Carbon Recycling Fund Institute

Progress Report 2023

—Achieving Concrete Progress Toward a Carbon Recycling Society—

September 2023

Carbon Recycling Fund Institute

Contents

Outline

- **Trends in carbon recycling**

  * Measures against climate change, as well as trend setting and actions to achieve carbon neutrality, are in progress though energy and resources supply chain risks persist. The Sharm el-Sheikh Implementation Plan to call for the strengthening of measures in each field of climate change remedies and the Mitigation Work Program were adopted at COP27 (November 2022, Sharm el-Sheikh in Egypt). The Conference decided to take measures to compensate for loss and damage, establish a fund as part of these efforts, and set up a migration committee to make recommendations on starting the operation of these financial measures in the lead-up to COP28.

  * The Sixth Assessment Report published by the IPCC in March 2023 points out that the greenhouse gas emissions reduction targets set by national governments are not enough, and suggests CO_2 reduction of 65% by 2035 and 80% by 2040 (compared with FY2019) as targets after 2030 to control the average global temperature increase to 1.5°C. Current actions are not enough to achieve NDCs and further actions such as investment expansion are required. Meanwhile, the Report clearly shows that the 1.5°C target can be achieved by implementing inclusive long-term plans and adaptation activities, that the implementation costs are falling, and that measures selected and implemented over the next ten years are highly likely to have impact from now until several thousand years ahead.

  * To realize green transformation (GX), the Japanese government has launched Tokyo GX Week since 2022 (scheduled to be held from September to October in 2022 and 2023) to organize international conferences related to energy and the environment. The government hosted international meetings such as the International Conference on Carbon Recycling and the Asia CCUS Network Forum during GX Week to deepen discussions and promote the implementation and realization of policies leading to GX. Furthermore, the government is stimulating dialogue among businesses in the GX League. The GX League comprises businesses that are trying to accomplish GX and aim for sustainable growth now and in the future with an eye to realizing carbon neutrality and social change by 2050, and that can collaborate with companies having the same ambition as well as with government and academia.

  * Summary of the communique at the G7 Hiroshima Summit in May 2023: Alignment and reconsideration of nationally determined contribution (NDC) goals for the 1.5°C target and goals in long-term low-GHG emissions strategies, fund raising including private capital for further implementation and development of clean technologies and activities, importance of transition finance, shift to a nature-positive economy, and pursuit of safe, healthy, and low-cost sustainable clean energy supply chains.

  * The GX Promotion Act (Act on the Promotion of a Smooth Transition to a Decarbonized Growth-Oriented Economic Structure) was passed 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 to reduce CO_2 emissions throughout the supply chain of products, etc. and contribute to realizing a carbon-neutral society by 2050. The potential of CO_2 recycling through carbon recycling is

estimated to be about 200 to 100 million tons as of 2050 (equivalent to carbon recycled products used in Japan).

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

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

The CRF is a platform for coordination between stakeholders who are working to create a sustainable carbon system and provides a place for information sharing. We consolidate members' opinions to overcome obstacles CRF members face in taking initiative for the development and social implementation of carbon recycling technologies, and support creation and social implementation of innovations that contribute to carbon recycling as a facilitator to promote measures through dialogues with stakeholders.

* Progress of activities from 2022 to July 2023:

- The CRF has begun group activities for realizing a sustainable carbon recycling system. In FY2022, the CRF studied possibilities in Takehara and other cities in Hiroshima Prefecture, with members and participating companies exploring items that would lead to collaboration.
- Regarding research grants, the CRF selected 16 projects, including three conducted by start-ups in FY2023, and 16 projects including three conducted by start-ups in FY2022. Of 40 projects selected from FY2020 to FY2022, progress has been made in 11 of them. Specifically, one project is in the process of verification testing, seven have been selected as national projects, and three are being jointly researched in the private sector.
- The CRF has promoted information sharing among members and other stakeholders by, for example, enhancing our website and organizing the online carbon recycling salon. More than ten introductions have led to dialogues between individual companies.
- To establish an environment where the private sector works on carbon recycling related to CO_2 sinks as a business activity, the CRF established a forestation fund as the third fund in April 2023 and started afforestation with fast-growing trees. We also created the CO_2 Sinks Study Group as a place for discussion about the future development of green and blue carbon.
- The CRF organized the second term of a program called "Carbon Recycling University" to develop carbon recycling coordinators. We also jointly organized a "local Carbon Recycling University" with Hiroshima University in February 2022, where local young people and young employees from member companies think about the future of the community through carbon recycling.

- The then-Chairperson of the CRF, Mr. Nobuo Fukuda, gave a video speech as a high-level government respondent at the 8th UN STI Forum. The moderator commented that carbon recycling is an extremely important technology for mitigating climate change in his speech in response to the significance of building a sustainable carbon system that leverages the Earth's inherent functions.

■ **Revisions to three core recommendations to promote the achievement of a carbon recycling society (Revisions are underlined.):**

The CRF made the following recommendations based on discussions among members about what society should become and processes to realize it, as members take the initiative in working on the development and social implementation of carbon recycling technologies. The CRF is taking the lead with its members in implementing the recommendations to achieve carbon neutrality, mainly through carbon recycling and realize a carbon recycling society, according to the roles described in Chapter 2.

Develop and promote innovation, develop human resources

- 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, we should engage in cross-industry coordination, including coordination with start-up companies, and take full advantage of open innovation. We should also leverage government-led support to implement measures such as a "Basic GX Policy."
- To support the activities of these industries, the national government should enhance its measures, such as by providing greater support to accelerate green transformation. Solid and continuous support should be provided for highly motivated companies that take the initiative.
- Between 2030 and 2050, personnel who can implement carbon-neutrality measures and carbon recycling should be developed.
- A deeper understanding of carbon neutrality and carbon recycling should be fostered among the general public in order to promote greater adoption by society.

Create CO_2 value chains

- Carbon recycling technologies and products establish their importance and roles in society through their deployment and application, so CRF members should promote the creation of CO_2 value chains that contribute to the valuation of CO_2 by promoting the understanding and usage of carbon recycling technologies and products.
- CO_2 separation and recovery is the key technology in the value chain. The CRF will enhance the efforts that will work with it and help CO2 suppliers and users work together to develop a strategy for the dissemination of CO_2-derived products.
- To maintain and enhance Japan's international competitiveness, 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.
- Quantitative evaluation of obtained and accumulated data regarding CO_2 separation, capture, and usage 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.
- 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.
- 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.

Integration with regional revitalization and expansion to the global market

- CRF members should create examples that leverage the strengths and features of communities by collaborating 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.
- The national government should strengthen support for creating examples of CO_2 value chains through collaboration between the private sector and local communities.
- Efforts should be expanded 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.

■ Summary

The importance of carbon recycling to capture and fix CO_2, and use CO_2 and carbon compounds as resources, is rising at an unprecedented speed in order to achieve carbon neutrality based on a balanced combination of environment and economy. As such, the Carbon Recycling Fund Institute serves as a platform for cross-industrial and industry-academic-government coordination, implementing these recommendations and other activities. The Institute will promote the creation of a framework for global carbon recycling, namely a "Sustainable Carbon System," in various fields including resources, energy, and food through industry-academic-government coordination and cooperation with overseas parties as well as cross-industrial collaboration in the private sector to help achieve carbon neutrality not only in Japan but also across the globe.

■ Attachment 1. Progress made through actions by members of the CRF working towards the realization of a carbon recycling society

CRF members have made progress in verification as well as research and development on CO_2 separation and capture, fuel conversion, mineralization, conversion to chemicals for the social implementation of carbon recycling technologies, as well as CO_2 capture and fixing. These are the next to renter practical use coordination with the agriculture, forestry, and fishing industries. Attachment 1 introduces examples of these developments.

■ Attachment 2. Summary of the questionnaire conducted to CRF members

■ Attachment 3. Overview of the CRF

1. Trends in carbon recycling

Measures against climate change and movements to achieve carbon neutrality continue, and trend setting and action are in progress even though resources and energy supply chain risks persist. The Sharm el-Sheikh Implementation Plan, which calls for the strengthening of measures in each field of climate change remedies, and the Mitigation Work Programme to enhance ambitions for and implementation of mitigation by 2030, were adopted at COP27 (November 6 to 20, 2022, Sharm el-Sheikh in Egypt). Conference delegates also decided to take measures to compensate for loss and damage (loss and damage caused by adverse effects of climate change), establish a fund as part of these efforts, and set up a migration committee to make recommendations on putting these financial measures into action ahead of COP28.

The IPCC's Sixth Assessment Report published in March 2023 recommends CO_2 reductions of 65% by 2035 and 80% by 2040 (compared with FY2019) as targets after 2030 to control the average global temperature increase to 1.5°C. It updates scientific insights from the Fifth Assessment Report with regard to the reality and impact of climate change, and updates long-term and short-term prospects. It argues that current actions are not enough to achieve NDCs, so further action such as investment expansion are required. Meanwhile, the Report clearly shows that the 1.5°C target can be achieved by implementing inclusive long-term plans and adaptation activities, that the implementation costs are falling, and that measures selected and implemented over the next ten years are highly likely to have impact from now until several thousand years ahead.

To realize green transformation (GX), the Japanese government launched Tokyo GX Week in 2022 (September to October 2022) to organize international conferences related to energy and the environment. The government hosted international meetings such as the International Conference on Carbon Recycling and the Asia CCUS Network Forum during GX Week to deepen discussions and promote the implementation and realization of policies leading to GX. Furthermore, the government is stimulating dialogue among businesses in the GX League. The GX League comprises businesses that are trying to accomplish GX and aim for sustainable growth now and in the future with an eye to realizing carbon neutrality and social change by 2050, and that can collaborate with companies having the same ambition as well as with government and academia.

G7 Ministers' Meeting on Climate, Energy, and Environment (April 2023) associated with the G7 Hiroshima Summit in May 2023 positioned data-based decarbonization in the industry and appropriate evaluation of contributions to reduction towards a net-zero society as priorities, and agreed on taking concrete action to coordinate initiatives. The keywords were nature positivity and the promotion of business leadership, actions, and partnerships for a recycling-based economy and resource efficiency.

The GX Promotion Act (Act on the Promotion of a Smooth Transition to a Decarbonized Growth-Oriented Economic Structure) was passed 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).

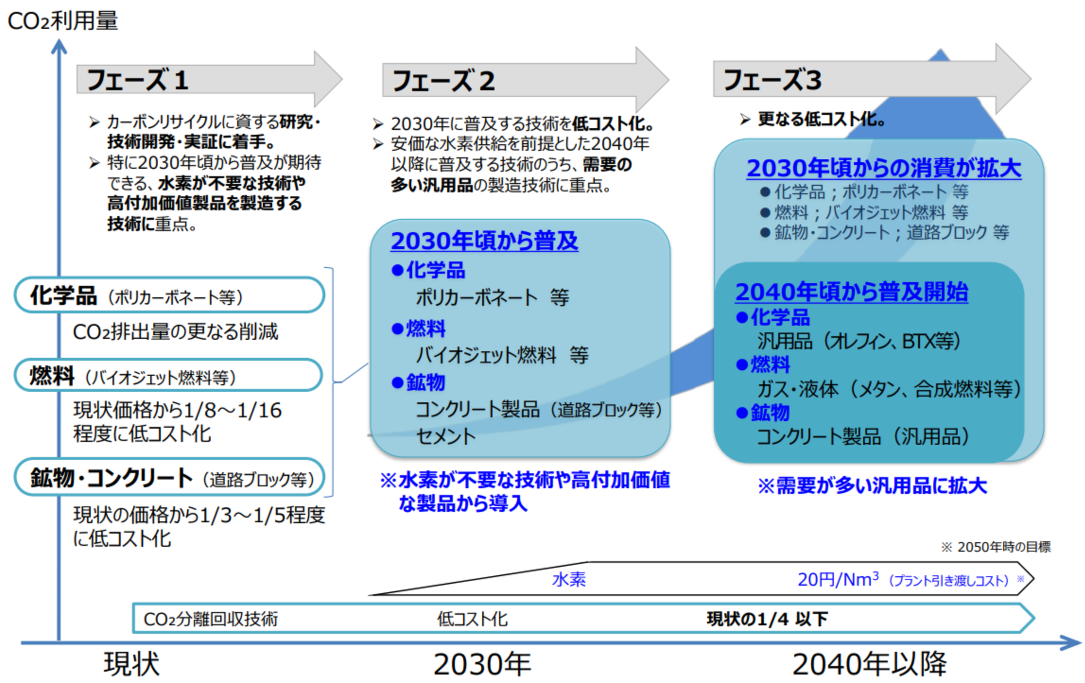


Figure 1. Ministry of Economy, Trade and Industry – Plan for expanding carbon recycling

Source: Ministry of Economy, Trade and Industry website

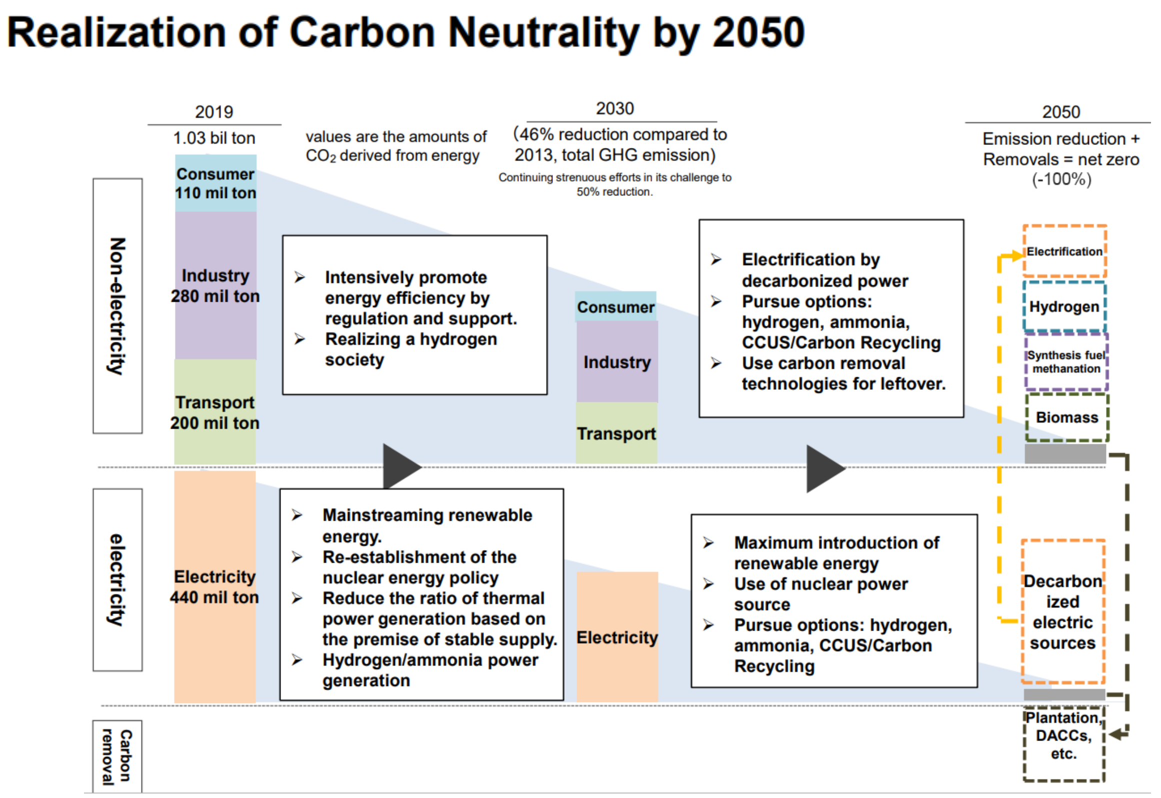


Figure 2. Ministry of Economy, Trade and Industry – Forecast of energy-derived CO_2 emissions

Source: Ministry of Economy, Trade and Industry website

2. 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 system is a vital part of the atmosphere, land, and seas.

