with a view to international collaborations as well.