Carbon Recycling Fund Institute
Progress Report
2024

— Paving the Way for a Sustainable Carbon Recycling System —

October 2024

Carbon Recycling Fund Institute

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■ Trends in carbon recycling

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- 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 CO_2 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 CO_2 sinks. In FY2023, the CO_2 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 CO_2 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 CO_2 value chains that contribute to the valuation of CO_2. Both CO_2 suppliers and users should share exit strategies for CO_2-derived products.

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

The national government should strengthen support for creating examples of CO_2 value chains.

The CRF should consider local CO_2 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 CO_2 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, CO_2 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 CO_2 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 CO_2 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 CO_2 recycling through carbon recycling to be about 100 to 200 million tons as of 2050 (equivalent to carbon recycled products used in Japan).

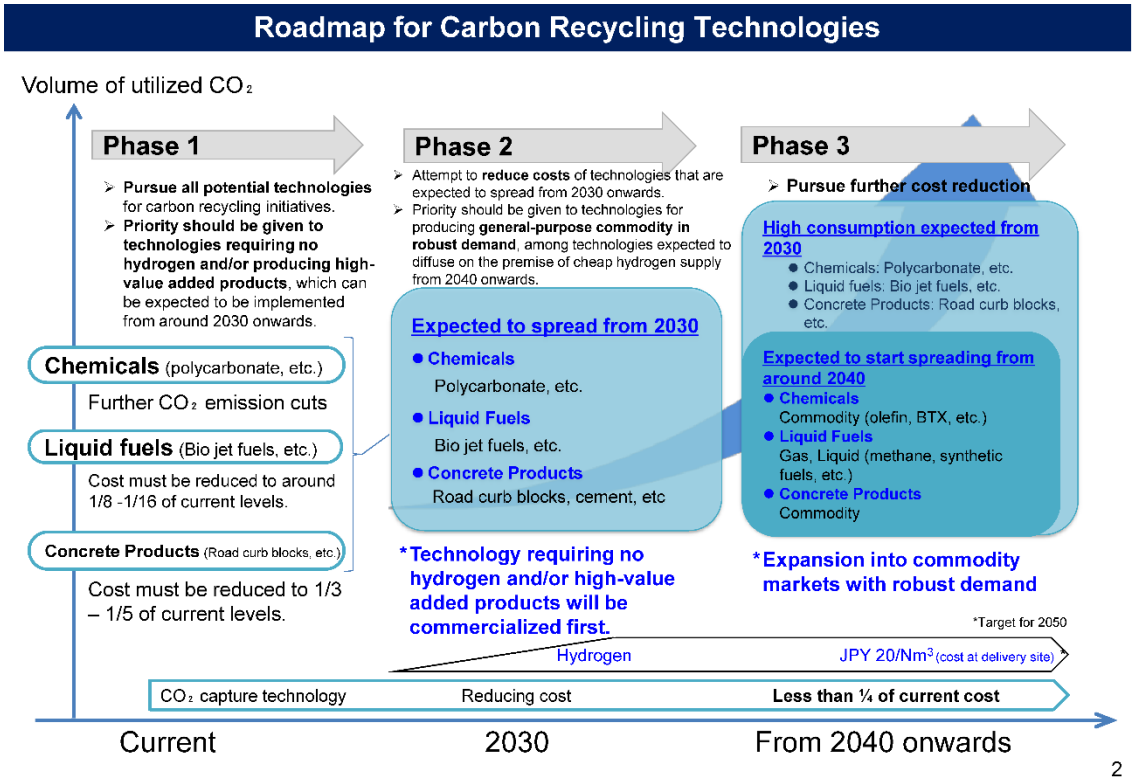


Figure 1. Ministry of Economy, Trade and Industry – Plan for expanding carbon recycling
Source: Ministry of Economy, Trade and Industry website

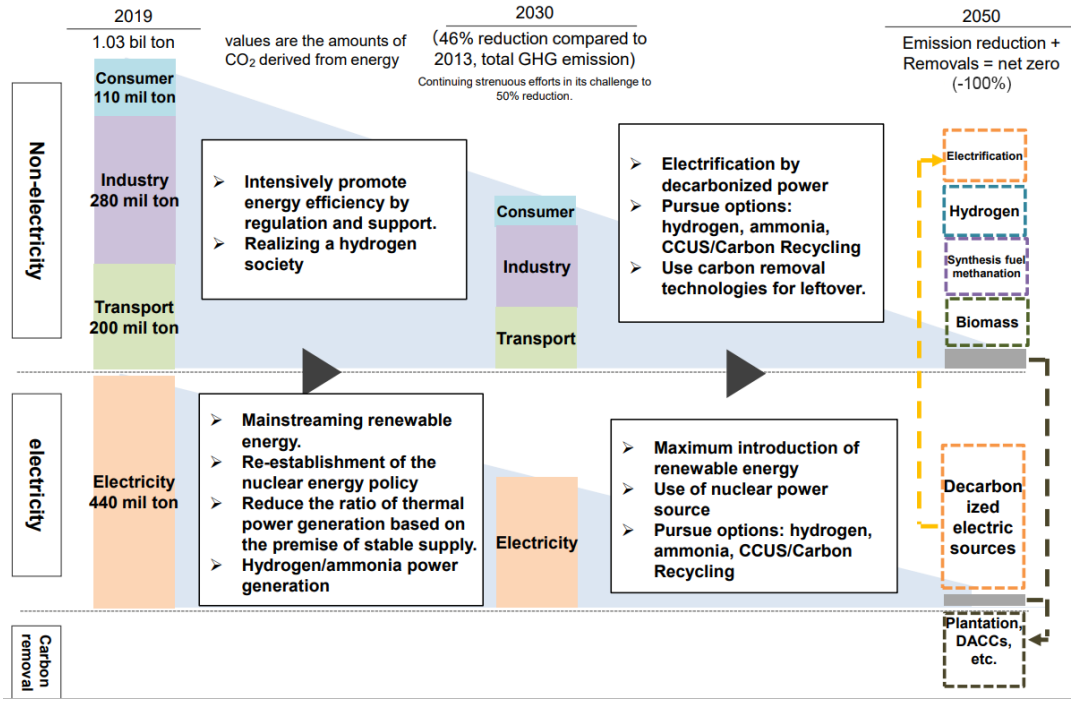


Figure 2. Ministry of Economy, Trade and Industry – Forecast of energy-derived CO_2 emissions
Source: Ministry of Economy, Trade and Industry website

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 CO_2 are essential for maintaining the Earth's systems, including life itself. For example, greenhouse gases, including CO_2, protect the Earth's environment from the harsh cold of space. Plants use CO_2 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.

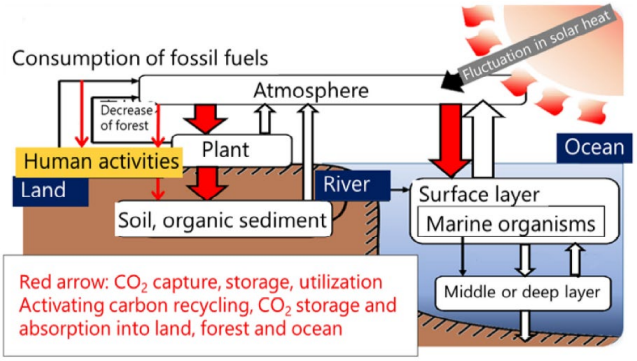


Figure 3. Model of the Earth's carbon cycle
Source: Created by the Carbon Recycling Fund Institute based on materials from the National Institute for Environmental Studies, Center for Global Environmental Research

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 CO_2 as an enemy but instead restore and maintain our planet's health by creating carbon recycling societies that are based on the idea that CO_2 is a resource to be circulated and utilized. Based on this comprehensive approach, it is vital that we identify and capture CO_2 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 CO_2 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 CO_2 value chain, including CCS and hydrogen, into account.

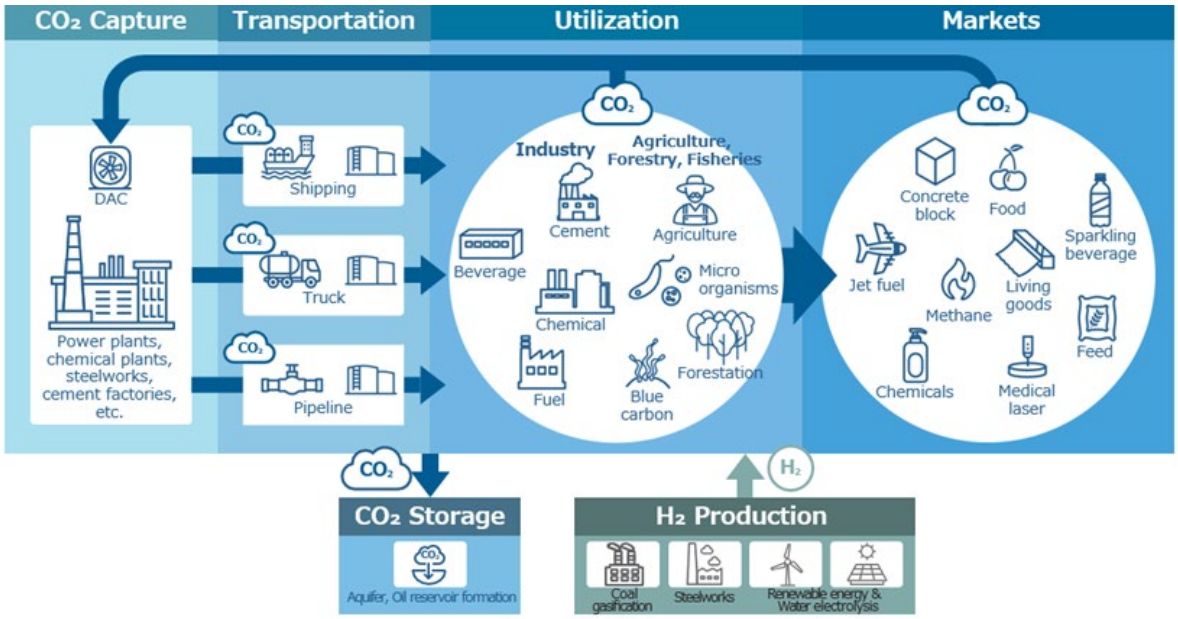


Figure 4. Conceptual image of the CO_2 value chain used in realizing carbon recycling societies
Source: Carbon Recycling Fund Institute materials

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 CO_2 separation and capture, conversion to fuels and chemicals, mineralization, social science-related research, research related to CO_2 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

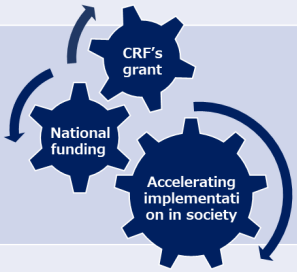


Figure 5. Overview of the Carbon Recycling Fund Institute's research grant activities
Source: Carbon Recycling Fund Institute materials

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.