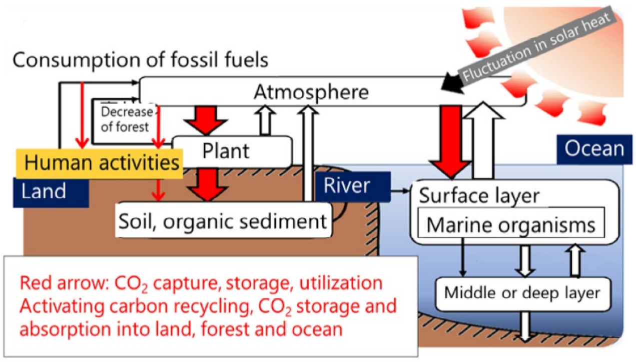


Figure 3. Model of the Earth's carbon cycle

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 usage, 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.

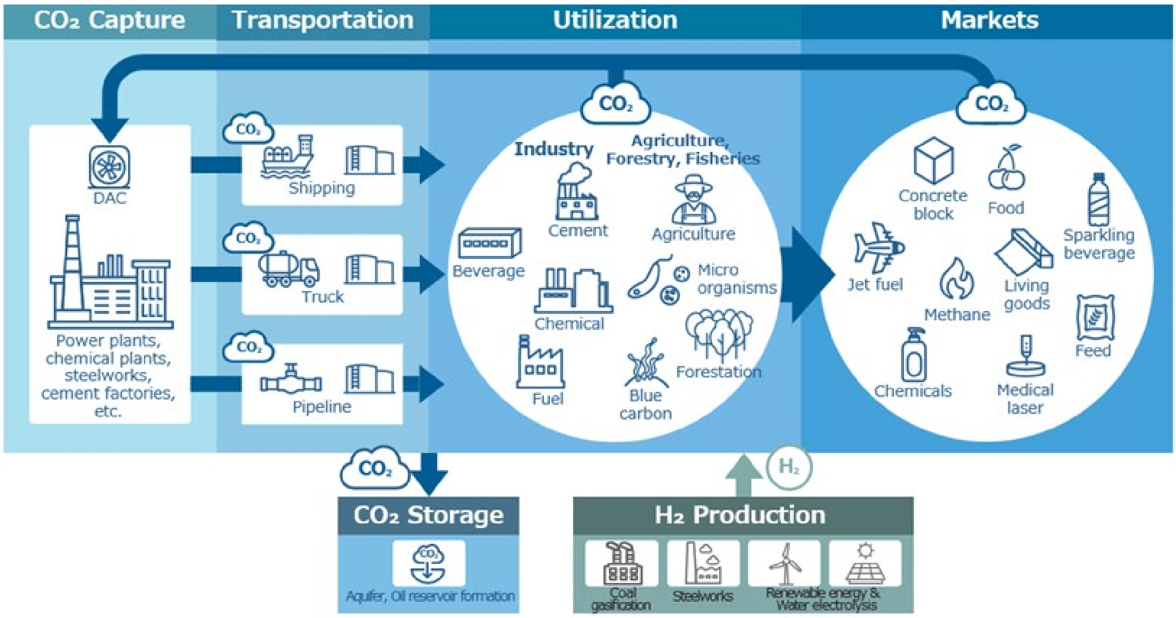


Figure 4. Conceptual image of the CO_2 value chain used in realizing carbon recycling societies

Source: Carbon Recycling Fund Institute materials

In August 2019, employees 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 publicity 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, four years since its establishment, the CRF has more than 180 members who support its goals and participate in its activities (125 corporate members, 13 local governments, 19 academic members, and 26 individuals, as of August 20, 2023). 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 start-ups 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 fuel usage 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: 39 applications → 12 accepted FY2021: 46 applications → 12 accepted FY2022: 84 applications → 16 accepted FY2023: 87 applications → 16 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 12 of the 35 applications in FY2020, 12 of the 46 applications in FY2021, 16 (including three start-up projects) of the 84 applications in FY2022, and 16 (including three start-up projects) of the 87 applications in FY2023. Over the four years from FY2020 to FY2023, the CRF has provided over 350 million yen in grants.

Research Grant: 16 Projects Adopted in FY2023

Field	Study title	Name of Research Representative (Organization)
CO_2 separation and capture	Development of Defect-Free MOF Ultrathin Membranes for CO_2 Capture	Shunsuke TANAKA（Kansai University）
	Room temperature and atmospheric pressure CR technology using innovative separation adsorbent and photocatalyst	Hideki TANAKA（Shinshu University）
CO_2 separation and capture（Direct Air Capture）	Highly efficient atmospheric CO_2 capture featuring with a new CO_2 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 CO_2 reduction	Yoshikazu ITO（University of Tsukuba）
	Development of Fluidized Bed Plasma Reactor for Innovative Direct Methanol Production from CO_2	Nobusuke KOBAYASHI（Gifu University）
	Development of Reaction System for Selective Conversion of CO_2 to Chemicals with Waste Silicon as a Reducing Agent	Ken MOTOKURA（Yokohama National University）
	Development of technology to convert CO_2 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 CO_2 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）
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 CO_2	CO_2 hydrate storage and discharge system	Shin'ya OBARA（Kitami Institute of Technology）

Research Grant: 16 Projects Adopted in FY2022

Field	Study title	Name of Research Representative (Organization)
CO_2 fixation by mineralization	Development of next-generation CO_2 solid adsorbent without the use of water or heat	Kiminori SATO (Tokyo Gakugei University)
	Development of a novel CO_2 immobilization technology using microbial fuel cell	Daisuke SANO (Tohoku University)
	Practical strengthening of biomass concrete using wood ash	Masahiro OUCHI (Kochi University of Technology)
Conversion to fuels	Development of heat exchanger-less CO_2 methanation process using advanced thermal storage technology	Takahiro NOMURA (Hokkaido University)
Conversion to chemicals	Ultra-high efficient CO_2 reduction developed using an innovative photocatalyst design	Tomoko YOSHIDA (Osaka Metropolitan University)
	Small molecule conversion in nanopores created by cyclic porphyrin assemblies	Yusuke KURAMOCHI (Tokyo University of Science)
Conversion to chemicals (Using organisms)	Development of microbial production technology for nylon precursor compounds from biomass resources	Masashi SHIMIZU (Micro Bio Factory Co., Ltd.)
	Development of a clean carbon recycling process using microbes with C1 methanol, which is industrially available in stable supply	Shuhei NODA (RIKEN)
Reuse and recycle of carbon resources, etc.	Development of CO_2 reduction method using hydrothermal processing of industrial waste	Naoto TSUBOUCHI (Hokkaido University)
	[Startup support framework] Development of carbon neutral technology and carbon value creation using biomass materials	Koryu KAWATANI (Innovare Co., Ltd.) International joint research with the Bandung Institute of Technology, etc.
CO_2 separation and recovery	Selective airborne CO_2 collection triggered by solidification	Fuyuhiko INAGAKI (Kobe Gakuin University)
	[Startup support framework] Development of a direct air capture (DAC) system incorporating porous PCPs/MOFs	Daisuke ASARI (Atomis Inc.)
Social sciences	Message design to promote carbon recycling products	Hidenori KOMATSU (Central Research Institute of Electric Power Industry), International joint research with Saint Mary's University
Utilization of CO_2 sinks	Development of ocean mobility for visualization of CO_2 absorption and circulation processes in the ocean and analysis of blue carbon in coastal shallow water areas	Ikuo YAMAMOTO (Nagasaki University) Joint research with JAMSTEC, Meteorological Research Institute, Nagasaki Marine Industry Cluster Promotion Association
	Epigenetics analysis of plants for the development of functional fertilizers that increase the photosynthesis rate under long-term and high carbon dioxide concentrations	Shoko MATSUSHITA plant CO_2 (Nihon University)
	Enhancement of plant CO_2 uptake using a chemical compound	Yohei TAKAHASHI (Nagoya University)

Figure 6. List of research projects selected for grants by the CRF

FY2023 (upper list) and FY2022 (lower list)

Source: Carbon Recycling Fund Institute materials

Among the applications chosen to receive grants from the CRF, seven 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. One of the projects selected in FY2022 entered the verification testing phase in July 2023 after development proceeded due to using the CRF grant.

Research Grant: Stepped-up Projects

Field	Adopting institution	Study title	Name of Research Representative (Organization)	Adopted year
CO_2 fixation	Field trial	Development of a novel CO_2 immobilization technology using microbial fuel cell	Daisuke SANO (Tohoku University)	FY2022
	NEDO MOE	Development of new CO_2 mineralization method using waste seawater and biogenic amine	Ko YASUMOTO (Kitasato University, Kitasato Institute)	FY2021
Conversion to fuels	JST/OPERA	Removal of the bottlenecks in microalgal biofuel production through molecular breeding of a unicellular green alga	Shigeaki HARAYAMA (Chuo University)	FY2021
Conversion to chemicals	GI Fund	Development of an Ultra-efficient Method for Producing Polyurethane Raw Materials from CO_2	Katsuhiko TAKEUCHI (National Institute of Advanced Industrial Science and Technology)	FY2021
	Joint research with companies	Development of technology for synthesizing lactic acid and polylactic acid from carbon dioxide	Hajime KAWANAMI (National Institute of Advanced Industrial Science and Technology)	FY2021
	Joint research with companies	Adaptive research on new low-temperature methanol synthesis catalyst to IGCC+CCS	Noritatsu TSUBAKI (University of Toyama)	FY2020
CO_2 separation and capture	JST	Development of CO_2 absorber for low-cost CO_2-free hydrogen production	Kei INUMARU (Hiroshima University)	FY2021
	Joint research with companies	Selective airborne CO_2 collection triggered by solidification	Fuyuhiko INAGAKI (Kobe Gakuin University)	FY2021, FY2022
Social sciences	MOE	Research on the Realization for "Carbon-Recycle Complex" along Seto-Inland-Sea	Takayuki ICHIKAWA (Hiroshima University□	FY2020
Utilization of CO_2 sinks	JST/A-STEP (tryout)	Development of a compact horticultural system with atmospheric CO_2 enrichment by membrane separation	Shigenori FUJIKAWA (Kyushu University)	FY2021
	JSPS/Grants-in-Aid for Scientific Research	Enhancement of plant CO_2 uptake using a chemical compound	Yohei TAKAHASHI (Nagoya University)	FY2022

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. Not only member companies that have offices in Takehara or other cities in Hiroshima Prefecture, but also leading local companies and officials, participated in the workshop and discussed creation of the Takehara Model. Several CO_2 value chains are now connected following introductions to the technologies and activities of participating companies, tours at related facilities, and other activities. As individual activities start, the CRF will support them.

We plan to deploy this model to other regions by organizing similar workshops on deploying carbon recycling technologies in society.

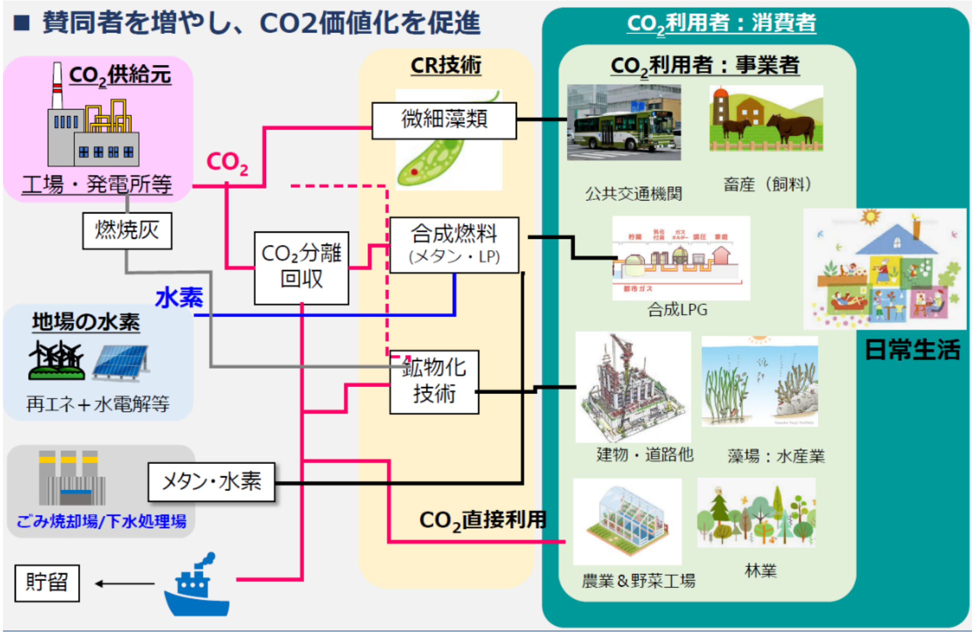


Figure 8. Overview of the CO_2 value-chain creation workshop

Source: Carbon Recycling Fund Institute materials

■ [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 requires a major, global-scale mission and long-term efforts involving complex systems. That is why it is essential that the people involved in the process see the challenges as ones that they face themselves and that 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 young 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 startup companies and colleagues. In 2022, the second year of the courses, 20 young employees from member companies participated. They engaged in group work on four themes selected based on their own recognition of issues: (1) energy, (2) upcycling, (3) decentralized societies, and (4) CO_2 visualization and valuation.

In addition, the CRF planned the local Carbon Recycling University as an opportunity for young workers from member companies and local young people to think about the future together. In FY2022, we organized this event at Hiroshima University with the University’s help.

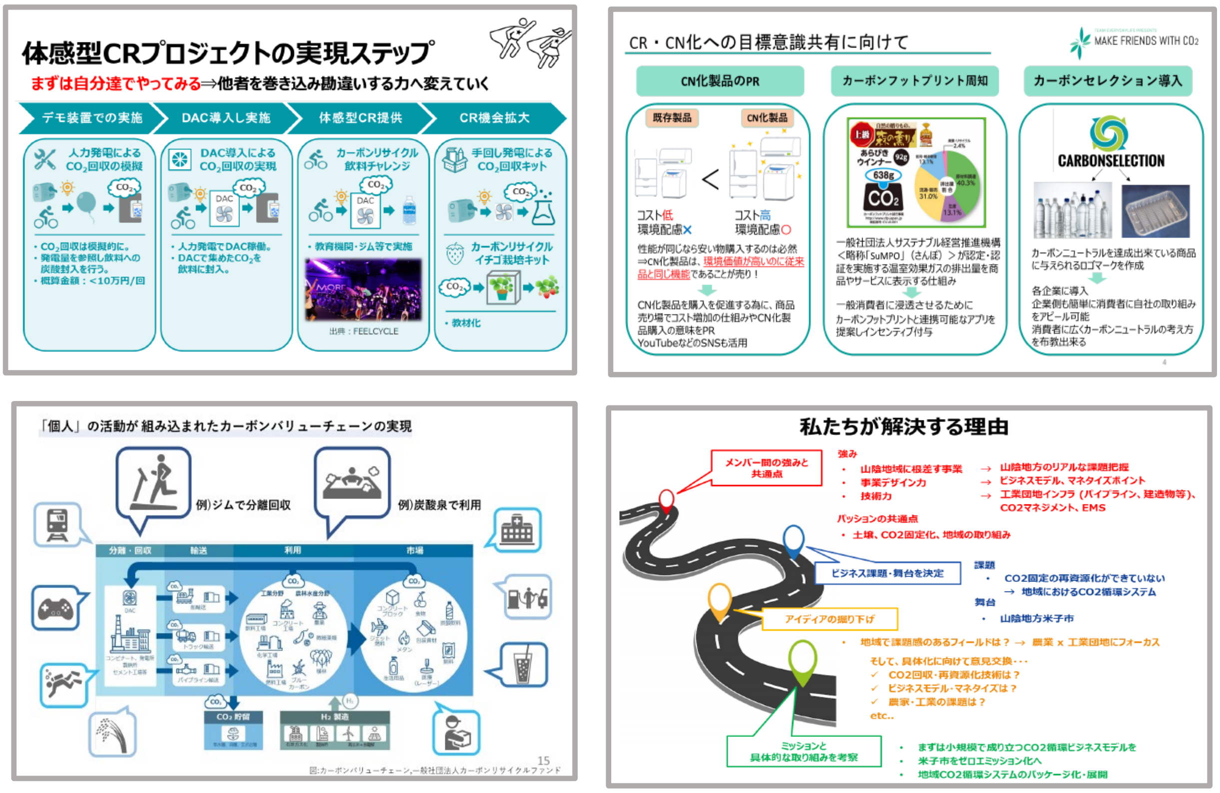


Figure 9. Samples of team presentations at the Carbon Recycling University courses in the second year

Source: Carbon Recycling Fund Institute materials

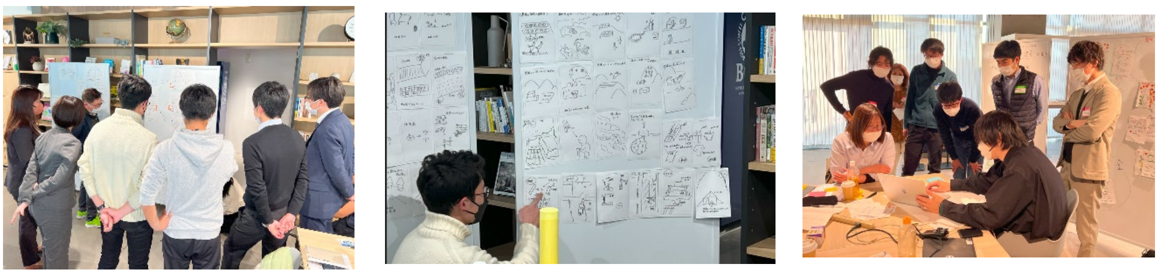


Figure 10. Local version of the Carbon Recycling University (at Hiroshima University)

Source: Carbon Recycling Fund Institute materials

■ [Example of progress: The Tale of Carbo and Risa – Digital content for the young]

Due to the importance of reaching the younger generation, the CRF created “The Tale of Carbo and Risa,” digital content for junior high and senior high school students. The fascinating story introduces examples of carbon recycling. We are 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.