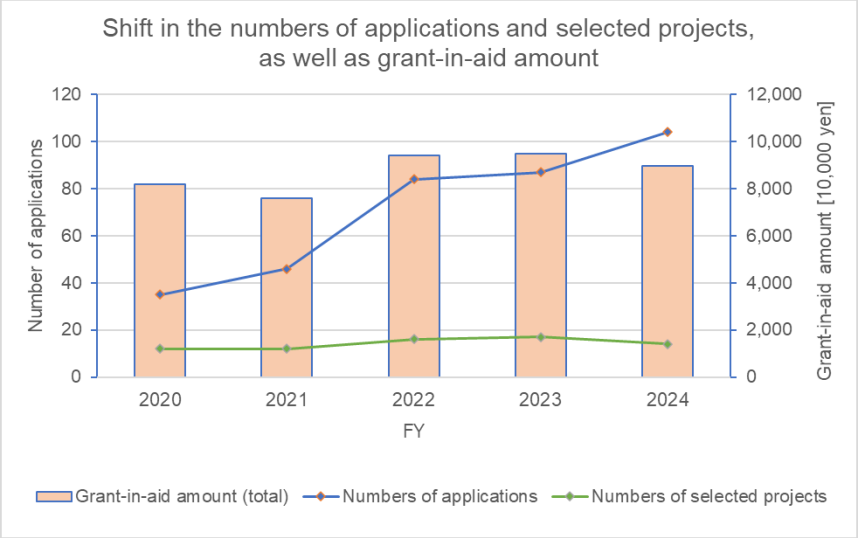


Figure 6. Shift in the numbers of research grant applications and selected projects as well as grant-in-aid amount
Source: Carbon Recycling Fund Institute materials

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	Tokuhisa 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 CO_2 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)
	DAC System with Innovative Separation Membrane and Photoresponsive Absorbent	Tatsushi IMAHORI (Tokyo University of Science)
	[Startup support framework] Development of Direct Air Capture (DAC) system using zeolites	Kei IKEGAMI (Planet Savers Inc.)
Conversion to fuels	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)
	Development of technology to convert CO2 into useful chemicals using electrochemical dehydration reactions	Katsuhiko TAKEUCHI (National Institute of Advanced Industrial Science and Technology)
Conversion to chemicals (Using organisms)	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 novelnew CO_2 mineralization method usingfor 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 CO2 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 CO_2 emitters and potential CO_2 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 CO_2 emissions (supply potential) in Omuta and the CO_2

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 CO_2 based on CO_2 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.

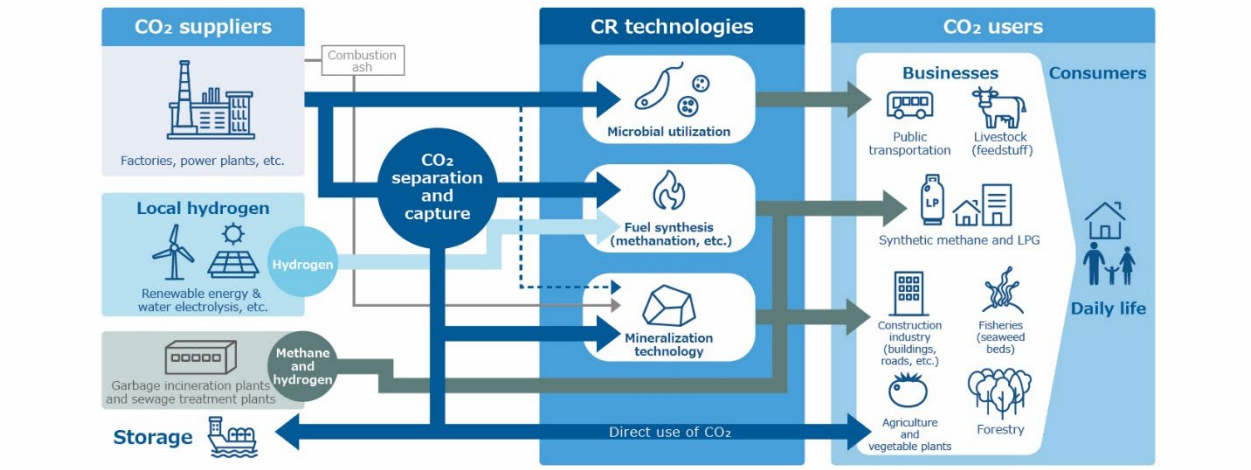


Figure 8. Overview of the CO_2 value-chain creation workshop

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.

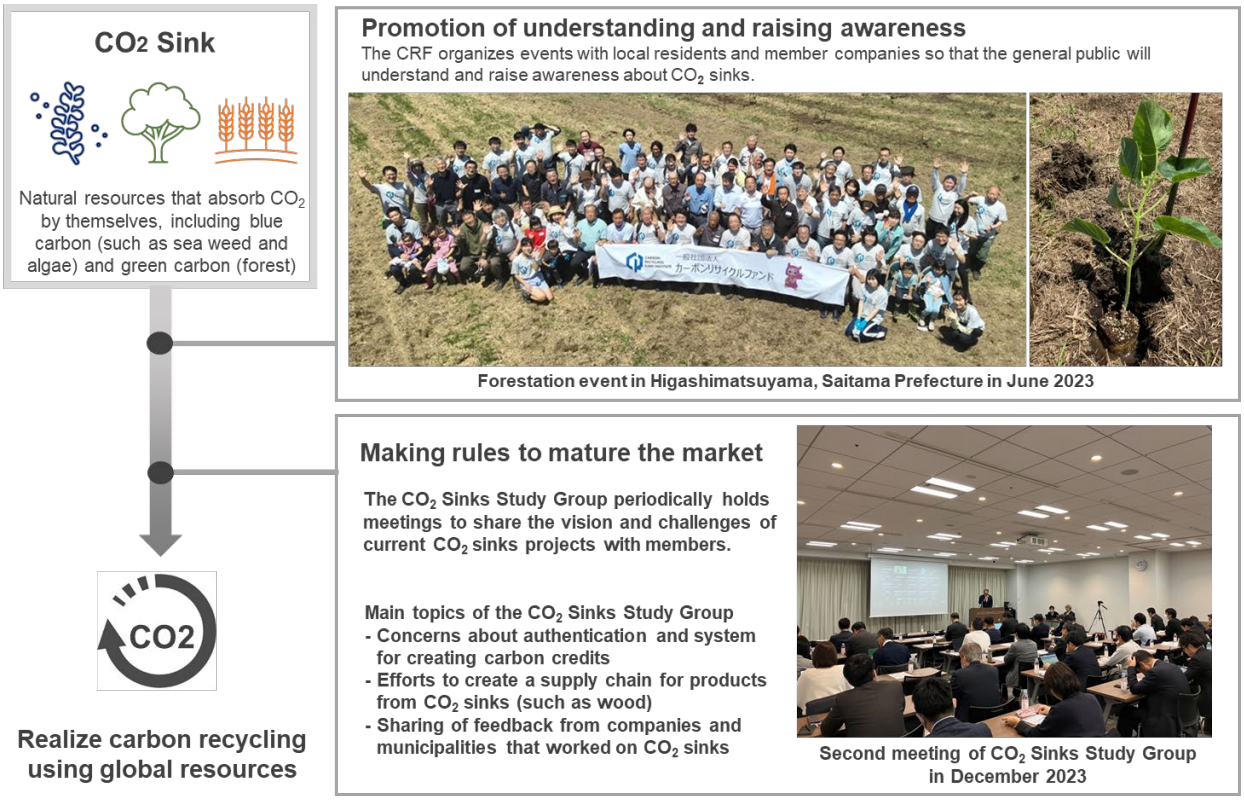
Figure 14. Then-Vice-Chairperson Mr. Eguchi giving a presentation and Chairperson Mr. Mitsuoka standing on the stage (rightmost)
Source: Carbon Recycling Fund Institute materials

■ [Activity progress: Activity for CO_2 sinks: Understanding and raising awareness about supply chain creation, including CO_2 sinks]

CO_2 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 CO_2 sinks in April 2023. Initially operated for forestation, it was renamed as the activity for CO_2 sinks in FY2024 to address CO_2 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 CO_2 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 CO_2 absorption.

The second purpose is to make rules to mature the market of CO_2 sinks. To achieve this purpose, the CO_2 Sinks Study Group periodically holds meetings. This study group is intended to share challenges and vision in using carbon credits in relation to CO_2 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 CO_2 absorption and credit creation, (2) one of the major challenges in promoting blue carbon in the future is improving the efficiency of CO_2 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 CO_2 value chains from the source of CO_2, 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 CO_2 value chains

- The national government should promote measures across the ministries that provide incentives, such as offering premiums for products and services that use CO_2 value chains to maintain and enhance Japan’s international competitiveness. Specific examples are as follows.
  (1) Quantitative evaluation of obtained and accumulated data regarding CO_2 separation, capture, and utilization should be promoted, as should the visualization of CO_2 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) CO_2 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 CO_2 value chains that contribute to the valuation of CO_2. Efforts around the key technology for these activities, CO_2 separation and capture, should be enhanced while both CO_2 suppliers and users share exit strategies for CO_2-derived products.

Integration with regional revitalization and expansion to the global market

- The national government should strengthen support for creating examples of CO_2 value chains, including CCS and hydrogen supply, through collaboration between the private sector and local communities.
- The CRF and its members should consider local CO_2 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 CO_2 sinks. Examples include planting fast-growing trees and building fish reefs made of CO_2 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 CO_2 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, CO_2 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.

Attachment 1. Members' Progress Reports on Building a Carbon Recycling Society

1. Development of carbon recycling technologies and projects in Japan

1-1. Progress of technologies and research and development

Development of next-generation LIMEX (TBM Co., Ltd.)

Development of a DAC-U system (Sojitz Institute of Innovative Technologies, Ltd.)

Making glass from CO_2 captured from air (Revcell Co., Ltd.)

Next-generation technology to fix CO_2 in air using microbial fuel cells (Shin Nippon Air Technologies Co., Ltd.)

Bio-based biodegradable resin compound, Forzeas (Mitsubishi Chemical Group Corporation)

Production of UCDI® Hydrogen-Oxidizing Bacteria-derived alternative protein feedstock made of CO_2 and food development (Utilization of Carbon Dioxide Institute Co., Ltd.)

Informal decision to adopt four new methanol dual fuel engines (MITSUI E&S Co., Ltd.)

1-2. Acceleration of domestic collaboration to create value chains

Technology development for the practical use of conduit injection using a large-scale CO_2 methanation system (INPEX Corporation and Osaka Gas Co., Ltd.)

Delivery of the standard methanation system to Toho Gas Chita e-methane production demonstration facility (IHI Corporation)

Mitsubishi Gas Chemical plans to supply its methanol as fuel for domestic car carriers for the first time in Japan (Mitsubishi Gas Chemical Company, Inc.)

JAL and ENEOS Conclude an SAF Agreement on the Sale and Purchase of SAF ~Promotion of Construction of a Domestic SAF Supply Chain~ (ENEOS Holdings, Inc. and Japan Airlines Co., Ltd.)

Verification for the implementation of a carbon dioxide fixation system using carbon dioxide contained in emissions from asphalt mixture plants and recycled pavement (Sumitomo Osaka Cement Co., Ltd.)

Commencement of Joint Study on CCUS to Achieve Carbon Neutrality in the Cement Manufacturing Process (Mitsubishi UBE Cement Corporation)

Promoting Waste Cooking Oil Collection: Campaign Launch "Tokyo Fry to Fly Project" (JGC HOLDINGS CORPORATION)

Scale expansion of MATSURI, the microalgae industry creation project operated by CHITOSE Group (CHITOSE BIO EVOLUTION PTE. LTD.)

1-3. Environmental valuation for CO_2 in CR products

The Japanese government calculated the amount of CO_2 fixation of environmentally-conscious concrete, CO_2-SUICOM®. (Kajima Corporation)

Adding biocoal concrete to the inventory (Shimizu Corporation)

Joint development and launch of decarbonization impact finance "Forest Like" (Marubeni Corporation)

2. International collaboration to create cost-competitive supply chains

Mitsui O.S.K. Lines, Idemitsu Kosan, and HIF signed the MOU for the joint development of synthetic fuel (e-fuel) and synthetic methanol (e-methanol) supply chain, including the marine transport of CO_2 (Idemitsu Kosan Co., Ltd.)

Supplying biodiesel fuel to Ground Support Equipment for the first time at Chubu Centrair International Airport (Toyota Tsusho Corporation)

Signing a memorandum for the survey on joint commercialization by four Japanese or Australian companies to create a supply chain of e-fuel (synthetic fuel) using green hydrogen and CO_2 transport by ship (Itochu Corporation)

3. Consideration of carbon management business models

Signing a partnership agreement to realize carbon neutrality—combination of university and think tank to flexibly create a virtuous cycle among government, industry, and academia required to solve challenges—(The Japan Research Institute, Limited.)

Establishment of a carbon recycling demonstration research center (Osaki-kamijima-cho, Hiroshima Prefecture) and consideration of carbon recycling demonstration in Shunan and Oita (Japan Carbon Frontier Organization)

4. Progress of business development related to CO_2 sinks

Creating blue carbon and reducing CO_2 using J Blue Concrete (Electric Power Development Co., Ltd.)

Developed of technology to create their ocean digital twin by using AI to sharpen undersea images and 3D shape data acquisition technology (Fujitsu Limited)

1. Development of carbon recycling technologies and projects in Japan

The separation and capture, fuel conversion, mineralization, and conversion to chemicals of CO_2 are expected to be widespread around 2030. This will then be followed by the commercialization of CO_2 absorption and fixation, creation of CR systems, and others. Their demonstrations and technology development are in progress through cross-industry collaboration, industry-academia-government collaboration, and collaboration between municipalities. Examples of the progress are introduced below.

1-1. Progress of technologies and research and development

Research and technology development has made progress in a variety of fields, including CO_2 separation and capture, conversion to fuel, mineralization, and conversion to chemicals, so the number of technologies reaching the demonstration to social implementation level has stably increased. This section presents examples of the latest advanced projects by CRF members.

[A Member's Progress Report] Announcement of a low carbon material using the carbon recycling technology, CR LIMEX

Stage: Demonstration
Implementing member(s): TBM Co., Ltd.

TBM Co., Ltd. announced (patented) CR LIMEX that uses the carbon recycling technology at the World Economic Forum's Annual Meeting in Davos in the eastern part of Switzerland (Davos Meeting, January 15 to 19, 2024).

CR LIMEX (Carbon Recycle LIMEX) is a low carbon material that promotes carbon neutrality. It replaces mineral-derived calcium carbonate mainly made of limestone that was used in the conventional LIMEX with calcium carbonate made by chemically synthesizing CO_2 derived from emissions and waste containing calcium emitted from plants, such as concrete sludge and iron and steel slag, in an environmentally friendly process. Made of CO_2 in plant emissions or atmosphere, this material can be used to produce a variety of high added value products from industrial materials to familiar consumer goods with CO_2 fixed. CR LIMEX has gathered attention in and outside Japan because domestically obtained CO_2 can be reused to produce products, which contributes to economic security as well. For example, this product was selected in a NEDO project as a key technology to reduce CO_2 emissions to the air.

In the future, TBM will attempt to develop more environmentally friendly materials by replacing the conventional petroleum-derived resin part, which is an auxiliary material, with recycled resin or plant-derived resin while aiming to mass-produce the CR LIMEX they announced this time.

What is CR LIMEX?

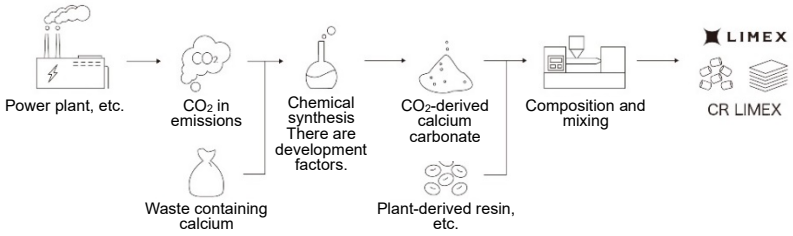


Figure 1-1-1 About CR LIMEX
Source: TBM Co., Ltd.

[A Member's Progress Report] Making glass from CO_2 captured from air

Stage: Commercialization
Implementing member(s): Revcell Co., Ltd.

Revcell Co., Ltd. has deployed projects to capture CO_2 from the air and recycle it as glass in a direct air capture (DAC) system in and outside Japan.
The company has deployed many different businesses under the theme of "scientifically considering the air," as exemplified by this carbon recycling using a compact DAC system.

Measures such as DAC and CO_2 adsorption play an important role in climate change remedies. However, they are still costly and difficult to implement in everyday life. In addition, there are challenges related to the usage of captured CO_2. Underground injection of carbon dioxide is also difficult in Japan, where earthquakes often occur.

Developed by Revcell, this system allows you to set a Revcell proprietary CO_2 sorbent to the filter of air cleaner, etc. It then reacts with carbon dioxide in the air and recycles the sorbent that has adsorbed carbon dioxide as glass in glass plants. The production method and chemical composition of the glass made in this way are the same as those of normal glass. Assumed usage examples include bottles, high-end cosmetic containers, glasses, construction materials, crystal trophies at events, and local souvenirs. Revcell is also conducting technology development while eyeing carbon recycling for concrete products and resin products as well for future development.

In Japan, Revcell collaborates with leading clean room manufacturers on air cleaners with the DAC function and leading glass manufacturers on recycling to glass.

Revcell and AC Biode also plan to jointly present their carbon recycling technology in Expo 2025 Osaka next year.

(1) RECO Glass products (2) Resin concrete

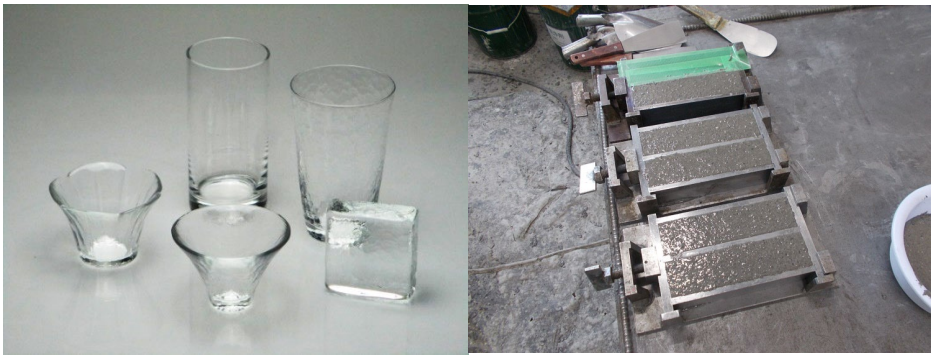


Figure 1-1-2

(1) Glass products made by reusing CO_2 actually captured by the DAC system as a material
(2) Production of resin concrete test pieces currently under development

Source: Revcell Co., Ltd.