Figure 11. Sample content from the Tale of Carbo and Risa and Sasuke

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. In FY2022, the then-CRF’s Chairperson, Mr. Nobuo Fukuda, gave a presentation at the International Conference on Carbon Recycling in October and Vice-Chairperson Mr. Masayoshi Kitamura presented during World Smart Energy Week 2022 in March, receiving many responses.

In addition, Mr. Fukuda, CRF Chairperson at the time, gave a three-minute video speech as a high-level government respondent at the 8th UN STI (Science, Technology, and innovation) 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.

Figure 12. Then-Chairperson Mr. Fukuda and Vice Chairperson Mr. Kitamura giving speeches

Source: Carbon Recycling Fund Institute materials

■ [Activity progress: Establishment of a forestation fund and strengthening of work on CO_2 sinks]

The CRF established a forestation fund in April 2023 as a measure for concrete work on CO_2 sinks, which play a key role in attaining carbon neutrality. In the preparatory stage, we interviewed CRF members and exchanged information and opinions with the relevant ministries, namely the Ministry of Economy, Trade and Industry and the Ministry of Agriculture, Forestry and Fisheries (Forestry Agency). Positioning the CO_2 sinks study group founded at the same time as the basis, we will plan and implement the following activities: afforestation using fast-growing trees, etc. and exit strategies; discuss the credit system associated with these activities; obtain necessary data; organize PR activities and events to promote understanding across the general public; coordinate with the agriculture, forestry, and fishing industries on measures such as blue carbon; and cooperate with municipalities and local industries. The first study group meeting took place in July 2023 under a theme of forestation.

In June 2023, we organized a forestation event, "Forest of Carbo and Risa," in the town of Higashimatsuyama, Saitama Prefecture (area flooded due to the collapse of the Oppegawa River embankment during Typhoon Hagibis in 2019). Over 80 people, including local agricultural workers, assembly members, CRF members and their families, joined this event. They planted 200 fast-growing paulownia saplings developed by a CRF member, which mature in about five years. We hope that similar activities will spread as measures for abandoned farmland and disaster control in addition to afforestation.

We believe that this activity also provides a solution to strengthen the energy, resources, and food supply chain and their production in Japan.

Forest of Carbo and Risa can be searched for on Google Map.

https://goo.gl/maps/4LjryK8NBu6AS2mF8

A panoramic airborne video is available on YouTube.

https://youtu.be/z0k0z58fZ24

3. Recommendations for realizing a carbon recycling society

The CRF made the following recommendations based on discussions among members about what society should become and processes to realize it, as members take the initiative in working on the development and social implementation of carbon recycling technologies. The CRF is taking the lead with its members in implementing the recommendations to achieve carbon neutrality, mainly through carbon recycling and realize a carbon recycling society, according to the roles described in Chapter 2

Develop and promote innovation, develop human resources

- 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, we should engage in cross-industry coordination, including coordination with start-up companies, and take full advantage of open innovation. We should also leverage government-led support to implement measures such as a "Basic GX Policy."
- To support the activities of these industries, the national government should enhance its measures, such as by providing greater support to accelerate green transformation. Solid and continuous support should be provided for highly motivated companies that take the initiative.
- Between 2030 and 2050, personnel who can implement carbon-neutrality measures and carbon recycling should be developed.
- A deeper understanding of carbon neutrality and carbon recycling should be fostered among the general public in order to promote greater adoption by society.

Create CO_2 value chains

- Carbon recycling technologies and products establish their importance and roles in society through their deployment and application, so CRF members should promote the creation of CO_2 value chains that contribute to the valuation of CO_2 by promoting the understanding and usage of carbon recycling technologies and products.
- However, suppliers, which reduce CO_2 emissions, have no connection with users, and there is no linkage to product s with respect to exit strategies and markets, so and it is important to establish these networks. The CRF serves this purpose.
- To maintain and enhance Japan's international competitiveness, 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.
- Quantitative evaluation of obtained and accumulated data regarding CO_2 separation, capture, and usage 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.
- 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.
- 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.

Integration with regional revitalization and expansion to the global market

- CRF members should create examples that leverage the strengths and features of communities by collaborating 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.
- The national government should strengthen support for creating examples of CO_2 value chains through collaboration between the private sector and local communities.
- Efforts should be expanded 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.

4. Summary

The importance of carbon recycling to capture and fix CO_2, and use CO_2 and carbon compounds as resources, is rising at an unprecedented speed in order to achieve carbon neutrality based on a balanced combination of environment and economy. As such, the Carbon Recycling Fund Institute serves as a platform for cross-industrial and industry-academic-government coordination, implementing these recommendations and other activities. The Institute will promote the creation of a framework for global carbon recycling, namely a "Sustainable Carbon System," in various fields including resources, energy, and food through industry-academic-government coordination and cooperation with overseas parties as well as cross-industrial collaboration in the private sector to help achieve carbon neutrality not only in Japan but also across the globe.

Attachment 1. Examples of Progress of Members for Building a Carbon Recycling Society

CO_2 separation and capture, fuel conversion, mineralization, and conversion to chemicals are expected to become widespread around 2030. Following these advancements, CO_2 absorption and fixation, carbon recycling (CR) system building, and other related subjects will be put into practice. Related verification and technology development are conducted through cross-industry coordination, collaboration among industry, academia, and government, as well as municipality coordination. This attachment introduces examples of these developments.

List of examples:

Comprehensive actions

- (Verification testing and research and development) Establishment (main operator: New Energy and Industrial Technology Development Organization (NEDO)) and operation and administration (Japan Carbon Frontier Organization) of an R&D and demonstration base for carbon recycling (Osaki-kamijima-cho, Hiroshima)
- (Technology demonstration) Advances at Soma IHI Green Energy Center (IHI Corporation)
- (Development and verification testing) Construction of a plastic recycling system to build a recycling society (Mitsubishi Chemical Group Corporation)
- (Development and verification testing) Development of technology for producing liquid fuel from CO_2 (Idemitsu Kosan Co., Ltd.)

CO2 separation and capture

- (Commercialization (financial contribution and joint development)) Development of next-generation compact CO_2 separation and capture equipment (Marubeni Corporation)
- (Verification testing) Japan’s first test to separate and capture CO_2 in exhaust gas from a coal-fired plant using a solid absorbent (Kawasaki Heavy Industries, Ltd.)
- (Verification testing) Installation of a biogas purification system at a sewage treatment plant in Kurashiki, Okayama (Asahi Kasei Corp.)

Fuel conversion

- (Commercialization) Start of Japan’s first continuous procurement of biofuel for ships on a commercial basis (Toyota Tsusho Corporation)
- (Research and development) Research and development of a technology to produce liquid fuel from CO_2 (Sumitomo Heavy Industries, Ltd.)

Conversion to chemicals

- (Pre-feasibility study) Partnership with an overseas company in the circular carbon methanol business using CO_2 and green hydrogen (Mitsubishi Gas Chemical Company, Inc.)
- (Commercialization) Successful creation of glass from CO_2 in the air (Revcell Co., Ltd.)

Mineralization

- (Verification testing) Development of biochar concrete and its application to construction site facilities (Shimizu Corporation)

- (Verification testing) Successful development of a system to fix CO_2 into fresh concrete efficiently (Taiheiyo Cement Corporation)

CO2 sinks

- (Commercialization) Wooden construction technology and ZEB that contribute to the creation of a recycling society (Toa Corporation)
- (Verification testing) J Blue Concrete to create blue carbon and reduce CO_2 (Electric Power Development Co., Ltd.)
- (Verification testing) Coordination agreement with Miyazaki Prefecture on a resource recycling project using agricultural resources (Sojitz Corporation)

System building and support

- (Verification testing) Verification of a GX cycle management service that helps companies promote green transformation (ITOCHU Corporation)
- (Verification testing) Application of a water-surface drone for blue carbon calculation (verification by KDDI Research, Inc.)
- Building of a CCUS value chain digital platform (development by Mitsubishi Heavy Industries, Ltd.)

Comprehensive actions

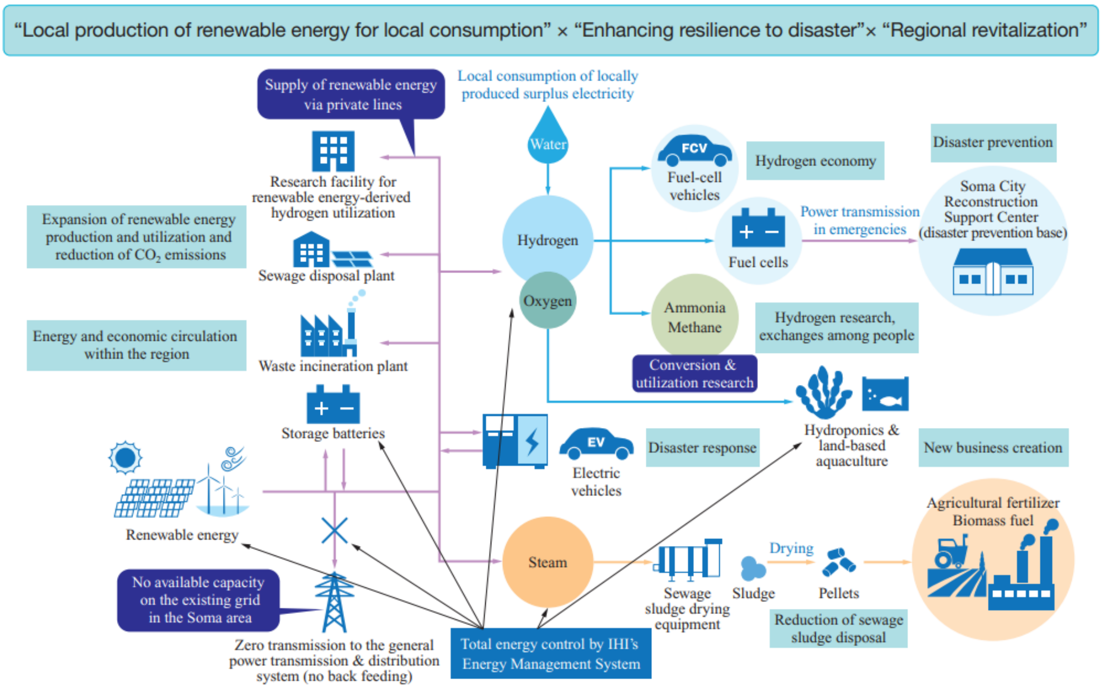
- Example of a member's progress: Establishment of an R&D and demonstration base for carbon recycling (Osaki-kamijima-cho, Hiroshima)
  Stage: Verification testing and research and development
  Main operator: New Energy and Industrial Technology Development Organization (NEDO)
  Implementation member(s): Japan Carbon Frontier Organization

NEDO held an opening ceremony for an R&D and demonstration base for carbon recycling (Osaki-kamijima-cho, Hiroshima) in September 2022. NEDO started the construction of the facility in 2020 in accordance with the Carbon Recycling 3C Initiative released by the Ministry of Economy, Trade and Industry in 2019. Japan Carbon Frontier Organization operates and manages the base. The base attracts many domestic and international visitors as a showcase of carbon recycling technologies.
The base supplies CO_2 that has been separated and captured at the Osaki CoolGen IGCC demonstration plant to companies and organizations that research carbon recycling technologies.
The base consists of three areas: a demonstration research area, an algae research area, and a basic research area. NEDO has adopted 11 themes (one of them was finished in FY2022) and conducted research and development on them for early social implementation to contribute to the realization of carbon neutrality by 2050.

R&D and demonstration themes	Research and development by
Development of efficient CO_2-use concrete (FY2020 to FY2022: Ended in FY2022)	The Chugoku Electric Power Co. Inc. Kajima Corporation Mitsubishi Corporation
Research of selective synthesis technology of chemical products for carbon recycling (FY2020 to FY2024)	Kawasaki Heavy Industries, Ltd. Osaka University
Development of a gas-to-lipids bioprocess (FY2020 to FY2023)	Hiroshima University The Chugoku Electric Power Co. Inc.
Establishing a research base and developing technologies that lead to increased CO_2 utilization rate for the production of microalgae-derived SAF (FY2020 to FY2024)	Institute of Microalgal Technology, Japan (IMAT)
Research & development of CO_2 fixation by microalgae and high-value ingredients production (FY2022 to FY2024)	Algal Bio Co., Ltd. The Kansai Electric Power Co., Inc.
Development of a CO_2 decomposition and reduction process using atmospheric pressure plasma (FY2022 to FY2024)	Tokai National Higher Education and Research System Kawada Industries, Inc.
Production of value-added chemicals from CO_2 using boron-doped diamond electrodes (FY2022 to FY2024)	Keio University Tokyo University of Science Japan Carbon Frontier Organization
Research and development of carbon recycled LP gas manufacturing technology and process (FY2022 to FY2024)	ENEOS GLOBE Corporation Nippon Steel Corporation University of Toyama
R&D of silicon carbide derived from industrial waste using CO_2 as a carbon source (FY2022 to FY2024)	Tohoku University
Development of algal biomass production and application technologies enabling high efficient CO_2 utilization (FY2022 to FY2024)	Nippon Steel Corporation
Carbon recycling technology demonstration and R&D with co-production of multiple valuable commodities by using seawater (FY2022 to FY2024)	Waseda University Sasakura Engineering Co., Ltd.

■ Example of a member's progress: Advances at Soma IHI Green Energy Center
Stage: Technology demonstration
Implementation member(s): IHI Corporation

Since April 2018, IHI has coordinated with Soma City in Fukushima Prefecture in operating the Soma IHI Green Energy Center (SIGC), a smart community project site aimed at new urban development in order to recover from the Great East Japan Earthquake and restore the local economy. As the figure below shows, SIGC's concept is generating renewable energy mainly based on solar power and using it within Soma city area (local production of energy for local consumption), reinforcing the area's disaster prevention functions and revitalizing the area.



5. Figure 13. Smart community model

Source: IHI materials

The SIGC operates 1.6 MW solar power generation facilities, a 5.5 MWh battery system with an output of 1 MW and water electrolyzers which generate hydrogen. The electric power is mainly supplied to the neighboring sewage treatment plant and waste incinerator of Soma City. Any intermittent power shortage is compensated by purchasing grid power. When the facility generates power at full capacity during good weather, the amount of power exceeds the battery capacity, resulting in surplus power. Then, hydrogen is generated using the water electrolyzers and stored in the tanks. Two tanks at the site can store up to 400 Nm^3 of hydrogen.

Figure 14. Equipment used at the SIGC: (from left to right) solar power generation facilities, battery system, and hydrogen tanks

Source: IHI materials

SIGC is working on 'aquaponics,' which is a novel method of combining onshore aquafarming and hydroponics and completely circulating water and nutrients. Also, Recycled Fertilizer Soma is produced from sewage sludge emitted from the sewage treatment plant powered by SIGC.