[A Member's Progress Report] Start of a verification test for carbon dioxide gas capture and fixation technology

Stage: Application research and pilot
Implementing member(s): Shin Nippon Air Technologies Co., Ltd.

Shin Nippon Air Technologies Co., Ltd. (referred as "SNK" below) and Airport Facilities Co., Ltd. (referred as "AFC" below) conducted a verification test of a carbon dioxide gas capture and fixation technology using microbial fuel cells (MFCs) in the aircraft wastewater treatment facilities at Tokyo International Airport owned by AFC (referred as the "Haneda SD Plant" below).

SNK has researched this technology for practical use with Professor Daisuke Sano, Graduate

School of Engineering, Tohoku University since 2021. The company also received a research grant from Carbon Recycling Fund Institute in 2022. Using this research grant, SNK conducted a verification test by supplying an organic substance from wastewater (sludge) in the Haneda SD Plant to MFCs to continuously operate them in order to obtain their operation data.

AFC agreed to the concept of an eco airport promoted by the Ministry of Land, Infrastructure, Transport and Tourism and is promoting environmental efforts at and around the airport. This time, AFC will gain insight on the latest technological trend by collaborating in this verification test and explore the practical use in the Haneda SD Plant to accelerate efforts to realize an eco airport and carbon neutrality.

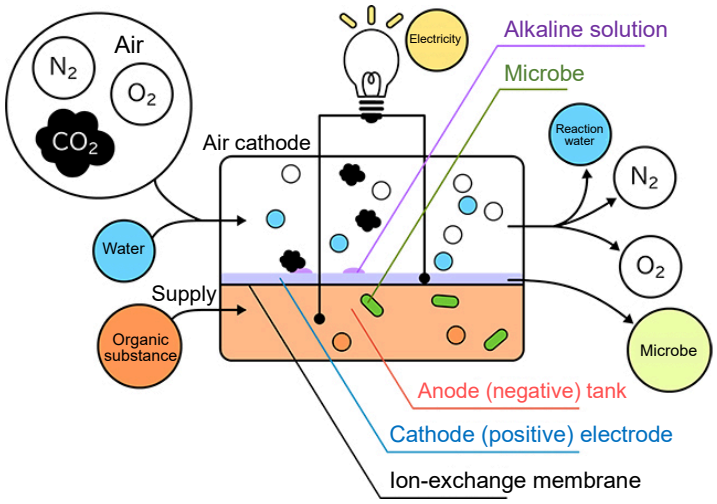


Figure 1-1-3 Conceptual diagram of microbial fuel cell

Source: Press release of Shin Nippon Air Technologies Co., Ltd.

[A Member's Progress Report] Creation of a recycling system based on a bio-based compound, FORZEAS™

Stage: Commercialization

Implementing member(s): Mitsubishi Chemical Group Corporation

Mitsubishi Chemical Corporation has conducted demonstration experiments taking advantage of its strengths in bio-based resins and their compounds, collaborating with various companies and municipalities, with the aim of creating a recycling system. FORZEAS™ is a compounding resin developed by Mitsubishi Chemical using biodegradable and bio-based BioPBS™ and other materials. Each grade has its own unique features and can be used in various applications. FORZEAS™ can be flexibly formulated depending on customers' requirements for performance and bio-degradable/bio-based certification.

This material reduces the use of fossil resources and is decomposed into water and carbon dioxide by microbes in the natural world, which leads to reducing plastic waste. FORZEAS is expected to have various applications with each grade having characteristic features.

Seedling boxes made from FORZEAS™ have been available from Tokai Kasei K.K. since 2022.

Being biodegradable underground, they can be directly planted in fields or planters. A special set of seedling boxes in five colors with the Flower Expo mark was sold in Hamanako Flower Expo 2024 in April 2024.

Set of biodegradable seedling boxes in five colors with the Flower Expo mark

浜名湖花博2024

Figure 1-1-4 Seedling box using FORZEAS™

Source: Mitsubishi Chemical Group Corporation

A fishing bait cage (fishing gear used for ground baiting in the sea) employing the marine biodegradable grade of FORZEAS for the first time as fishing gear has been available since August 2023. It was confirmed that about 90% of this grade of FORZEAS can be decomposed in one year in the marine biodegradation test according to ISO 19679 using a 25-μm thick film. Furthermore, this grade is also employed in a straw, which was the first straw to acquire the marine biodegradable biomass plastic mark from Japan BioPlastics Association.

Figure 1-1-5 Recycling scheme

Source: Mitsubishi Chemical Group Corporation

[A Member's Progress Report] Status of the CO_2 valorization project using "UCDI® Hydrogen-Oxidizing Bacteria"

Stage: Research and Development

Implementing member(s): Utilization of Carbon Dioxide Institute Co., Ltd. (UCDI Co., Ltd.)

Since its founding in 2015, UCDI Co., Ltd. has researched the commercialization of CO_2 valorization technologies emanating from its proprietary UCDI® Hydrogen-Oxidizing Bacteria.

Hydrogen-Oxidizing Bacteria are microorganisms that produce organic substances from CO_2 using H_2 as an energy source. The microorganisms are anticipated to contribute appreciably towards the realization of carbon neutral industry because of their ability to capture CO_2. UCDI® Hydrogen-Oxidizing Bacteria was isolated from nature in 1976 by Dr. Tohru Kodama, professor emeritus at Tokyo University. The bacteria multiply much faster than other Hydrogen-Oxidizing Bacteria. The rate at which one bacterial cell divides into two is an important determinant of their industrialization potential.

UCDI Co., Ltd. is currently pursuing commercialization with the help of joint research partners in four business fields: In the protein business field, the company was a grantee of the first public invitation of the Small Business Innovation Research (Phase 3 Fund) program of the Ministry of Agriculture, Forestry and Fisheries at the end of 2023 and established a technology to produce alternative protein derived from UCDI® Hydrogen-Oxidizing Bacteria on a pilot scale in preparation to enter the global market.

In the chemical business field, UCDI Co., Ltd. established a technology to produce chemicals with UCDI® Hydrogen-Oxidizing Bacteria strains by using gene recombination technology. The company has already secured foundational patents for various technologies to generate the bio-jet fuel materials such as isobutanol, ethanol, lactic acid, and amino acids, with several more patents in the pipeline.

At UCDI Co., Ltd., innovating around challenges spanning global warming, fossil fuel independence, and food security underpin our efforts to accelerate R&D geared towards early CO_2 valorization and its general availability to society at large.

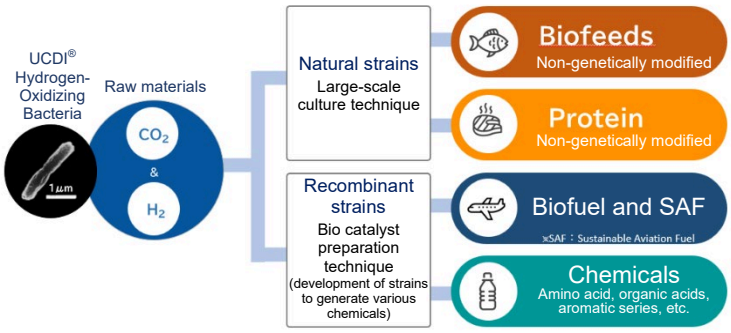


Figure 1-1-6 CO_2 valorization project using UCDI® Hydrogen-Oxidizing Bacteria

Source: Utilization of Carbon Dioxide Institute Co., Ltd.

[A Member's Progress Report] Scale expansion of MATSURI, the microalgae industry creation project operated by CHITOSE Group

Stage: Demonstration
Implementing member(s): CHITOSE BIO EVOLUTION PTE. LTD.

CHITOSE Group is promoting the realization of carbon neutrality through MATSURI, a large-scale microalgae production project, which utilizes CO_2 as carbon resources and the energy of sunlight for autotrophic growth via photosynthesis. This initiative aims to build a new microalgae-based industry that will replace the petroleum industry. CHITOSE collaborates with partner companies to establish new businesses and develop microalgae-based products that support people's lives, such as fuels, chemical materials, and food. In March 2023, CHITOSE started the operation of the world's largest microalgae production facility (*1) with an area of 5 ha, CHITOSE Carbon Capture Central (referred to as "C4" below) (*2), in Sarawak, Malaysia. The C4 is intended to produce 350 tons of microalgae biomass (dry weight) per year, fixing 700 tons of CO_2 annually. CHITOSE Group is developing a wide range of applications, including SAF, plastics, cosmetics, proteins, and animal feed from the microalgae biomass produced at C4.

The core company of CHITOSE Group, Chitose Laboratory Corp., proposed to create a "global industry originating in Japan based on the direct use of CO_2 through photosynthesis" under the Green Innovation Fund Project announced by the New Energy and Industrial Technology Development Organization (referred to as "NEDO" below). This proposal was selected with a total project cost of about 58 billion yen. In this project, Chitose Laboratory Corp. will develop the microalgae production technology with an eye to both economic rationality and environmental sustainability on a production scale of 100 ha, as well as a wide range of applications where microalgae biomass, produced through the direct utilization of CO_2, is used as a raw material.

*1: Scalable flat-panel type photobioreactor system suitable for the efficient production of microalgal biomass
*2: C4 was built by the core company of CHITOSE Group, Chitose Laboratory Corp., in a project commissioned by NEDO

MATSURI website: https://matsuri-partners.chitose-bio.com/en
Contact: contact-matsuri@chitose-bio.com

Figure 1-1-7 CHITOSE Carbon Capture Central (C4), a 5 ha microalgae production facility
Source: CHITOSE BIO EVOLUTION PTE. LTD.