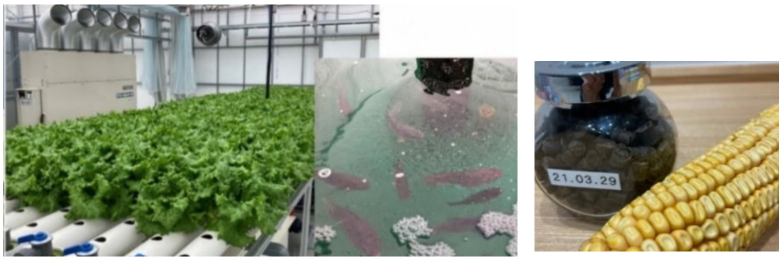


Figure 15. Aquaponics (left) and corn cultivated using recycled fertilizer from sewage sludge (right)

Source: Soma City website

The supply of e-methane (synthetic methane) for Odekake Minibus, a community bus service operated by Soma City, started in January 2023. These are Japan's first vehicles that use e-methane. This fueling service is operated as part of the smart community project intended to contribute to the local production for local consumption of solar power, as well as regional promotion and development in Soma City. The e-methane is produced by using green hydrogen produced using solar power and CO_2 methanation system in the SIGC. The SIGC will continue to produce e-methane and to demonstrate its application as renewable vehicle fuel.

Figure 16. e-methane station and Soma City community bus

Source: IHI website

- Example of a member's progress: Construction of a plastic recycling system to build a recycling society

  Stage: Development and verification testing

  Implementation member(s): Mitsubishi Chemical Group Corporation

As a specialty material company that provides innovative solutions, Mitsubishi Chemical Group Corporation aims to build a recycling society. For plastic recycling, the company works on plastic recycling in addition to the sales expansion of plant-derived bio engineering plastic, DURABIO™, and biodegradable plastic, BioPBS™.

The Mitsubishi Chemical Group started the verification testing of a resource recycling system that starts from paper cups made of BioPBS™ by coordinating with Okinawa City. Okinawa City hosted the FIBA Basketball World Cup 2023 from August 25, 2023. To add biodegradability, BioPBS™ is used instead of PE, which is conventionally used to add water resistance, for the interior of 40,000 originally designed paper cups produced by Okinawa City to promote the event. The paper cups were used at home games of Ryukyu Golden Kings, a professional basketball team of the B League, in March 2023 and will be used as drink cups at events in Okinawa City, etc. Ryukyu Kanri Sangyo K.K. collects and transports used paper cups. Kyowa Kako Co., Ltd. and Ryukyu University jointly combine them with cattle feces for composting using composting facilities at the university. The compost is planned to be used for greening activities and other purposes in Okinawa City. The resource recycling system in Okinawa City will be verified through this project. Okinawa City and Ryukyu Kanri Sangyo also plan to take a leading role in organizing delivery lectures at elementary schools in Okinawa City and other events.

The operation of a plant to reuse waste plastic as a petrochemical raw material is scheduled[*] to start by the end of FY2023. Development of an acrylic resin chemical recycling technology and consideration for the social implementation of the recycling system are also underway.

[*] ENEOS Corporation and Mitsubishi Chemical Corporation jointly operate one of Japan's largest facilities with a processing capacity of 20,000 tons per year.

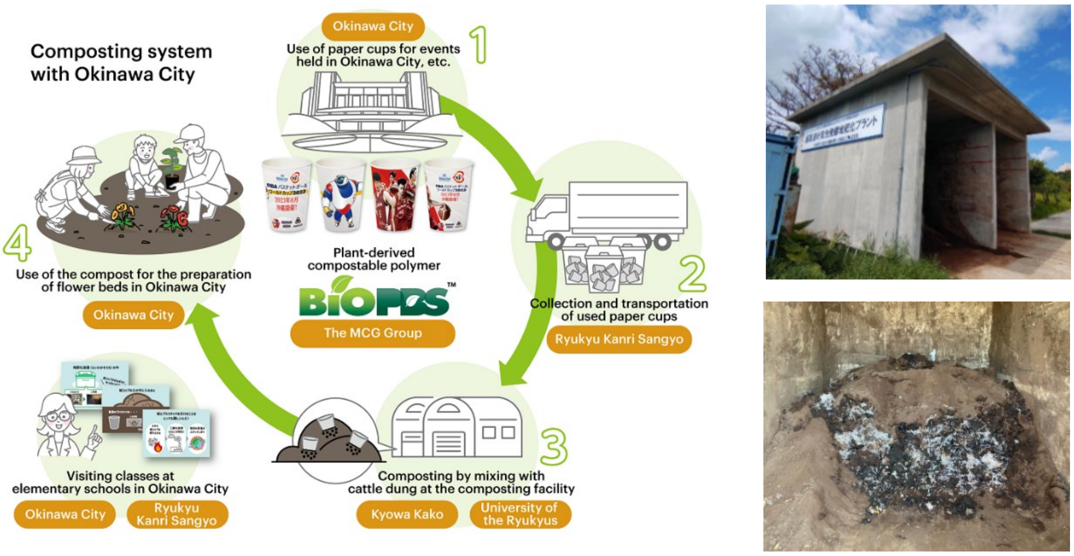


Figure 17. Resource recycling system operated with Okinawa City (left), composting facilities at Ryukyu University (upper right), and composting (lower right)

Source: Mitsubishi Chemical Group website

- Example of a member's progress: Development of technology for producing liquid fuel from CO_2
  Stage: Research and development and verification testing
  Implementation member(s): Idemitsu Kosan Co., Ltd.

  Idemitsu Kosan Co., Ltd. is developing next-generation technologies for Fischer-Tropsch reaction (FT reaction/synthesis),* which is considered to be the most compatible for chemicals production from CO_2 and the production of carbon hydrogen. The company is also building and optimizing the consecutive production process of liquid synthetic fuel and is involved in research and development for scaling up in the future. This research is conducted on consignment for New Energy and Industrial Technology Development Organization (NEDO).

* Reaction process to synthesize liquid high hydrogen that can serve as an alternative to petroleum from CO and hydrogen through catalysis reaction

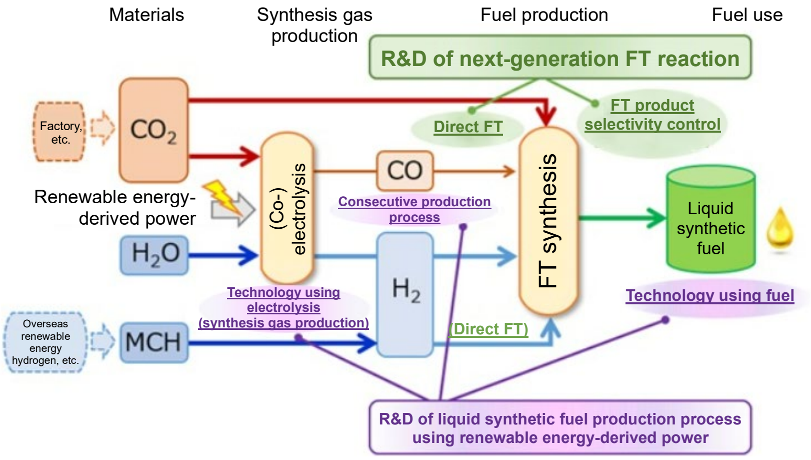


Figure 18. Consecutive liquid synthetic fuel process using FT reaction

Source: NEDO website

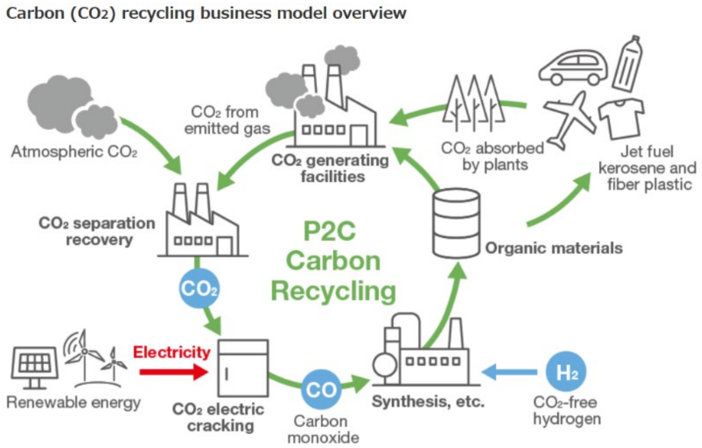


Figure 19. Conceptual image of a circular carbon society model through CO_2 recycling
Source: Idemitsu Kosan website

In addition, the company proposed a project to consider local CO_2 recycling through electrolysis using an artificial photosynthesis technology in order to promote the creation of a circular carbon society model through CO_2 recycling that is publicly sought by the Global Environment Bureau of the Ministry of the Environment, with Toshiba Energy Systems & Solutions Corporation, Toyo Engineering Corporation, and other companies. The project was adopted as a consignment project.

The company creates a basic plan that assumes that all processes from CO_2 separation and capture and SAF* production through consumption will be verified using CO_2 electrolysis equipment developed by Toshiba Energy Systems & Solutions, and evaluates the feasibility of the business.

In addition, the development and deployment of ATJ** verification equipment using the state-of-the-art process technology proposed by Idemitsu Kosan for the widespread use of SAF was adopted as a NEDO Green Innovation Fund Project (Fuel production technology development projects using CO_2).

* Sustainable aviation fuel. The jet fuel is produced from sustainable supply sources with small CO_2 emissions from raw material production, captured through combustion processes.

** Alcohol to jet. Technology and process to produce SAF from ethanol.
Registered in Annex 5 of the SAF international standard, ASTM certification, ASTM D7566.

The company aims to build Japan's first large-scale SAF supply chain with an eye on creating the above-mentioned carbon recycling society in the long run.

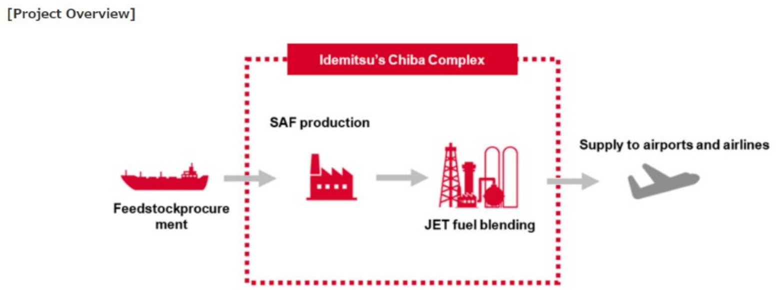


Figure 20. Establishment of SAF supply chain

Source: Idemitsu Kosan website

CO2 separation and capture

- Example of a member's progress: Development of next-generation compact CO_2 separation and capture equipment

  Stage: Commercialization (and joint development, with investment)

  Implementation member(s): Marubeni Corporation

Marubeni Corporation is developing Carbon Capture, Utilization (CCU) for reusing CO_2 or converting the same into other valuable products jointly with Carbon Clean Solutions Limited (hereafter referred to as CCSL) in the U.K., whose proprietary technologies are introducing out-of-the-box modular solutions for easy, affordable and scalable carbon capture.

Figure 21. Facilities of CCSL
Source: Marubeni materials

The chemical absorption method is a CO_2 separation and capture technology. CCSL has developed their own new recovery solvent used in this method and offers a technology to capture CO_2 at higher efficiency and lower cost than with conventional recovery solvents. This technology has the world's highest cost competitiveness among currently commercialized CO_2 capture technologies. This technology has been adopted in CCU projects around the world and in about 50 cases of CO_2 capture.

The company is continuing development to commercialize compact next-generation CO_2 separation and capture equipment that further reduces cost.

- Example of a member's progress: Japan's first test to separate and capture CO_2 in exhaust gas from a coal-fired plant using a solid absorbent

  Implementation stage: Verification testing

  Implementation member(s): Kawasaki Heavy Industries, Ltd.

Kawasaki Heavy Industries, Ltd. and Research Institute of Innovative Technology for the Earth (RITE) constructed pilot-scale test equipment (a capacity of 40 tons of CO_2/day) of an energy-saving CO_2 separation and capture system with Kansai Electric Power Co., Inc. in the Maizuru power plant of Kansai Electric Power. They will start a test to separate and capture CO_2 in combustion exhaust gas from the coal-fired plant in FY2023. This project was adopted as research on the applicability of advanced carbon dioxide solid absorbent to coal combustion exhaust gas by NEDO and is conducted by Kawasaki Heavy Industries and RITE with the help of Kansai Electric Power. Verification testing is scheduled from FY2023 to FY2024.

To realize a carbon neutral society, it is necessary to establish and apply technologies to separate and capture CO_2 in exhaust gas from factories, thermal power plants, etc., which will save more energy. Among others, the solid absorption method can significantly reduce the energy required for CO_2 separation from conventional technologies and has great potential as a next-generation separation and capture technology.

Kawasaki Heavy Industries and RITE have set the goal of improving the performance of their energy saving CO_2 separation and capture system and making it larger by developing and improving solid absorbent and the KCC (Kawasaki CO_2 Capture) moving bed system in the carbon dioxide capture technology practical application research project started in FY2015 on consignment for the Ministry of Economy, Trade and Industry. (NEDO became responsible for the project in FY2018). Kawasaki Heavy Industries will design and construct the pilot-scale test equipment. A consecutive operation test will be conducted using a solid absorbent developed by RITE. In addition, there is a plan to evaluate the reliability, operability, and economic efficiency when the equipment is installed in a coal-fired plant with the help of Kansai Electric Power while considering future social implementation.

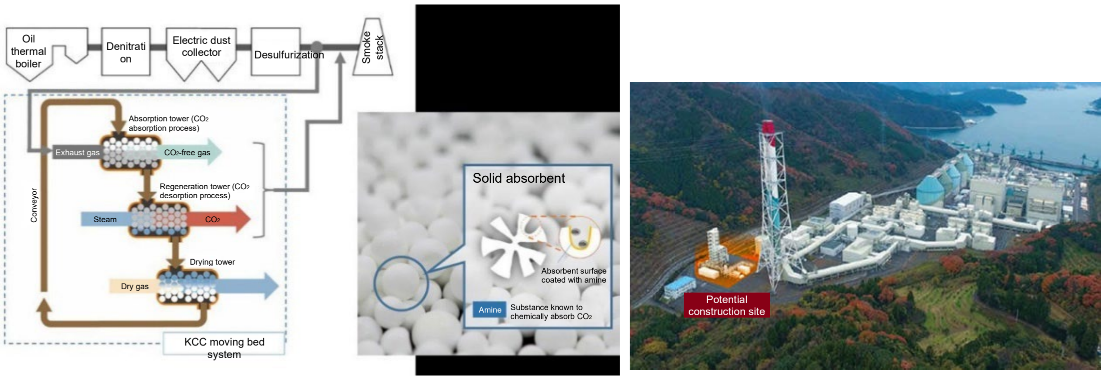


Figure 22. Verification testing flowchart (left and middle) and conceptual image of the pilot-scale test equipment installation in Maizuru power plant (right)

Source: News release from Kawasaki Heavy Industries

■ Example of a member's progress: Installation of a biogas purification system at a sewage treatment plant in Kurashiki, Okayama

Stage: Verification testing

Implementation member(s): Asahi Kasei Corp.

Asahi Kasei Corp. and Kurashiki City concluded an agreement on the performance evaluation and verification of a biogas purification system in Kurashiki, Okayama in September 2022.
This system performs highly selective separation of CO_2 and methane gas (bio methane) in biogas using K-GIS zeolite. K-GIS zeolite is a new absorbent developed by Asahi Kasei that selectively absorbs CO_2. Conventional absorbents absorb methane at the same time as CO_2, but K-GIS zeolite absorbs an extremely small amount of methane, which makes it possible to separate and capture highly pure methane very efficiently. In addition, this absorbent can also capture highly pure CO_2.
The biogas consists of methane generated from sewage sludge, garbage, etc. (about 60%) and CO_2 (about 40%). For example, bio methane is gathering attention in the U.S. and Europe as a carbon neutral fuel that serves as an alternative to natural gas, resulting in a rapid increase in demand.
Kurashiki City uses the biogas generated from sewage sludge for power generation at the Kojima sewage treatment plant. Some portion of the biogas is input into this system to purify bio methane.
Note that the biogas is mixed with separated CO_2 to return it to the original state and is used as power generation fuel at this verification to avoid wasting it.