[A Member's Progress Report] Production of a methanol dual fuel engine

Stage: Commercialization
Implementing member(s): MITSUI E&S Co., Ltd.

Recently, resources such as LNG, ethane, methanol, and LPG have gained attention in environmental terms as vessel propulsion energy sources. In this background, the demand for dual fuel engines is rising as marine engines that can use both the conventional heavy oil and these new resources as fuels.

MITSUI E&S Co., Ltd. has received orders for a total of 17 methanol dual fuel engines from domestic shipyards since it delivered the world-first marine methanol dual fuel engine in 2015. Recently, the demand for larger-sized products in their lineup has been rising. To respond to such a rise in demand for dual fuels in large-sized marine engines, the company has been enhancing dual fuel engine production facilities since FY2022 to create a stable supply system.

They are also developing next-generation fuel engines that use not only methanol but also ammonia or hydrogen with licensers.

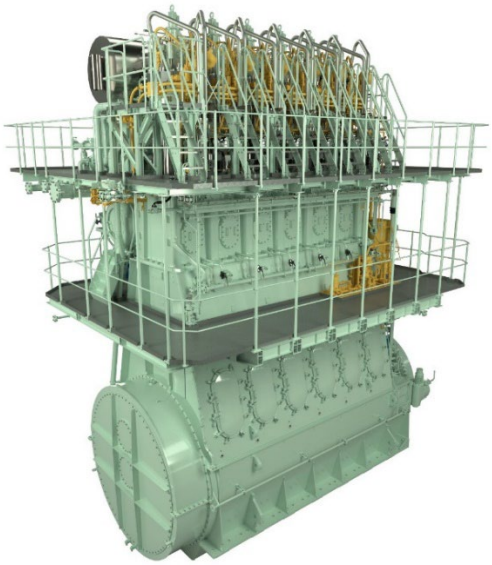


Figure 1-1-8 Methanol dual fuel engine (conceptual diagram)
Source: MITSUI E&S Co., Ltd.

1-2. Acceleration of domestic collaboration

Many business collaboration projects to create domestic supply chains have started.

[A Member's Progress Report] Starting the production of bio-methanol and planning to supply methanol as the fuel for domestic car carriers for the first time in Japan

Stage: Commercialization
Implementing member(s): Mitsubishi Gas Chemical Company, Inc.

Mitsubishi Gas Chemical Company, Inc. (MGC) completed equipment to produce bio-methanol from digestive gas in their Niigata Plant and started the production of bio-methanol for the first time in Japan. Mitsubishi Gas Chemical Company reached a master sales agreement with Niigata Prefecture to effectively use unused digestive gas generated from the terminal treatment plant of the sewage line owned by Niigata Prefecture in 2023. To produce methanol from unused digestive gas in the Niigougawa sewage treatment center, they installed unused digestive gas shipment equipment in the sewage treatment center and receiving equipment in their Niigata Plant and started the production of bio-methanol using the existing pilot plant in March 2024. In June, Niigata prefecture and MGC each acquired the ISCC PLUS certification for the entire supply chain from the sewage treatment center through the Niigata Plant and started the production and sales of ISCC PLUS-certified bio-methanol. In addition, they will make substantial progress towards the practical use of methanol-fueled ships in the domestic fuel market by supplying the fuel to ships, including two new domestic car carriers with methanol as the main fuel that will be built by TOYOFUJI SHIPPING CO., LTD.

In the international maritime market, methanol has gained much attention as an environmentally friendly vessel fuel that will replace heavy oil, and more vessels are now using methanol as the main fuel. The market has focused on activities to increase the number of such vessels. TOYOFUJI SHIPPING CO., LTD. decided to build two domestic car carriers with methanol as the main fuel (scheduled to be completed in 2027). MGC plans to supply fuel methanol, and its group company, Kokuka Sangyo Co., Ltd. plans to directly refill (bunker) the fuel using existing domestic methanol carriers. This is one of the first efforts to use methanol fuel in Japan, making environmentally friendly transport possible. They will continue activities by cooperating with related parties, for example, to establish measures for port safety and a supply system.

Advocating a methanol-based carbon recycling platform, Carbopath™, where a circular economy is realized by producing methanol from renewable resources such as emitted CO_2, waste plastics, biomass, etc., and using it in fuels, materials, and chemicals, MGC aims to contribute to the realization of carbon neutrality through cross-industry cooperation. The company contributes to the carbon neutrality in the marine fuel market as well by supplying environmentally friendly methanol, as well as supporting the whole supply chain and establishment of a protocol for the new fuel.

[A Member's Progress Report] JAL and ENEOS Conclude an Agreement on the Sale and Purchase of SAF ～Promoting the Construction of a Domestic SAF Supply Chain～

Implementing member(s): ENEOS Holdings, Inc. and Japan Airlines Co., Ltd.

Japan Airlines Co., Ltd. (Head Office: Shinagawa-ku, Tokyo, hereinafter "JAL") and ENEOS Corporation (Head Office: Chiyoda-ku, Tokyo, hereinafter "ENEOS") have signed an agreement on the sale and purchase of Sustainable Aviation Fuel (SAF) to accelerate its early implementation in Japan. Under this agreement, ENEOS will become the first Japanese leading energy company to import SAF and supply it to JAL, which is actively procuring SAF both in Japan and overseas. In the aviation industry, the International Civil Aviation Organization (ICAO), has set a goal to achieve net-zero CO2 emissions from international flights by 2050 and aims to reduce emissions in the international aviation sector by 15% compared to 2019 levels starting from 2024. To accelerate the decarbonization of the aviation industry, the promotion of domestically produced SAF is crucial. As a first step towards this goal, both companies have agreed to promote the establishment of a domestic SAF supply chain through this agreement.

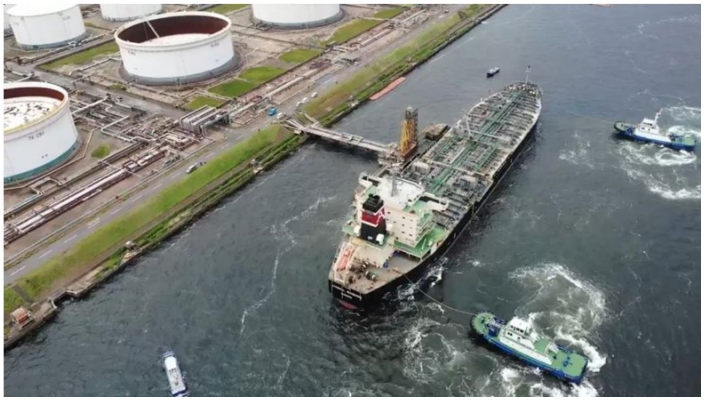


Figure 1-2-2 The arrival of the SAF import vessel at the ENEOS Kashima Refinery dock
Source: News releases of Japan Airlines Co., Ltd. and ENEOS Corporation

[A Member's Progress Report] Verification for the implementation of a carbon dioxide fixation system using carbon dioxide contained in emissions from asphalt mixture plants and recycled pavement

Implementing member(s): Sumitomo Osaka Cement Co., Ltd.

Maeda Road Construction Co., Ltd (referred as "MD" below) and Research Institute of Innovative Technology for the Earth (referred as "RITE" below) started basic research on the carbon neutrality technology to fix CO_2 from mixture plants in 2020. Since 2022, they conducted indoor verification with the aim of further improving the system through technical cooperation with Sumitomo Osaka Cement (referred as "SOC" below). By putting together the technologies that they have accumulated thus far, the three companies started a verification to implement a CO_2 fixation system that uses the carbonation reaction of CO_2 in emissions from MD's mixture plant and recycled pavement made by crushing concrete mass (referred as "RC40" below) or ready-

mixed concrete sludge disposed of as waste. This CO_2 fixation system employs a carbon neutrality technology to fix about 5 to 15 kg of CO_2 for 1-ton RC40 quickly in one hour. The three companies aim to apply this system to mixture plants across Japan. In the future, they will accelerate efforts to reduce greenhouse gas emissions throughout the supply chain to realize carbon neutrality by 2050 by optimizing the design of real machines using the experimental plant installed in MD based on their solid mutual cooperation framework.

SOC uses calcium oxide (CaO) in ready-mixed concrete sludge disposed of as waste to capture and fix CO_2 in emissions and is verifying the carbonation reaction with CO_2 in emissions. As a cement manufacturer, SOC uses the technologies and expertise that it has accumulated to verify the optimal conditions for carbonation reaction (such as concentration, fixation method, reactivity, and chemical properties) and develop a CO_2 fixation and recycling system optimized for mixture plants. By making recycled pavement from sludge after the carbonation reaction ($CaCO_3$), they achieve further carbon neutrality and support the reduction in cement-based waste and efforts for carbon neutrality of mixture plants.

Figure 1-2-3 General view of the experimental plant

Source: Maeda Road Construction Co., Ltd.

Figure 1-2-4 CO_2 fixation system

Source: Maeda Road Construction Co., Ltd.

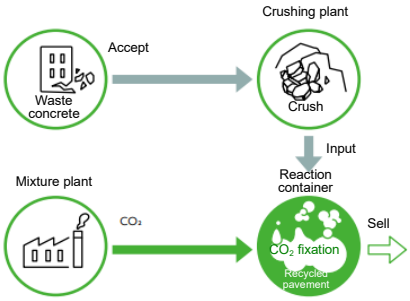


Figure 1-2-5 Conceptual diagram of using waste concrete and CO_2

Source: Maeda Road Construction Co., Ltd.

Figure 1-2-6 Concrete Sludge

Source: Sumitomo Osaka Cement Co., Ltd.