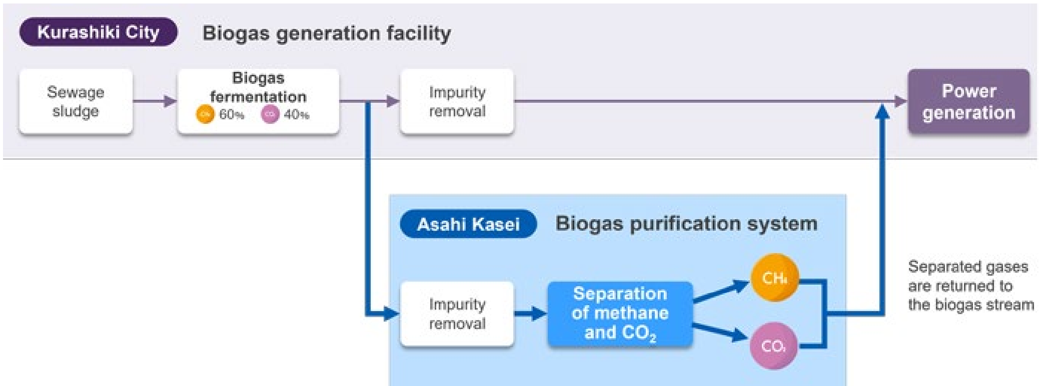


Figure 23. Flowchart of biogas processing and a new biogas purification system verification equipment at the Kojima sewage treatment plant in Kurashiki

Source: News release from Asahi Kasei

Fuel conversion

- Example of a member's progress: Start of Japan's first continuous procurement of biofuel for ships on a commercial basis

  Stage: Commercialization

  Implementation member(s): Toyota Tsusho Corporation

Toyota Tsusho Corporation conducted the first biofuel operation trial at Singapore Port in 2021. Since then, the company has verified the effectiveness of biofuel and supply operations at Nagoya Port for commercialization, including biofuel supply trials with the ship-to-ship bunkering, where a fuel supply ship pulls in next to a tugboat or a coastal trading vessel operating within a port and supply fuel to it. In April 2023, the company started Japan's first continuous supply of biofuel for ships on a commercially basis.

Toyota Tsusho, in cooperation with a recycling company, is continuing to procure waste cooking oil collected from the employee cafeterias and other facilities of the Toyota group and Toyota Tsusho group companies, and biofuel refined from these oils as part of the raw materials that are blended with heavy oil and supplied.

Figure 24. Car carrier receiving biofuel from the fuel supply ship

Source: Toyota Tsusho website

- Example of a member's progress: Development of a liquid fuel synthesis technology using CO_2 through FT synthesis
  Stage: Research and development
  Implementation member(s): Sumitomo Heavy Industries, Ltd.

Sumitomo Heavy Industries, Ltd. is developing a mineralization technology*, algae cultivation technology, electrochemical reduction of CO_2 using diamond electrodes, carbon recycling liquid fuel technology, and other technologies to use CO_2. For the carbon recycling liquid fuel technology, Fischer-Tropsch (FT) synthesis** using CO_2 as a carbon source for conversion to heating oil, jet fuel, or middle distillate equivalent to light oil can be used to reduce loads on end users, for example, by combining with currently distributed mobility fuel.
In FY2022, the company confirmed that liquid carbon hydrogen and wax are generated even at atmospheric pressures with a CO_2-CO-H_2 feed by using the FT catalyst to which a promoter to improve reaction characteristics is added. The company is considering the use of a slurry bed reactor for FT synthesis using a feed containing CO_2 and continuing technology development to start a 50-L scale bench test in 2025.

* Technology to inject CO_2 into extracted calcium to fix it as $CaCO_3$

** Reaction process to synthesize liquefied hydrocarbons that can serve as an alternative to fuels from CO and H_2 through catalytic reaction

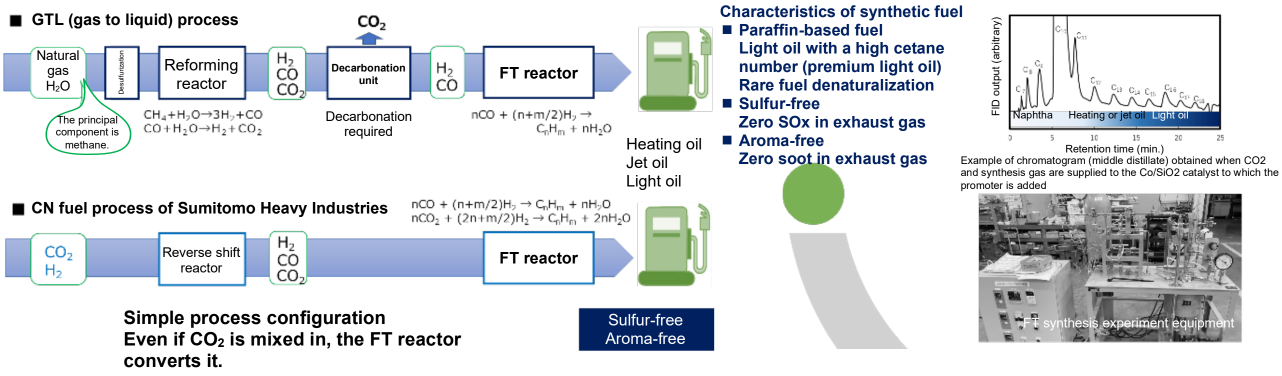


Figure 25. FT fuel synthesis process (left) and characteristics of synthetic fuel (right)

Source: Sumitomo Heavy Industries materials

Conversion to chemicals

■ Example of a member's progress: Partnership with an overseas company in the circular carbon methanol business using CO_2 and green hydrogen
Stage: Pre-feasibility study
Implementation member(s): Mitsubishi Gas Chemical Company

Mitsubishi Gas Chemical Company, Inc. (MGC) is promoting Circular Carbon Methanol ("Carbopath^{TM}"*), a technology for recycling CO_2, waste plastics, biomass and other inputs into methanol for use in chemical products, fuel, and power generation. Methanol can be used for a range of products and because it can be produced from CO_2 it is expected to be a powerful resource for building a carbon-neutral society through the deployment of CCU.
Cement Australia** (CA) and MGC signed a memorandum of understanding to study the manufacture and sale of renewable methanol made from CO_2 captured at CA's Gladstone plant and green hydrogen using MGC's newly developed methanol production technology. Through this collaboration, CA and MGC aim to establish an approach to CCU that can accelerate the transition to a net-zero future. Leading the shift to renewable construction in Australia, CA is committed to advancing Australia's 2050 net-zero targets from deploying its renewable building materials at scale to advancing next generation technologies such as carbon capture and utilization.

■ Example of a member's progress: Successful creation of glass from CO_2 in the air
Stage: Commercialization
Implementation member(s): Revcell Co., Ltd.

* Circular Carbon Methanol (CCM) has been officially named "Carbopath^{TM}" by MGC. The name Carbopath^{TM} expresses MGC's desire to be a pioneer in promoting CCM
https://www.mgc.co.jp/eng/corporate/news/2022/210704-e.html

** A Holcim and Heidelberg Materials joint venture company
Head Office: Darra, Queensland; CEO: Rob Davies

Revcell Co., Ltd. developed a CO_2 absorption and capture filter to capture CO_2 at locations around us such as home, stores, and commercial facilities after achieving success with its high-pressure oxygen capsule and infection prevention negative pressure room businesses under the concept of scientifically studying air. The company is proposing a system to absorb CO_2 with the filter attached to a compact device, such as an air purifier, and to recycle it as glass at glass factories.

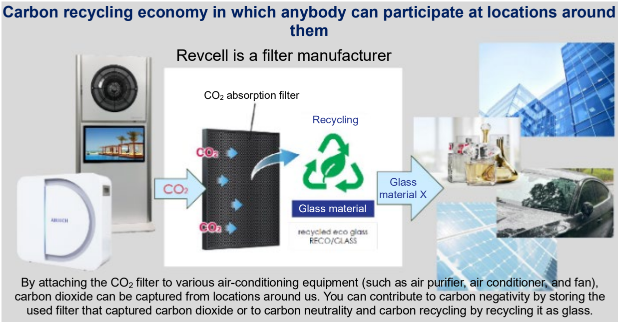


Figure 26 Conceptual image of the CO_2 absorption filter attached to an air purifier (left) and Recoglass (right)

Source: Revcell materials

Both the production method and chemical composition of Recoglass™ produced in this way is the same as conventional glass.

Recoglass can be used like conventional glass as jars, containers for high-end beauty products, bottles, glasses, and construction materials, for example. In Japan, Revcell collaborates with a leading clean room manufacturer for air purifiers with the DAC function and a leading glass manufacturer for recycling into glass.

Mineralization

- Example of a member's progress: Development of biochar concrete and its application to construction site facilities
  Stage: Verification testing
  Implementation member(s): Shimizu Corporation

Shimizu Corporation developed environmentally conscious concrete (hereafter referred to as SUSMICS-C) that stores carbon in concrete structures by mixing concrete with biochar to which the national J-Credit system can be applied as carbon storage for agricultural land use. SUSMICS-C uses biochar, which is carbonized wood that has absorbed CO_2 in the air during its growth process, and fixes CO_2 inside concrete. Carbon negativity can be achieved by using SUSMICS-C together with low-carbon cement, in which blast furnace slag replaces a portion of cement, in the production of which large amounts of CO_2 are emitted.

Biochar is made of sawdust disposed of during softwood or hardwood lumber processing. Sawdust biochar made by carbonizing sawdust can fix a large amount of carbon stably compared to other types of biochar. The carbon content is about 90% and the fraction of biochar carbon remaining after 100 years is also as high as about 90%. 1 kg of biochar fixes about 2.3 kg of CO_2. By adding 80 kg of biochar to 1 m^3 of concrete, approximately 183 kg of CO_2 can be fixed. Using low-carbon blast furnace cement as cement material can reduce CO_2 emissions by up to 118% compared to normal concrete. SUSMICS-C has great workability as well as superior environmental performance and can be pumped up at construction sites. In addition, its strength is equivalent to normal concrete. Therefore, SUSMICS-C can not only be applied to secondary concrete products, but also widely used for concrete work at construction sites.

This time, SUSMICS-C was applied to the temporary road paving at Shimizu's construction site for the first time at an actual work site and verified. Blast furnace cement type B was used as the cement material and 60 kg/m^3 of biochar was mixed into 1 m^3 of concrete, reducing CO_2 emissions by 99% compared to normal concrete. The volume of SUSMICS-C is 34.5 m^3 and the quantitative CO_2 reduction amount is about 6.7 tons. It was confirmed that SUSMICS-C can be used in the same way as normal concrete and that the compressive strength of SUSMICS-C core test pieces sampled from specimens retains performance that sufficiently satisfies the design standard strength.

Shimizu will expand the application range of SUSMICS-C and apply it to not only temporary structures but also permanent concrete structures to realize a decarbonized society. In addition, Shimizu will work on improving the environmental value by applying SUSMICS-C, for example, by aiming to obtain certification in the J-Credit system.

Figure 27. Powder and granular biochar (left) and application to an actual construction site (right)

Source: Shimizu Corporation website

- Example of a member's progress: Successful development of a system to fix CO_2 into fresh concrete efficiently

  Stage: Verification testing

  Implementation member(s): Taiheiyo Cement Corporation

Taiheiyo Cement Corporation developed CARBOCATCH®*, a system to fix CO_2 into fresh concrete efficiently. CARBOCATCH® is their proprietary system that circulates cement slurry, which is a mixture of cement and water, in a sealed container filled with CO_2 to fix CO_2 efficiently. This system can efficiently fix externally supplied CO_2 into the cement slurry as solid fine calcium carbonate at high efficiencies of more than 90% (more than 330 kg per ton of cement in the cement slurry).

* CARBOCATCH is a registered trademark of Taiheiyo Cement Corporation in Japan

CARBOCATCH® was established as part of a carbon recycling technology to fix captured CO_2 into cement and concrete based on the knowledge obtained from a NEDO grant-aided project of Development of Carbon Circulation Technology for the Cement Industry (FY2020 to FY2021). Wave-damping blocks made of CARBOCATCH® slurry fix about 8.0 kg (23 kg/t-cem**) of CO_2 per 1 m^3 of concrete. This result supersedes the 10 kg/t-cem targeted by NEDO. It has been also confirmed that the concrete made with the CARBOCATCH® slurry is equal to or better than conventional concrete in terms of fresh properties, strength development, durability, suppression of bleeding and reduction of setting time.

Practical applications of the CARBOCATCH® system are being studied. Production test on actual equipment was carried out for precast concrete products at one of the subsidiary companies. Test construction was also conducted at the Kumagaya Plant of Taiheiyo Cement to evaluate the applicability for pavement concrete. These tests revealed higher quality compared to conventional concrete, demonstrating that the system is an effective CCU technology that can be applied to general-purpose concrete production.

CARBOCATCH® can be applied for various purposes, so the company is currently conducting research and development with an eye to deploying it in every field.

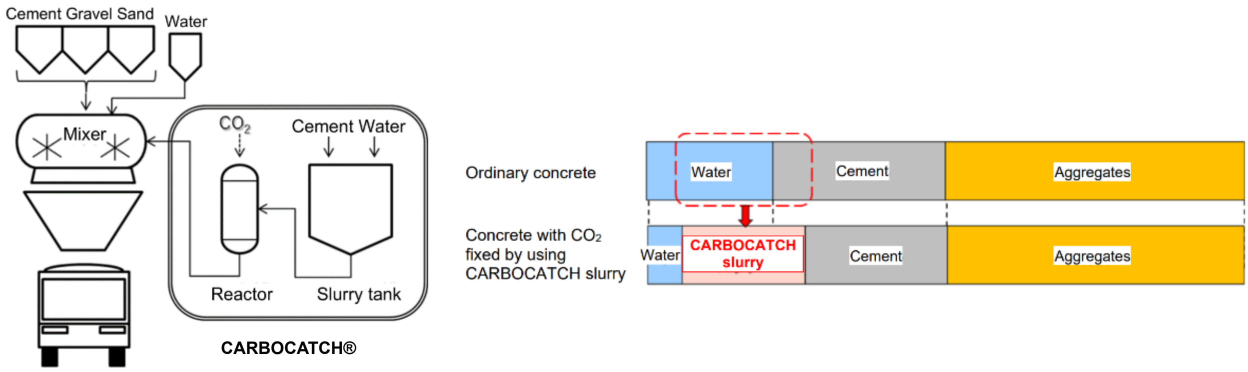


Figure 28. System of CARBOCATCH® (left)

Conceptual diagram of concrete composition using CARBOCATCH® slurry (right)

Source: News release from Taiheiyo Cement

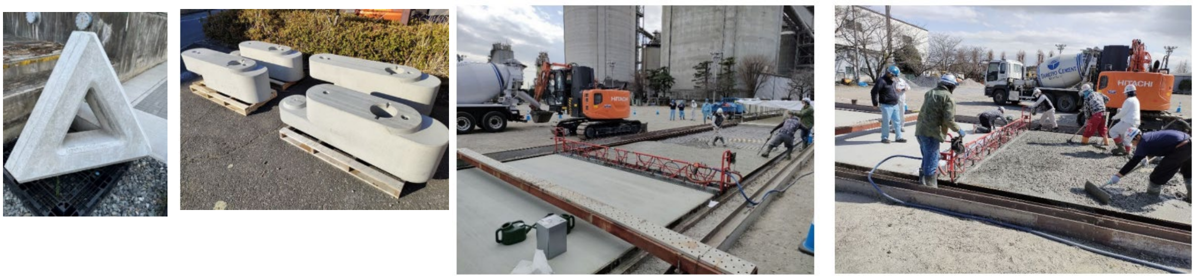


Figure 29. Wave-damping block made of CARBOCATCH® slurry (left)

Precast concrete products made of CARBOCATCH® slurry (second from left)

(consecutive foundation blocks for guardrail)

** The intensity changes due to the use of cement in addition to the CARBOCATCH® slurry during concrete manufacturing

Test work of pavement concrete using CARBOCATCH® slurry (second from right and right)

CO2 sinks

- Example of a member's progress: Wooden construction technology and ZEB that contribute to recycling society
  Stage: Commercialization
  Implementation member(s): Toa Corporation

  Toa Corporation has worked on the promotion of a recycling society in construction projects, for example, by renovating logistics facilities, hospitals, and large facilities or introducing co-generation and solar power generation facilities before recycling economy (circular economy) started gaining attention. The company currently focuses on wood buildings and zero energy buildings (ZEB). Recycling of forest resources leads to national land conservation and global warming prevention in Japan where forests account for two-thirds of the national terrain.
  Toa Corporation aims to achieve local production for local consumption of construction materials and a virtuous cycle of local economy and environmental preservation through effective use of these forest resources. Members for wood buildings are lighter than general steel construction with the same size, so the CO_2 generated during work is also reduced. Moreover, wooden structures are believed to reduce stress on people. The company has built wooden buildings, including two hotels. The company adopted a hybrid structure combining steel construction and wooden construction for the second experiment building completed in March 2023 in the Toa Research & Development Center and plans to obtain ZEB certification for it.


Figure 30. Hotel constructed using Toa's advanced wooden construction techniques (left)
Technology research building, Toa Corporation (right)
Source: Toa Corporation website

- Example of a member's progress: J Blue Concrete to create blue carbon and reduce CO_2
  Stage: Verification testing
  Implementation member(s): Electric Power Development Co., Ltd.

  Electric Power Development Co., Ltd. (J-POWER) is developing a technology to create seagrass bed more effectively using J Blue Concrete, which is an alternative material that is mainly made of coal ash and copper slag. Coal ash is a by-product from coal-fired plants and copper slag, which is a by-product from copper smelters. Blue carbon (CO_2 sequestration and storage by algae, etc.) is expected to be produced from seagrass bed creation. The company installed wave-damping blocks made of J Blue Concrete in Wakamatsu-ku, Kitakyushu, Fukuoka, where it is based, to create a new seagrass bed. Moreover, the company obtained a certified J blue credit, a new credit system for blue carbon, for the created seagrass bed in FY2021 for the first time as a private facility. Currently, J-POWER is improving the attachment of algae to increase the blue carbon amount by working on the surface shape of J Blue Concrete.

J Blue Concrete is a low-carbon construction material and the material-derived CO_2 emissions is about 40% of standard concrete because it uses a large amount of by-products and less cement. J Blue Concrete contributes to carbon neutrality both in terms of blue carbon and low carbon (material-derived CO_2 emissions) and is an effective construction material for blue infrastructure (symbiotic port structure). Therefore, J-POWER is not only meant for internal use, but also for social implementation.

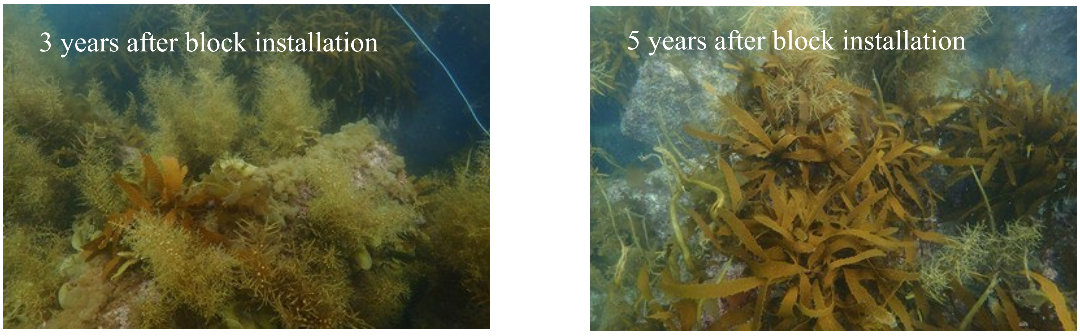


Figure 31. Algae attachment to J Blue Concrete blocks in Wakamatsu-ku, Kitakyushu, Fukuoka

Source: Electric Power Development materials

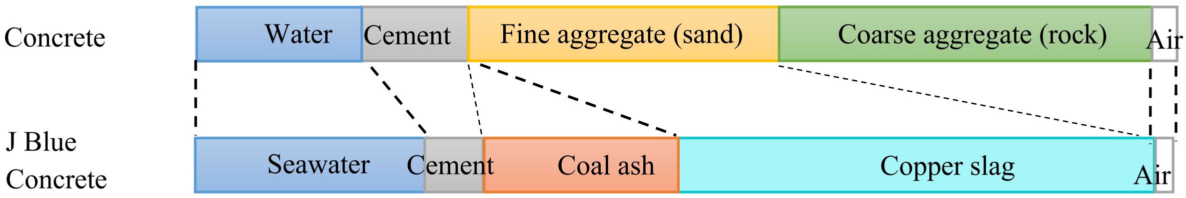


Figure 32. Comparison between concrete and J Blue Concrete

Source: Electric Power Development materials

■ Example of a member's progress: Coordination agreement with Miyazaki Prefecture on a resource recycling project using agricultural resources

Stage: Verification testing

Implementation member(s): Sojitz Corporation

Sojitz Corporation concluded a coordination agreement with Miyazaki Prefecture on a resource recycling project using agricultural resources in Miyazaki (such as fast-growing tree and Sorghum*). With the G7 Agriculture Ministers' Meeting in Miyazaki (April 22 to 23, 2023) as inspiration, the

* One of the five largest crops that is a widely used gramineous plant, from consumption to industrial use. Many species are available. Those with a strong growth potential grow over 5 m four months after seeding.

company uses agricultural resources through coordination between the public and private sectors and conducts verification with the aim of building a local recycling model in Miyazaki Prefecture.

Sojitz began test planting fast-growing Japanese aspen** at Kawaminami-cho in Koyu, Miyazaki as part of its fast-growing tree project in May 2022. In April 2022, the company started test production of Sorghum in addition to Japanese aspen, making use of unused agricultural land and agricultural land during the fallow period in the prefecture. The company had the first harvest in August and confirmed their growth potential. Going forward, they will work on the verification of resource recycling where harvests are processed into biomass fuel or ration for livestock and delivered to consumers. By concluding the agreement, the company receives information on the production of agricultural resources and other matters from Miyazaki Prefecture and plans to work together to evaluate its popularity and other characteristics as a product.

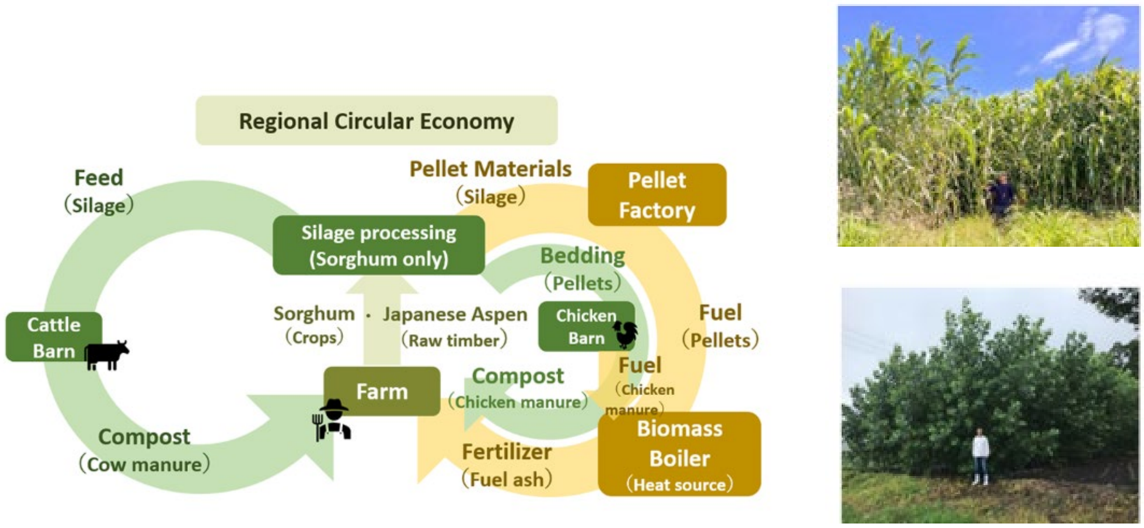


Figure 33. Conceptual image of circulation of Sorghum and Japanese aspen (left), Sorghum (upper right), and Japanese aspen (lower right)

Source: News release from Sojitz

** Tree species with a high growth amount and early cutting age that is expected to have a growth amount of 200 m^3 or more per hectare five years after planting

Many production materials such as fuel and feedstuff come from overseas. There is a need to shift towards a sustainable production structure that relies more on domestic resources. Sojitz aims to build a new local recycling model of agricultural resources with Miyazaki Prefecture to contribute to the growth of agriculture and related industries in Miyazaki Prefecture.

System building and support

- Example of a member's progress: Business partnership with a British environmental solutions company with an eye to expanding the scope of EU-ETS and introducing the Carbon Border Adjustment Mechanism

  Stage: Commercialization

  Implementation member(s): ITOCHU Corporation

  ITOCHU Corporation formed a business partnership with CF Partners* (CFP) to expand emission trading. CFP is a UK-based environmental solutions company that sells emission credits in Europe.
  In April 2023, the European Union (EU) Council decided on the introduction of the Carbon Border Adjustment Mechanism (CBAM). The CBAM is a mechanism to put carbon costs on steel products, aluminum, cement, fertilizer, and other products according to their emissions when they are imported to the EU. After the mandatory emissions reporting period started in October 2023, the imposition of carbon costs is expected to start in 2026. The EU Council also decided to expand the EU Emissions Trading System (EU-ETS) to the marine sector. The EU-ETS will apply to ships with a total tonnage of 5,000 tons or more departing from or arriving at EU from 2024. In 2026, it will be obligatory to purchase the emission quota for all emissions. This restriction is also expected to apply to the Japanese marine sector.
  ITOCHU Corporation supports emission trading, especially in Japan and Asian countries, as a sales liaison of emission credits procured and retained by CFP, using their global sales network across a wide range of industries. The company also organizes seminars and communicates industrial information based on the actual situation of the EU-ETS for customers in a wide range of industries, promotes the provision of solutions suitable for customer-specific needs, identifies needs to address the CBAM and the marine EU-ETS, and sells emission credits jointly with CFP.

*Headquarters: London, U.K., Co-CEOs: Jonathan Navon and Thomas Rassmuson

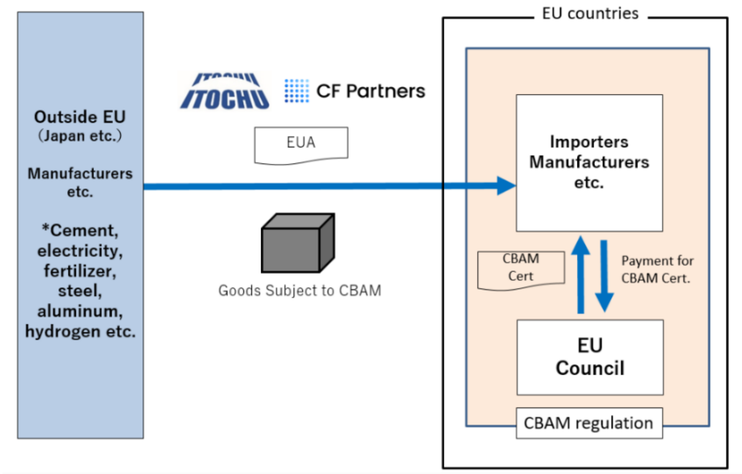


Figure 34. Conceptual diagram of actions with an eye for introducing CBAM

Source: ITOCHU Corporation website

■ Example of a member's progress: Application of a water-surface drone for blue carbon calculation

Stage: Verification

Implementation member(s): KDDI Research, Inc.

KDDI Research, Inc. conducted a verification experiment to survey seagrass beds and calculate blue carbon* by using a water-surface drone in June 2022 in collaboration with Toba City in Mie and KDDI Corporation.

During this verification, the water-surface drone autonomously followed a pre-set course using a smartphone to survey the distribution area of seaweed and algae and capture images of the target seagrass beds with its built-in underwater camera. The analysis of the recorded video footage confirmed that the ability to determine the cover degree, which represents the percentage of the area occupied by seaweed and algae, was confirmed. In the past, divers used to visually survey the distribution area of seaweed and algae in Toba. The use of water-surface drones enables remote navigation incorporating expert opinions and decisions, as well as fixed-point observation that consistently tracks precise locations. They will also mitigate the risk of accidents during diver surveys and allow for remote monitoring and control, thus enabling significant business DX.

This project won the 31st Grand Prize for the Global Environment Award* in March 2023.

* Carbon captured in the marine ecosystem, including seagrass beds

** The award is launched in 1992 to promote the coexistence of industrial development and global environment. It is hosted by Fujisankei Communications Group and sponsored by the Ministry of Economy, Trade and Industry, the Ministry of the Environment, the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Land, Infrastructure, Transport and Tourism, the Ministry of Agriculture, Forestry and Fisheries, the Ministry of Internal Affairs and Communications, Keidanren, and the Japan Chamber of Commerce and Industry.

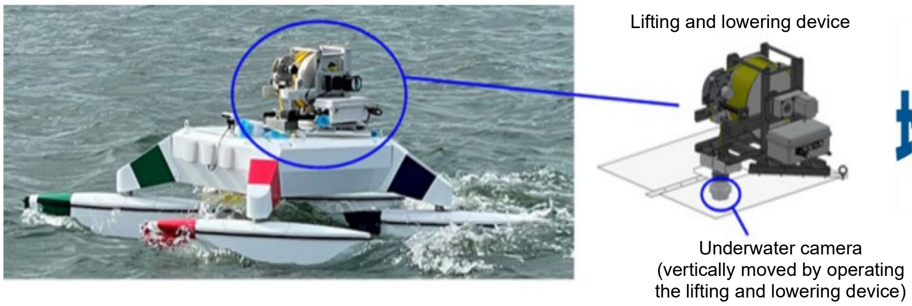


Figure 35. Water-surface drone (left and second from left), and the logo of the 31st Grand Prize for the Global Environment Award (right)

Source: KDDI Research, Inc. website

- Example of a member’s progress: Building of a CCUS value chain digital platform
  Stage: Development
  Implementation member(s): Mitsubishi Heavy Industries, Ltd.

  Mitsubishi Heavy Industries, Ltd. is jointly developing the CCUS value chain digital platform, CO_2NNEX™, with IBM Japan, Ltd. The company aims to contribute to the activation of the CO_2 ecosystem and global environment protection by connecting the CCUS value chain, where captured CO_2 is transported, utilized and stored, with the IoT and block chain, enabling visualization, tracking, trading and optimization.
  During the proof-of-concept of CO_2NNEX for e-methane started in October 2022, the company aims to promote the widespread use of e-methane and establish its environmental value while exchanging opinions with related organizations and companies.
  In February 2023, the company leveraged its CO_2NNEX knowledge to build a demonstration system of the CO_2NNEX for e-methane digital platform with Osaka Gas Co., Ltd. and IBM Japan Ltd. The CO_2NNEX for e-methane system visualizes CO_2 emissions across the supply chain, including the production, transportation, supply, and use of e-methane, which is synthetic methane produced as a result of methanation, and allows for the trading and transfer of environmental value.
  In March 2023, the company entered into an agreement with Osaka Gas Co., Ltd to conduct a feasibility study on a project to develop a CO_2 value chain for CCUS (Carbon Capture, Utilization, and Storage), including transporting CO_2 captured in Japan overseas, utilizing it to produce e-methane, synthetic gas produced through methanation, and storing it underground.