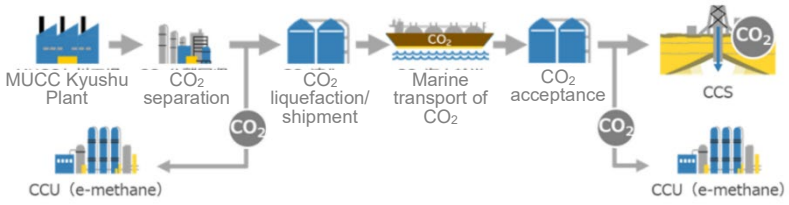
[A Member's Progress Report] Commencement of Joint Study on CCUS to Achieve Carbon Neutrality in the Cement Manufacturing Process

Implementing member(s): Mitsubishi UBE Cement Corporation

Mitsubishi UBE Cement Corporation (referred as "MUCC" below) and Osaka Gas Co., Ltd. have commenced a joint study on CCUS (Carbon Capture, Utilization, and Storage) of CO_2 emissions from the cement manufacturing process to achieve carbon neutrality in the process.

The project aims for carbon capture and storage (CCS), as well as carbon capture and utilization (CCU). In CCS, CO_2 emissions derived from both thermal energy discharged from cement firing kilns and raw materials for cement production at MUCC's Kyushu Plant (located in Miyako-gun, Fukuoka Prefecture), boasting the largest cement production capacity in Japan, are recovered, injected deep underground, and stored. In CCU, the recovered CO_2 is reused as a raw material for e-methane. In this joint study, both companies will collaborate on designing a comprehensive value chain covering CO_2 separation, capture, liquefaction, temporary storage, shipment, marine transportation of liquefied CO_2, underground CO_2 storage, and e-methane production, as well as evaluating its economic feasibility.

(Conceptual diagram of this project)



MUCC Kyushu Plant

Figure 1-2-7 Conceptual diagram of the project

Source: Mitsubishi UBE Cement Corporation and Osaka Gas Co., Ltd.

[A Member's Progress Report] Promoting Waste Cooking Oil Collection: Campaign Launch

Implementing member(s): JGC HOLDINGS CORPORATION

JGC HOLDINGS CORPORATION has deployed a campaign to collect waste cooking oil that will become a feedstock of sustainable aviation fuel (SAF) to realize "Zero Emissions Tokyo," which contributes to reducing global CO_2 emissions to effective zero by 2050, in collaboration with the Tokyo metropolitan government and other companies. Waste cooking oil is one of the SAF feedstocks. This campaign is intended to promote the collection of waste cooking oil from households to connect this with changes in attitudes and behaviors, creating opportunities for individuals to directly contribute to decarbonization.

In addition, JGC HOLDINGS CORPORATION operates the secretariat of the Fry to Fly Project where municipalities and companies cooperate to achieve a decarbonized society through resource recycling. This campaign envisions a world where airlines fly using SAF made of domestic resources as a result of collaboration between not only SAF manufacturers and users but also restaurants that provide waste cooking oil, municipalities, and other parties. As of September 2024, about 150 companies, municipalities, and organizations have participated in this campaign.

Figure 1-2-8 Courtesy of JGC HOLDINGS CORPORATION

1-3. Environmental valuation for CO_2 in CR products

Member companies aim to mature the market by leveraging carbon pricing and environmental valuation to solve the issue of reduced market competitiveness due to CO_2-derived production costs of some carbon recycling products for which technology development has advanced to the commercialization phase.

[A Member's Progress Report] The Japanese government calculated the amount of CO_2 fixation of environmentally conscious concrete, CO_2-SUICOM®.

Implementing member(s): Kajima Corporation

Kajima Corporation has jointly developed an environmentally conscious concrete that absorbs and fixes CO_2 during production named CO_2-SUICOM® with other companies. The amount of CO_2 fixed by this concrete was calculated as one of the three genres (four types) of environmentally conscious concrete for the first time in the world and reported to the U.N. In FY2022, a total of 7.70 tons was recorded as the amount of CO_2 fixed by CO_2-SUICOM. The breakdown is 3.614 tons from a pavement block of 55.6 m^3 (the amount of CO_2 fixation per cubic meter is 65 kg) and 4.087 tons from a buried formwork of 27.8 m^3 (the amount of CO_2 fixation per cubic meter is 147 kg). There are plans to consider including this product and other environmentally conscious concrete as J-Credit in the future.

Kajima Corporation declared that it will promote the deployment of CO_2-SUICOM in the market to accelerate the spread of CO_2 absorbing concrete with the aim of contributing to the realization of a carbon neutral society by 2050.

Figure 1-3-1 Buried formwork of CO_2-SUICOM and pavement blocks
Source: Website of Kajima Corporation

2. International collaboration to create cost-competitive supply chains

Member companies aim to achieve the stable supply of cost-competitive CR products in Japan by collaborating with overseas companies.

[A Member's Progress Report] Mitsui O.S.K. Lines, Idemitsu Kosan, and HIF signed an MOU for the joint development of synthetic fuel (e-fuel) and synthetic methanol (e-methanol) supply chain, including the marine transport of CO_2, to invest in HIF Global, and create a joint investment framework for HIF Global with JOGMEC to develop a synthetic methanol (e-methanol) supplier network.

Stage: Commercialization and demonstration
Implementing member(s): Idemitsu Kosan Co., Ltd.

Idemitsu Kosan Co., Ltd. (referred as "Idemitsu Kosan" below) agreed to the joint development of synthetic fuel (e-fuel) and synthetic methanol (e-methanol) supply chain, including the marine transport of CO_2, with Mitsui O.S.K. Lines, Ltd. (referred as "Mitsui O.S.K. Lines" below) as well as HIF USA LLC and HIF Asia Pacific Pty Limited, subsidiaries of HIF Global, which is a global company that produces synthetic fuel and synthetic methanol (referred as "HIF" below) and signed the MOU.

Challenges for the practical use of synthetic fuel and synthetic methanol are to stably ensure CO_2 as a material in addition to the production, transport, and supply of synthetic fuel and synthetic methanol. In this joint development, the companies will mainly survey the feasibility of 1 to 3 below and work on creating a synthetic fuel and synthetic methanol supply chain, including stably ensuring and transporting CO_2 as a material.

1. Survey the feasibility of marine transport of CO_2 from Japan to overseas synthetic fuel and synthetic methanol production plants.
2. Survey the feasibility of creating a supply chain to transport synthetic fuel and synthetic methanol that HIF produces in overseas production plants to Japan.
3. Consider CO_2 transport and efficient marine transport of synthetic methanol.

Mitsui O.S.K. Lines, Idemitsu Kosan, and HIF jointly consider the establishment of a synthetic fuel and synthetic methanol supply chain and to develop potential business opportunities together to lead decarbonization in the energy and transport industries.

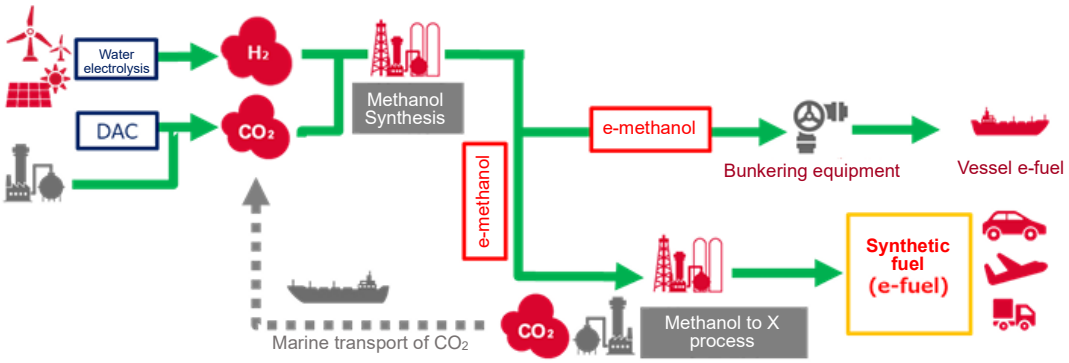


Figure. 2-1-1 Conceptual diagram of a synthetic fuel and synthetic methanol supply chain
Source: Idemitsu Kosan Co., Ltd.

Idemitsu Kosan invests (investment amount USD114M) in HIF to promote the production and development of e-methanol and synthetic fuels at their oversea locations. They will dispatch a director to HIF, as well as their employees in the areas of marketing and project development, in order to acquire HIF's cutting-edge knowledge and expertise in the development and management

of synthetic fuel and e-methanol projects.

Also, they aim for early implementation of developing the e-methanol market by utilizing their existing supply and sales network in the fuel oil business and aim to establish a supply for e-methanol at a scale of 500,000 tons at domestic and overseas locations by 2035.

And Idemitsu Kosan has applied for the investment program*1 and been approved by the Japan Organization for Metals and Energy Security (“JOGMEC”; Head Office: Minato-ku, Tokyo; Chairman and CEO: Ichiro Takahara) for the investment in HIF. With this approval, their investment structure in HIF will change from a sole investment to a joint investment structure with JOGMEC. Through this joint investment structure, they will deepen their collaboration with government agencies and accelerate the construction of a supply chain for synthetic fuels such as e-methanol, which is a promising carbon-neutral fuel.

Idemitsu Kosan will conclude the Master Investment Agreement with JOGMEC concerning investment in HIF. And Idemitsu will make a joint investment with JOGMEC (about 36 million US dollars investment from JOGMEC) through Idemitsu Efuels America Corp. (“IEAC”), which is a US subsidiary of Idemitsu Kosan.

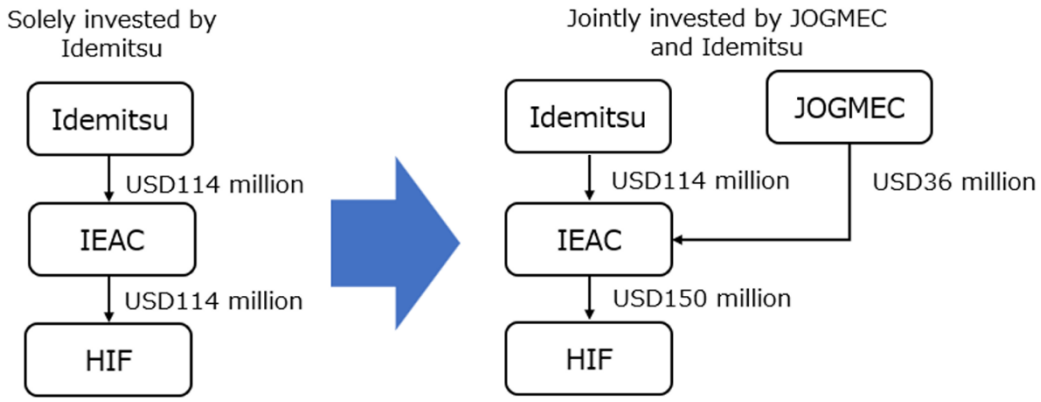


Figure. 2-1-2 Investment structure of joint investment

*1: Investment program to acquire shares of a corporation

An investment scheme intended to use funds necessary to acquire all or some of the shares of a corporation that deals with the production and storage of hydrogen.

[A Member's Progress Report] Supplying biodiesel fuel to Ground Support Equipment for the first time at Chubu Centrair International Airport

Stage: Demonstration
Implementing member(s): Toyota Tsusho Corporation

Chubu Sky Support Co., Ltd. (referred as "CSS" below) and Toyota Tsusho Corporation (referred as "Toyota Tsusho" below) started a demonstration experiment to use 100% biodiesel fuel in ground support equipment within an airport for the first time at Chubu Centrair International Airport. In the demonstration experiment, CSS, which operates ground support equipment at Chubu Centrair International Airport, and Toyota Tsusho, which procures biodiesel fuels, will supply biodiesel fuel with a concentration of 100% to a towing tractor and a forklift. The purpose of the experiment is to contribute to airport decarbonization and obtain insight to verify the impact on engines and future continuous operation for about one year until November 30 this year.

The biodiesel fuel to be used is partially made of the waste cooking oil that Toyota Tsusho collected mainly in the Chubu region, including company cafeterias of the Toyota Group and Toyota Tsusho Group with Daiseki Eco. Solution Co. Ltd. to contribute to the effective use of resources and local production and consumption of energy in the Chubu region.

This demonstration experiment is part of the "Centrair Zero Carbon 2050" campaign organized by Toyota Tsusho and Central Japan International Airport Co., Ltd. Replacing light oil supplied to ground support equipment within the airport with biofuel with a concentration of 100% contributes to reducing CO_2 emissions of 2.62 kg per liter.

In the future, CSS and Toyota Tsusho will consider continuous usage with an eye on expanding biofuel use to achieve decarbonization for the airport.

Figure 2-1-2 Towing tractor (left) and forklift (right) used in the demonstration experiment
Source: Press release of Toyota Tsusho Corporation

[A Member's Progress Report] Signing a memorandum for the survey on joint commercialization by four Japanese or Australian companies to create a supply chain of e-fuel (synthetic fuel) using green hydrogen and CO_2 transport by ship

Stage: Demonstration
Implementing member(s): Itochu Corporation

Itochu Corporation, HIF Asia Pacific Pty Ltd, which is a 100% subsidiary of the HIF Global, JFE Steel Corporation, and Mitsui O.S.K. Lines, Ltd. agreed to jointly conduct a commercialization survey on the creation of a supply chain, including (1) capturing carbon dioxide (referred as "CO_2" below) in Japan, (2) transporting it by ship to Australia, (3) producing and storing synthetic fuel made of the captured CO_2 (referred as "e-fuel" below) in Australia, and (4) exporting the e-fuel from Australia.

e-fuel is a liquid fuel generated by synthesizing hydrogen produced from recyclable energies and CO_2. The plan is to use the CO_2 emitted in industries where decarbonization cannot be achieved only through electrification, hydrogenation, or other processing as material. The use of e-fuel is expected as an early decarbonization measure because existing infrastructure including vessels, tank trucks, storage tanks, and gas stations can be used for its transport and storage and e-fuel itself can be used as a fuel for automobiles, airlines, and vessels without having to alter or replace existing equipment.

Itochu, HIF, JFE Steel, and Mitsui O.S.K. Lines will leverage the insight accumulated in their domestic and international networks and business experiences in Australia, and aim to achieve a decarbonized society and create an e-fuel supply chain, starting with considering its usage in JFE Steel.

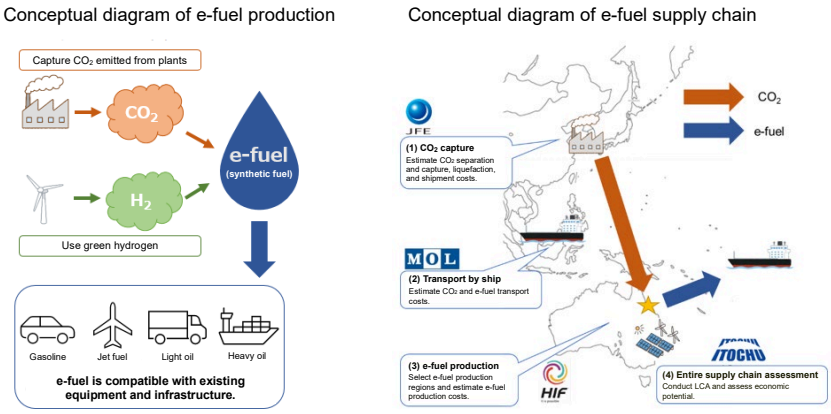


Figure 2-1-3 Conceptual diagram of e-fuel production (left) and supply chain (right)
Source: Press release of Itochu Corporation

3. Consideration of carbon management business models

Some companies aim to become carbon managers that optimize the supply and demand and process design of CO_2 in regions where industries gather.

[A Member's Progress Report] Creation of a carbon cycle material industry model based on local production and consumption in an industry-government-academia framework

Implementing member(s): The Japan Research Institute, Limited.

The Japan Research Institute, Limited. established an industry-government-academia framework, Carbon Cycle Innovation Consortium 2023, in September 2023 with Kyoto University (which is driving this movement), Kyoto University Original Co., Ltd., other private companies, and local governments. They started looking at creating a carbon cycle material industry model based on local production and consumption that uses biomass and CO_2 as carbon sources (referred as "this model" below) in the Sakata and Shonai area in Yamagata Prefecture, and other places. This model aims to create an industrial eco system to produce materials from biomass resulting from agriculture, forestry, and fisheries, as well as CO_2 dispersedly emitted from biomass power stations, paper mills, etc., for recycle within the region. They will design CO_2 reduction value rules for the process design of this model and to create demand in order to deploy this model to agricultural, forestry, and fishery areas across Japan in the future.

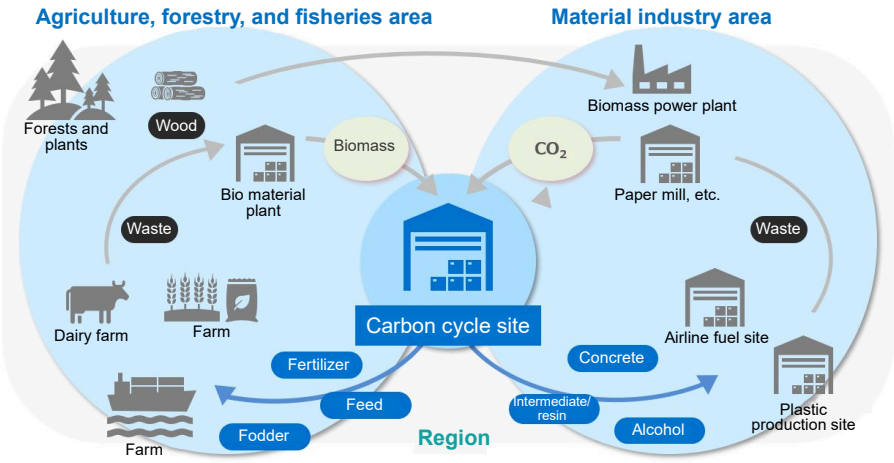


Figure 3-1-1. Target carbon cycle model of CCI Consortium based on local production and consumption
Source: The Japan Research Institute, Limited.

■ Activities in FY2024

In FY2024, the following three activities are planned in Carbon Cycle Innovation Consortium 2024 in light of the consideration result of CCI Consortium 2023.

(1) Creation of a framework and consideration of the business feasibility of the carbon cycle material industry in specific regions

Participants will design supply chains across the entire carbon cycle material industry according to industrial and climate characteristics in potential areas to be developed. They will also consider the business feasibility of the entire carbon cycle material industry around the carbon management business that serves as the carbon cycle controller, for example, by setting prices and guarantees

the quality and quantity of biomass and CO_2. In addition, they provide opportunities for dialogue between the local government and companies in the region, companies that have technologies, researchers, and other parties to collect local requirements, and consider solutions and processes.

(2) Process design combining the CCU technology and bio refinery technology

Participants will clarify the ideal way of gathering industries and the necessary political support according to industrial and climate characteristics in light of the consideration result in (1) and the "definition and design of the index for social value resulting from infrastructure investment across the entire region" and "overview of process blueprint combining the CCU technology and the bio refinery technology" created by this consortium in FY2023. In addition, the consortium will identify core technologies required for gathering industries and build a joint research framework consisting of researchers of Kyoto University and private companies.

(3) Design of CO_2 reduction value rules for demand creation

To create demand for products derived from CO_2 and biomass, participants consider initial demand while focusing on public purchase, and medium- to long-term demand while focusing on the emission trading system. To create initial demand, they will determine a specific calculation procedure and allocation rules in the supply chain of CO_2 reduction value for products derived from CO_2 and biomass required for public purchase based on the latest trends in and outside Japan using certain products as examples, in line with (1). Furthermore, they recommend policies to related ministries with an eye to public purchase and deployment to the emission trading system on the national scale.