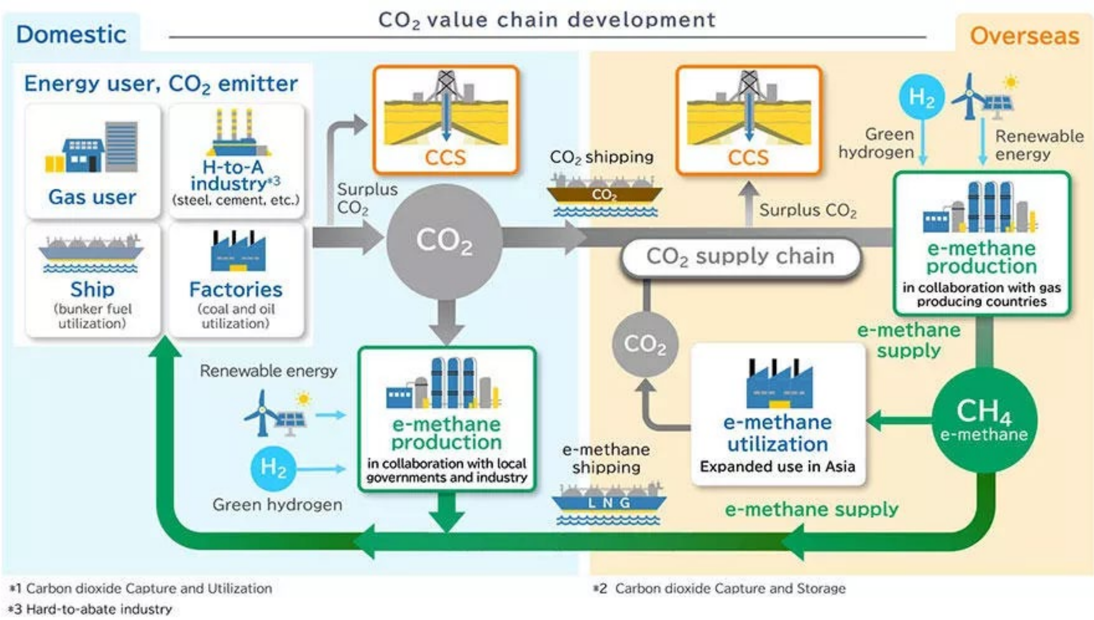


Figure 36. Building a global CO_2 value chain

Source: Mitsubishi Heavy Industries website

Attachment 2. Summary of the questionnaire conducted to CRF members

Questionnaire period: March 9, 2023 through March 28, 2023

Questionnaire targets: 117 corporation members, 21 individual members, 11 local government members, and 17 academic members

Number of responses: 88

1. Expectations from carbon recycling (CR)

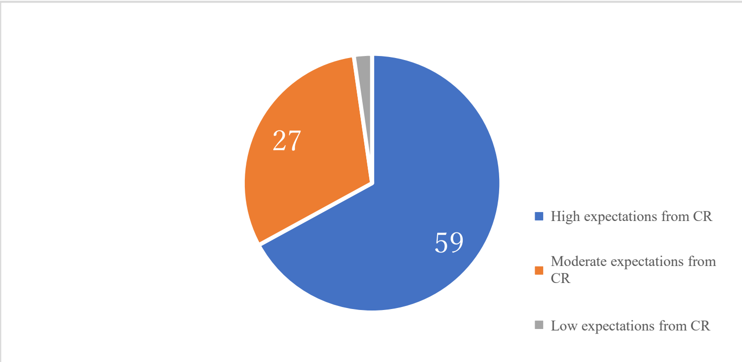


Figure 1 Expectations from CR

<u>Main reasons (High expectations and Moderate expectations from CR)</u>

- ✓ It's an important way to achieve carbon neutrality (CN) in and outside Japan.
- ✓ We expect future business opportunities from carbon separation, capture, and recycling.
- ✓ CO_2 separation and capture contribute to urban mine resources and S+3E.
- ✓ We look forward to system design such as subsidies and penalties in relation to GHG reduction.
- ✓ We have been asked to reduce CO_2 emissions from the supply chain.

<u>Main reasons (Low expectations from CR)</u>

- ✓ Feasibility is questionable in light of the current state of CR.

2. Roles and position in the CR area

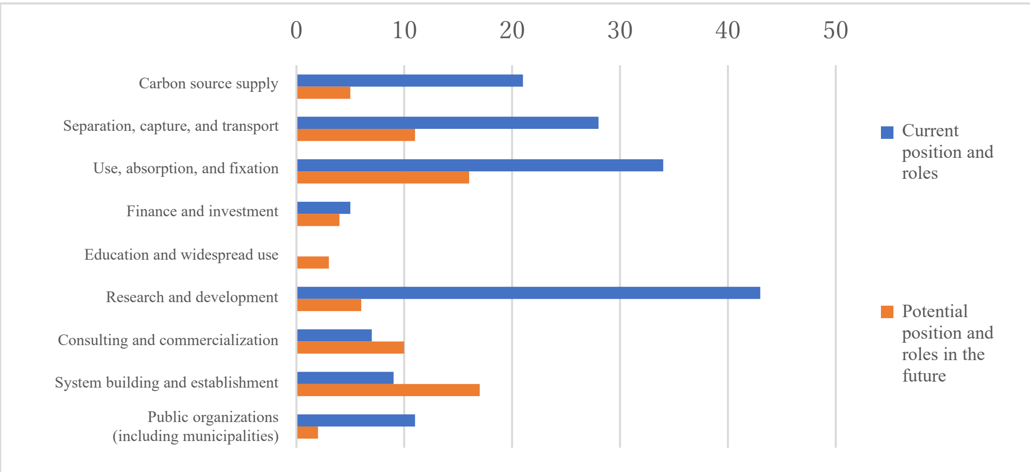


Figure 2 Current position and roles in the CR area

3. CR technology development areas

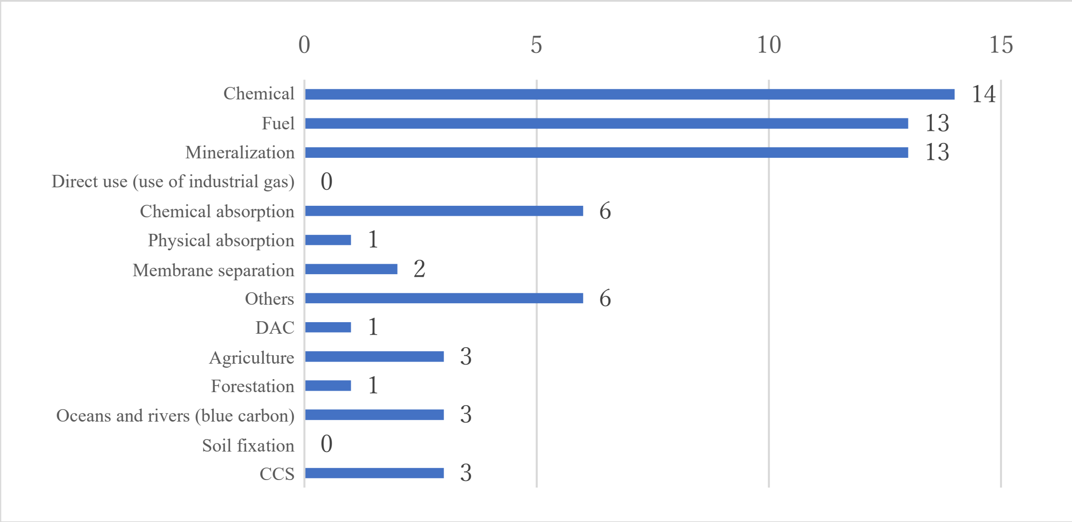


Figure 3 CR technology areas

<u>Other responses</u>

- ✓ We hope for cost reduction (CAPEX/OPEX) through modular development.
- ✓ Research and development that leverages our strengths
- ✓ Reduction in amine emissions

(1) What respondents expect from technology development and phases of technology development

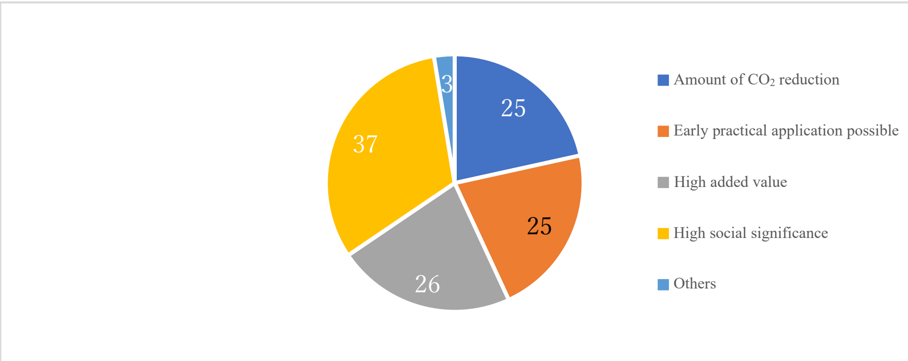


Figure 4 What respondents expect from technology development

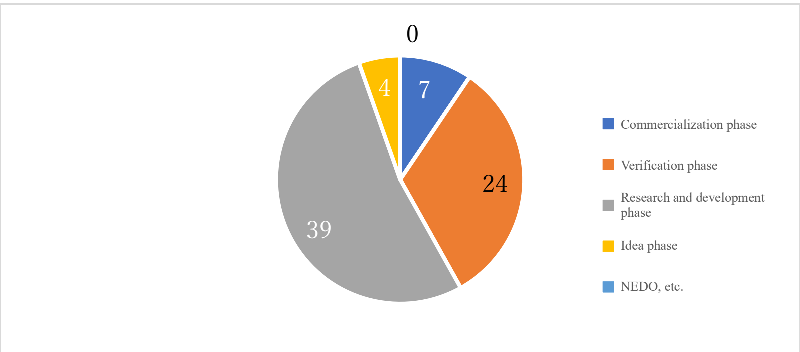


Figure 5 Phases of technology development

(2) Degree of challenges considered to be bottlenecks against social implementation

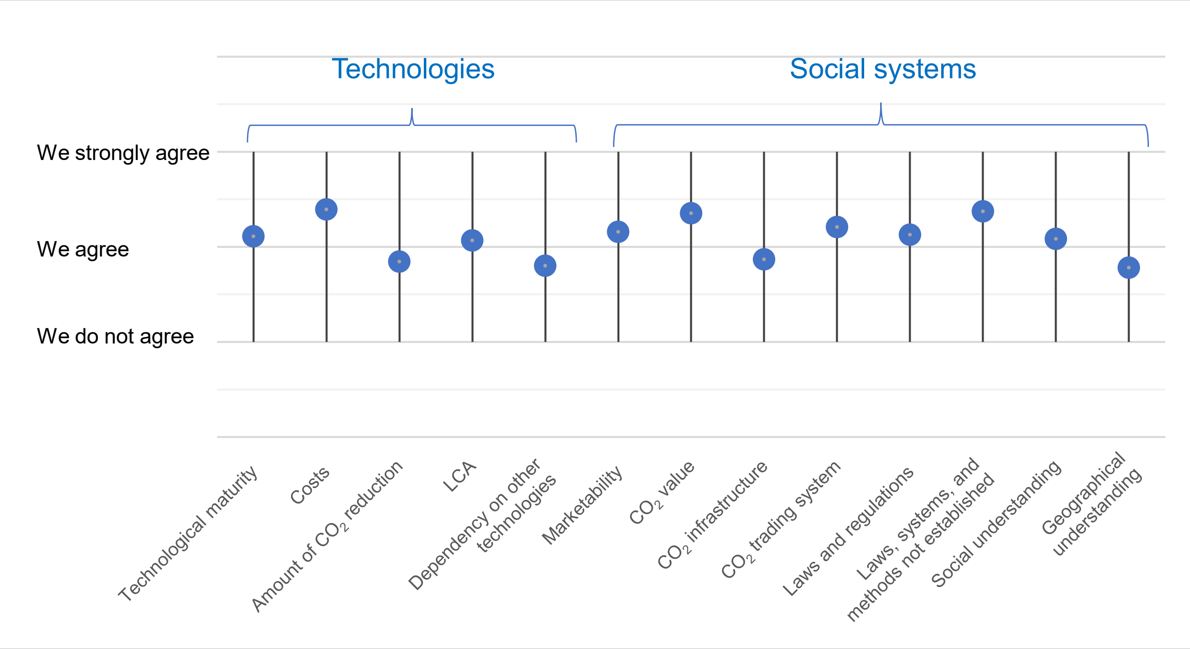


Figure 6 Degree of challenges considered to be bottlenecks against social implementation

(3) Support considered to be required (coordination between companies, coordination with startups, widespread use of related products, public financial support)

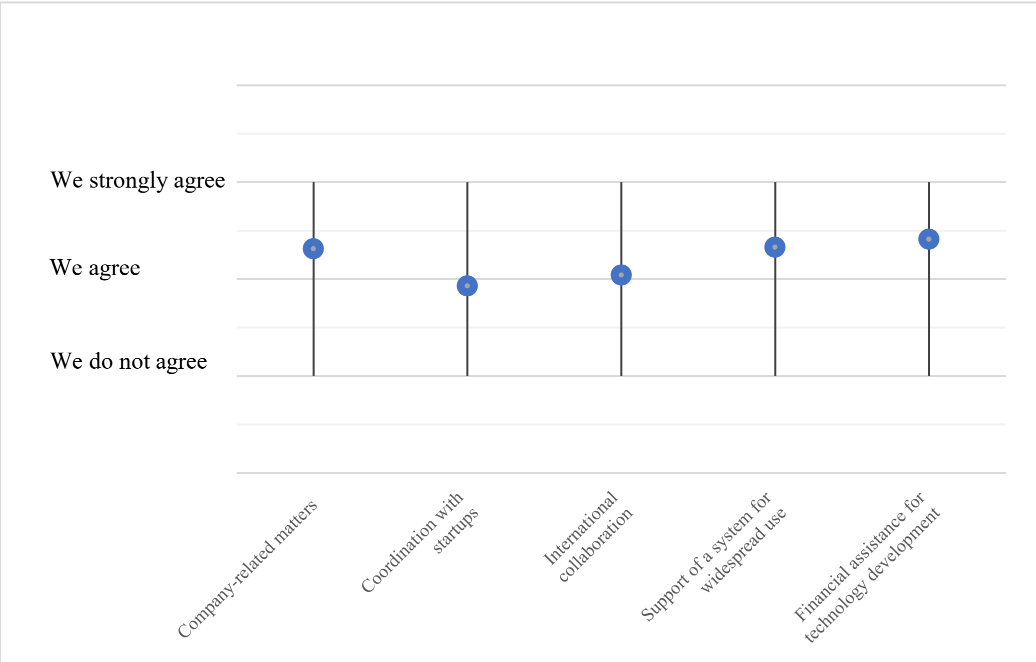


Figure 7 Support required for social implementation

3. What future direction do you recommend for the working group for social implementation of CR that the CRF organized as a venue for cross-sectional coordination in FY2022 in Takehara City, Hiroshima Prefecture?

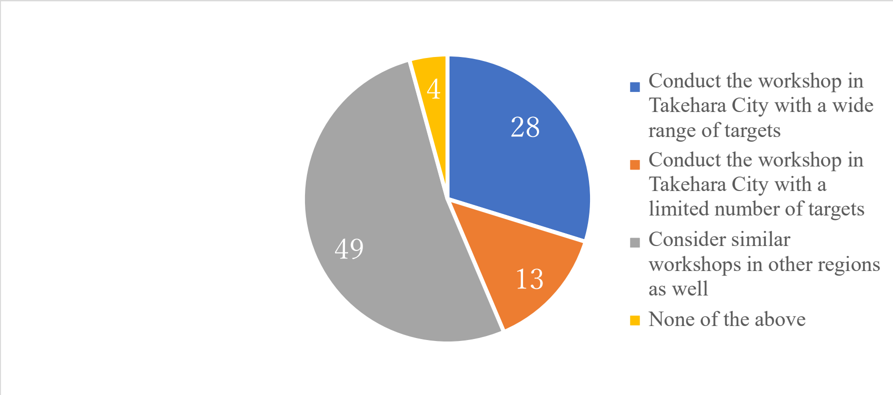


Figure 8 Future direction of the working group on social implementation of CR

Main comments

- ✓ Opportunities for development can expand if this initiative is more widely known.
- ✓ We expect the CRF to specify model cases and horizontally deploy this working group.
- ✓ Unique CO2 value chains based on local production for local consumption led, in principle, by municipalities contribute to the achievement of CN.
- ✓ We look forward to this initiative being widely deployed to many different regions.
- ✓ Seamless coordination with Osaki CoolGen, NEDO, and projects on R&D and Demonstration Base for CR at Osaki-Kamijima.
- ✓ CR verification at locations rich in renewable energies rather than high-concentration CO_2 emissions sources.

Municipalities with which members want to coordinate

Akita Prefecture (offshore wind power), Shunan City (Yamaguchi Prefecture), Nagasaki Prefecture, Hokkaido Prefecture (offshore wind power, biomass), Okoppe Town (Hokkaido Prefecture) (waste biomass), Tomakomai City (Hokkaido Prefecture), Niigata Prefecture (gas field), Kumamoto Prefecture, Miyagi Prefecture, Chiba Prefecture, Ichihara City (Chiba Prefecture), Kitakyushu City (Fukuoka Prefecture), Tsukuba City, Hamamatsu City (Shizuoka Prefecture)

4. Desire to participate in government-led projects

Want to participate	6
Considering	13
Possibly participate	15

5. Requests to industry and academic institutions

- ✓ Advances in individual technologies and reliable LCA toward social implementation.
- ✓ Development of required technologies, categorizing them not only according to the target and mode of application but also according to the application times, that is, 2030 and 2050.
- ✓ Educational activities in coordination with local universities.