■ Future vision

This consortium plans to implement a carbon cycle project in potential areas to be developed using the process assessment index, simulation tool, core technologies, and demand creation system considered this time after FY2025 as a pilot model for deployment to agricultural, forestry, and fishery areas across Japan.

In addition, this consortium will continue to work on raising awareness and recommending policies regarding the necessity of the carbon cycle material industry using biomass and CO_2 as carbon sources, its application to emission credit trading, and other matters to eliminate petroleum dependence as in the last fiscal year.

[A Member's Progress Report] JCOAL, Nomura Research Institute, Ltd., and RING started a joint feasibility survey on the carbon recycling business in the Oita industrial complex.

Implementing member(s): Japan Carbon Frontier Organization

Japan Carbon Frontier Organization (referred as "JCOAL" below), Nomura Research Institute, Ltd. (referred to as "NRI" below), and the Research Association of Industrial Complex Integration for Group-Operation (referred as "RING" below) will jointly conduct a feasibility survey on the carbon recycling business through cross-industry collaboration in the Oita industrial complex (referred as "this survey" below) for the full-fledged promotion of the carbon recycling business that will play an important role in realizing a carbon-neutral society. This survey was selected in the "Promotion of Carbon Recycling and Next-Generation Thermal Power Generation" and "Promotion of Carbon Recycling Technology Implementation through Cross-industry Collaboration" projects, of which the public invitation result was announced by the New Energy and Industrial Technology Development Organization (NEDO) on March 11, 2024.

This survey is intended to contribute to the early social implementation of the carbon recycling business by leveraging NRI's insight on promising technologies and survey analysis methods in the relevant field, JCOAL's insight on CO_2 emissions reduction technologies, and RING's insight on the industrial complex business (Table 1).

Table 3-1-1 Overview of this survey, which is a NEDO project

Selected theme	Feasibility survey on the carbon recycling business through cross-industry collaboration in the Oita industrial complex
Purpose of survey	Taking factors such as the characteristics of the Oita industrial complex and the decarbonization policies of related parties into account, select the carbon recycling technology suitable for the region, and consider CO_2 management
Details of survey	● Understand the current situation of oil refinery and petrochemical companies, steel-, electricity-, cement-, and gas-related companies, and other members of the Oita industrial complex ● Consider the system creation, conceptual design, ideal CO_2 management, and companies for the carbon recycling business through cross-industry collaboration and the demonstration business for social implementation
Survey period	FY2024 to FY2025

4. Progress of business development related to CO_2 sinks

Business development related to many different CO_2 sinks has been accelerated, so efforts are also made to commercialize blue carbon.

[A Member's Progress Report] Creating blue carbon and reducing CO_2 using J Blue Concrete

Stage: Mastery (spread) of technological development
Implementing member(s): Electric Power Development Co., Ltd.

Electric Power Development is developing the J Blue Concrete technology. Serving as a concrete substitute material that is mainly made of industrial by-products (coal ash and copper slag), J Blue Concrete has a high density and algae attaches to it. The company became the first private facility to acquire J Blue Credit in 2021 by developing the J Blue Concrete technology and using J Blue Concrete in their facility in Kitakyushu. They are currently conducting a demonstration test using blocks with specially designed surface shapes to further facilitate algae to attach to J Blue Concrete, dramatically increasing the amount of attached algae (by about up to 10 times).

J Blue Concrete has also gone through a quality test based on concrete engineering, proving equivalent to standard concrete and it is also safe for the environment. In addition, J Blue Concrete is a low carbon construction material whose material-derived CO_2 emissions are about 40% of standard concrete (90 kg-CO_2/m^3) and uses a large amount of industrial by-products and less cement. Therefore, this concrete also serves as an effective construction material for blue infrastructure (port structure designed to coexist harmoniously with living organisms), which contributes to carbon neutrality both in terms of blue carbon and low carbon property (material-derived CO_2 emissions).

J Blue Concrete is a material already in the practical use stage, with 1,780 4 m^3-class blocks having been internally used so far. Electric Power Development is continuously studying production methods that cost less than standard concrete, putting importance on the cost aspect, while further reducing carbon emissions to achieve social implementation in the future, expanding beyond internal use. Additionally, the company is working on deploying J Blue Concrete overseas as well as in Japan, for example, by conducting a joint examination toward social implementation with a university in Queensland, Australia.

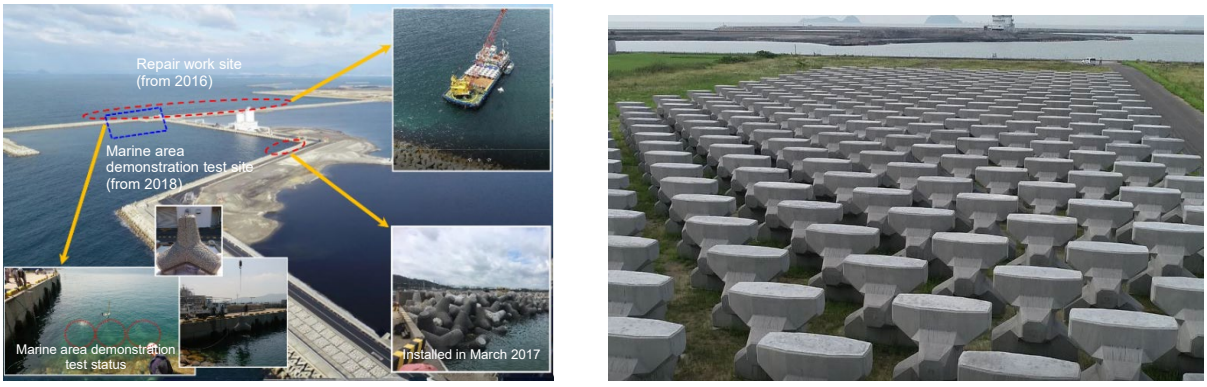


Figure XX Project for which J Blue Credit was acquired

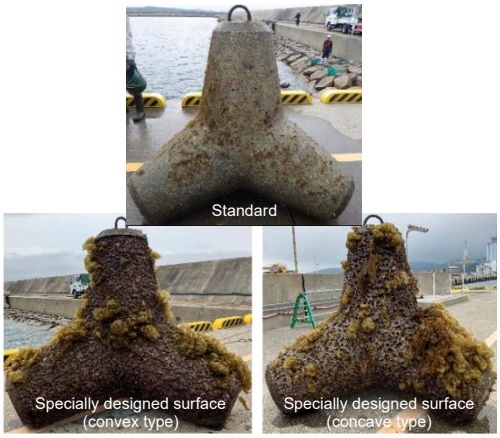


Figure XX J Blue Concrete blocks with specially designed surface shapes

[A Member's Progress Report] Developed of technology to create their ocean digital twin by using AI to sharpen undersea images and 3D shape data acquisition technology

Implementing member(s): Fujitsu Limited

Fujitsu developed a technology to obtain high-resolution 3D shape data on marine creatures and structures using AI and autonomous underwater vehicles (AUVs) as part of the research and development of marine digital twins to reproduce the ocean in digital space with high precision and make predictions by simulating the changes in the marine environment and the effects of measures that leverage ocean.

This technology consists of the image-sharpening AI technology that sharpens images by using AI to identify targets and measure their shapes even in a murky sea and the real-time measurement technology to enable stable measurement from AUVs even in waves or tides. This technology can be used to visualize the situation of target creatures and structures and estimate their data such as volume during marine survey for carbon neutrality and biodiversity preservation. Regarding these technologies, Fujitsu conducted a demonstration experiment in the sea around Ishigaki Island, Okinawa Prefecture, with the National Maritime Research Institute in the National Institute of Maritime, Port and Aviation Technology (referred as "National Maritime Research Institute" below) and succeeded in obtaining precise 3D shape data of coral reef, validating these technologies.

They will aim to expand the measurement target of the technologies established this time to seaweed that absorbs a large amount of blue carbon, etc., in the future and establish a marine digital twin of a seagrass bed within FY2026. They will help companies, municipalities, and other organizations estimate the carbon absorbed by seagrass beds and plan measures, including those to preserve and create seagrass beds and those to preserve biodiversity in coral reefs, promoting sustainability transformation (SX).

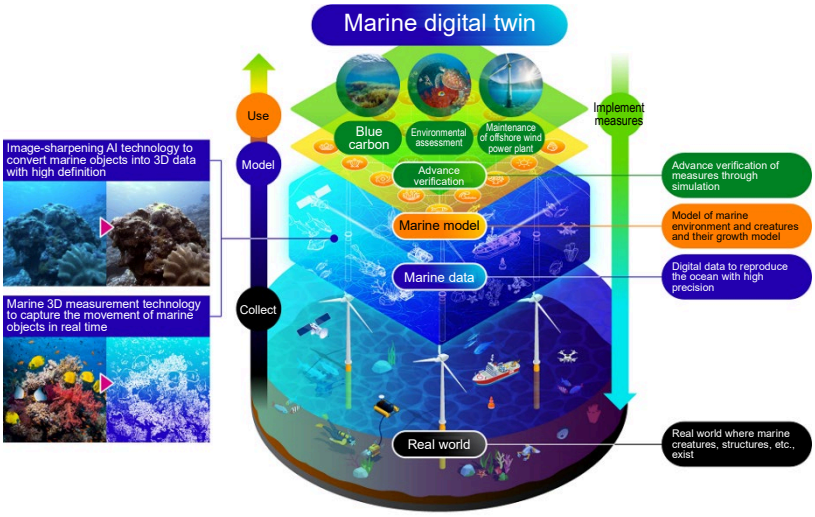


Figure 4-1.2 Vision of marine digital twin to realize SX
Source: Fujitsu Limited