- ✓ Industry expects academic institutions to propose new ideas related to CR technologies, and is ready to support interesting ideas even if they are not yet elaborated.
- ✓ People-to-people exchange system between industry and academia dedicated to the fields of CN and CR.
- ✓ Energy is required to leverage energetically stable CO_2. Catalysts and technology to convert CO_2 efficiently at low cost should be developed.
- ✓ Further progress in basic research on the DAC technology, as well as presentation of coordination cases and sharing of coordination-related information

  It would be desirable if there were places to discuss possibilities of scaling up and practical application besides laboratories.

6. Countries and regions that conduct or consider international coordination

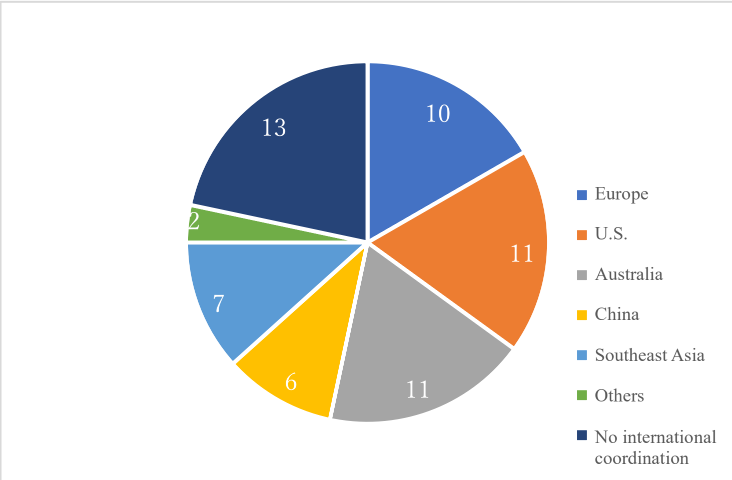


Figure 8 State of international coordination

7. How much demand is there among stakeholders such as investors, customers, general public, and government for initiatives toward CR and CN?

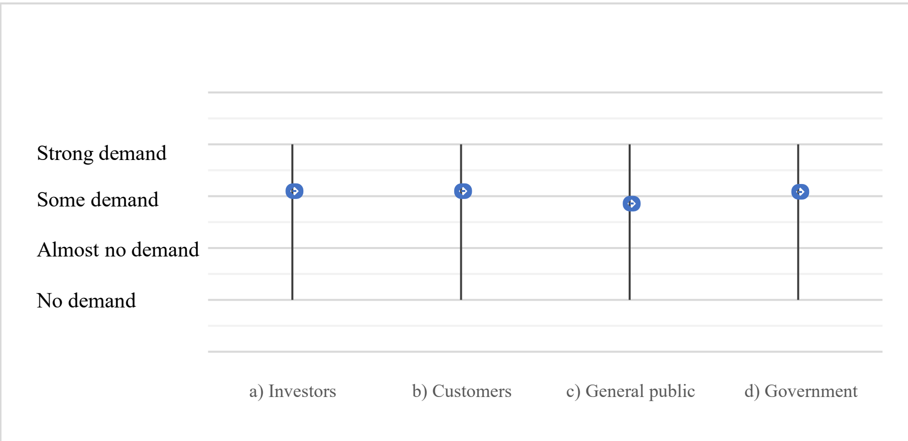


Figure 9 Demand from stakeholders

8. A Tree planting fund is planned to be established in FY2023. How can you participate in the fund?

(1) Initiatives for CO_2 sinks

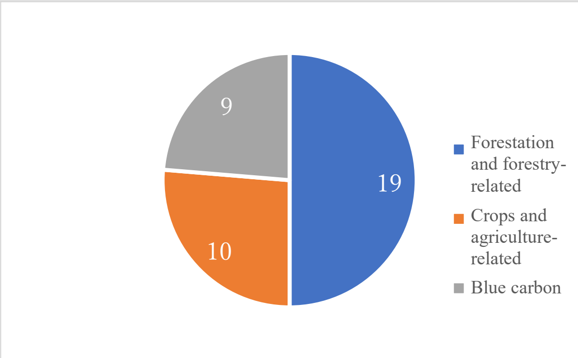


Figure 10 Fields of initiative for CO_2 sinks

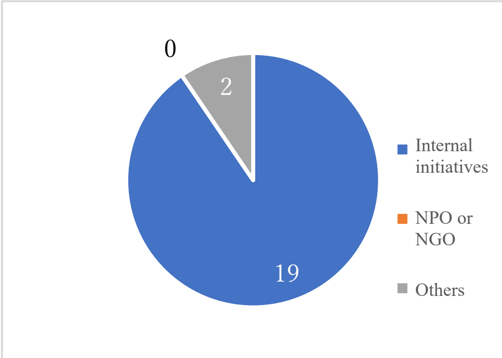


Figure 11 Implementation modes of CO_2 sinks

(2) Possibility of participation in the Tree Planting fund to be established

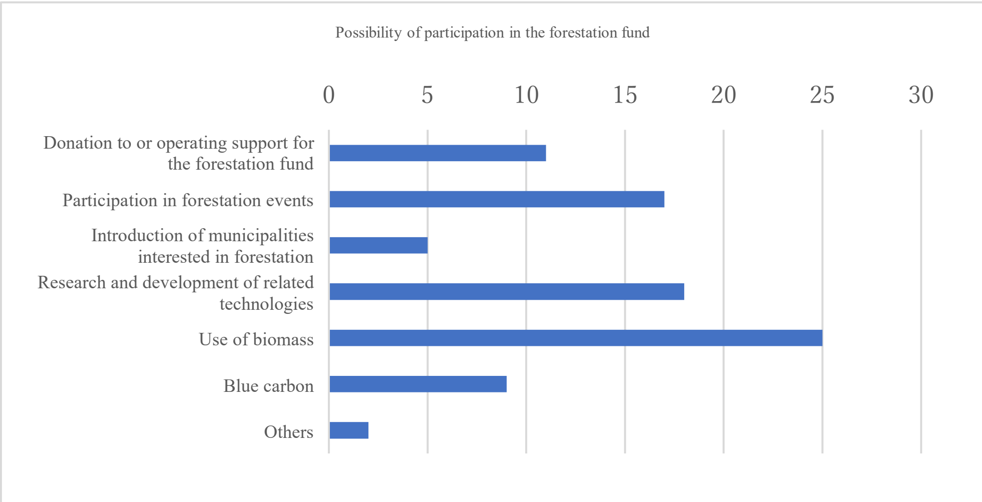


Figure 12 Possibility of future participation in the tree planting fund

9. Policies and system design such as the emissions trading system

(1) Effects of each policy on CR promotion

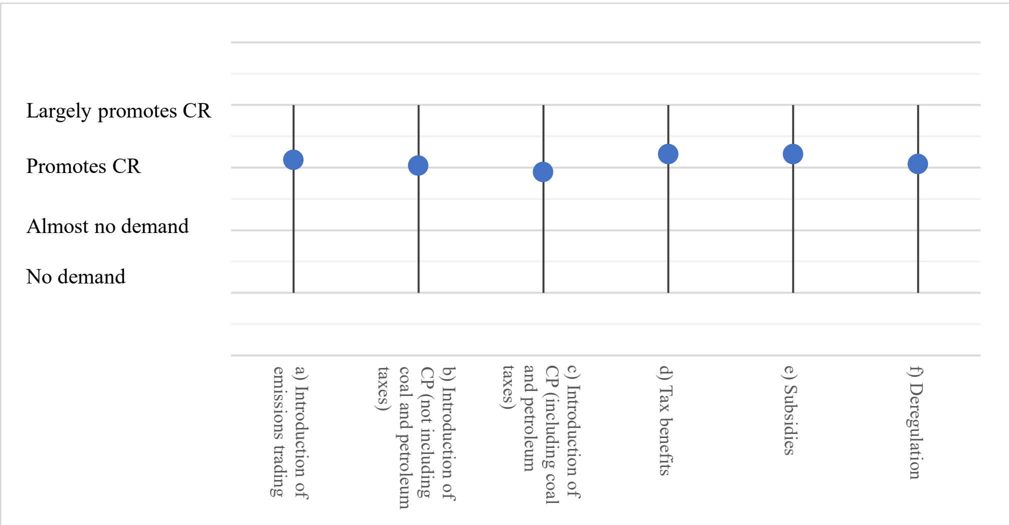


Figure 13 Each policy and promotion of CR

(2) Regulatory reform (such as deregulation and tighter regulations)

- ✓ Although in general we want the government to relax regulations, the government should clarify and tighten the quantitative assessment of the amount of CO_2 reduction throughout the whole lifecycle and eliminate phony CO_2 reduction initiatives that do not have effective results.
- ✓ Because current regulations do not sufficiently cover conversion to fuel and hydrogen handling, we expect the government to take action.
- ✓ It is important to increase the number of participating companies and make rules toward the second phase with more stringent regulations.
- ✓ We want the government to design the accounting system, pricing by emissions source, authentication system, organization, etc. according to international standards so that all prices have high competitiveness and market versatility (in other words, so that they are not left isolated from the world).
- ✓ Simple, clear rules, including those for an emissions trading system, are required. Ensuring the transparency of emissions calculation is also important.
- ✓ Quick action is needed to legislate and deregulate for the use of hydrogen, CCS, etc.
- ✓ We should prioritize eliminating CO_2 from power supplies at the lowest cost using conventional technologies and making affordable CO_2-free electricity available as of 2035. At the same time, we should advance research to realize a carbon recycling society by 2050. We expect the government to encourage the introduction of technologies with about 10,000 yen/t-CO_2 in 2030 and prevent carbon prices that are too low, which would make CO_2 reduction costs an obstacle against social implementation, assuming a higher carbon price for technologies toward 2040 to 2050.
- ✓ It is desirable that various regulations on ocean tests be relaxed.
- ✓ Such systems and regulations that allow carbon pricing, etc. work effectively in areas that do not advance according to market principles.
- ✓ A fair system is required so that specified businesses do not incur carbon loads (e.g. paying both the carbon tax and the GX-ETS costs).

10. Institutionalization of CO_2 valuation toward the social implementation of CR

- ✓ We must establish a business environment where emitters can sell separated and captured CO_2 as well as systems such as the one for attributing value recognized as CO_2 reduction by emitters.
- ✓ We should establish a system to assess CO_2 reduction effects properly so as to introduce carbon recycling technologies that contribute to reduction effects in society. We must (1) set public assessment rules on CO_2 reduction effects and (2) build a tracking and management system on the manufacturing process, including the sources and amount of CO_2.
- ✓ Gradual development of GX-ETS is preferable. We should start the first phase as voluntary initiatives in FY2023, and then tighten discipline such as by taking measures to increase the participation rate and demanding private third-party authentication for goal setting in the second phase after 2026.
- ✓ It would be desirable if CO_2 reduction through material recycling is considered in valuation besides emissions from fossil fuels.

- ✓ Although it is easy to recognize CO_2 as a valuable resource when it is used efficiently as a raw material, it would be desirable to have an incentive system that allows CO_2 capture technologies such as DAC stand alone as viable businesses.
- ✓ As a company that promotes CCS, a migration bond to introduce a CO_2 separation and capture system (+CCS) into a coal thermal power plant is a possibility.
- ✓ A market should be established where CO_2 emitters and businesses that capture and use CO_2 can trade CO_2 emissions in order to reduce them.
- ✓ Adequate operation of emissions trading, such as EU-ETS, will drive the popularization of CCS. Setting high values for DAC and biomass-derived CO_2 will have a similar effect.
- ✓ The government should revise the J-credit procedure and methodology.
- ✓ The government should make it obligatory or a rule to display environmental value and give positive points to adopters of CR materials at public works.
- ✓ We desire system design that is compatible with economic growth, ensuring consistency with global environmental valuation and trading rules for CO_2.
- ✓ We hope for a system that returns value to those that reduced CO_2 properly and sufficiently.

11. Effective use of GX economy migration bonds

- ✓ Although the introduction of carbon pricing is under consideration, whether it will cause product shift is unclear. Because it is important to reduce costs through a wider use of carbon recycling technologies, support such as a system to compensate for price differences from existing products (like hydrogen value difference compensation) can be effective in promoting widespread use of carbon recycling products.
- ✓ We want the government to consider application methods such as adopting the stage gate method to ensure that each developed technology leads to social implementation.

12. Challenges related to CCS in Japan

- ✓ Demand needs to be stimulated to reduce CO_2 through CCS. For this, we must build an appropriate business environment and show an outlook for commercialization. For example, it is probably necessary to ensure storage sites and establish a transport supply chain, laws and regulations, and business models to cover transport and storage costs.
- ✓ Selecting storage sites is a major challenge in Japan. It is necessary to consider the CO_2 separation and capture procedures along with effective use of separated and captured CO_2.
- ✓ Local production for local consumption using blue carbon, carbon fixation to agricultural land, or other means in addition to building relationships with neighboring countries are factors to consider.
- ✓ We must establish CCS technologies suitable for Japan (in terms of geographical features, culture, industry, and other aspects). Support for leveraging them industrially (in all industries) is also required. We recognize that they have a large impact not only on a limited range of industrial fields mainly operated in Japan but also international competitiveness of businesses that trade with foreign companies.
- ✓ It is essential to establish rules on CO_2 reduction assessment and environmental value trading in addition to cost-related support in order to recycle separated and captured CO_2 as fuel, chemical products, etc. A system to increase business predictability is required.

- ✓ Unlike the EOR in the U.S., because a large initial investment in storage infrastructure is required, the national government must set up a promotion framework and assist businesses in this area.
- ✓ In Europe, there are movements toward issuing credits for CO_2 injected during CCS, regarding it as carbon negative on the grounds of DAC. Systems and financial assistance are required so that processes including amine or membrane separation can be performed as a set with DAC.
- ✓ We should consider a CO_2 storage framework by strengthening coordination with Asian countries rather than limiting storage sites to domestic locations.
- ✓ The government should obtain the understanding of fishery businesses in the surrounding sea early on, and institutionalize the limited liability of storage businesses to ensure storage sites. The legal system for land storage must be established. In addition, initial investment support measures not associated with the introduction of a carbon tax, a carbon trading system or increases in electricity utility rates, are important for encouraging the proactive involvement of electricity companies, which supply carbon sources.
- ✓ It is necessary to determine who incurs CCS-related costs as social costs and how the costs are incurred, and gain national consensus about them.

13. Human resource development in the carbon recycling field, and other opinions

<u>Human resource development and other opinions</u>

(1) Human resource development

- ✓ Human resources for related technology development (such as chemical technology, plant development technology, and LCA) should be strengthened.
- ✓ In addition to the technological aspects, we think it is also important to provide education on what system design must be.
- ✓ Because commercialization of CR and CN is highly uncertain, those involved in it must be patient. Let's nurture people who have a strong sense of perseverance.
- ✓ We expect educational institutions and the national government to expand support, such as by including carbon recycling in textbooks or making it a required subject at university.
- ✓ CR work-study institutions, where children who will take over from us can learn, would be useful.

(2) Other opinions

- ✓ Although CR is a concept created to address fossil fuels, we should reconsider it as a carbon cycle in a wider sense, along with the material cycle, and create initiatives where participants work with the METI and the MOE in the future.
- ✓ To promote the shift to carbon-free fuels such as hydrogen and ammonia, eliminating differences in value from existing fuels is crucial. Although measures to compensate for value differences are currently being considered, there will be no overall shift and the effects will be limited if only first movers are involved. The government must support initiatives by private companies with value-difference compensation until the supply chain equivalent to those for current fossil energies is completed.
- ✓ We look forward to social implementation of negative emissions such as DAC in terms of offset in the near future.

14. Opinions and requests for the CRF

- ✓ Services such as providing a range of information are very helpful.
- ✓ Training for young employees at the Carbon Recycling University is a valuable opportunity. We hope that the CRF will continue this educational program.
- ✓ Since the concentration of CO_2 in the air has largely fluctuated throughout the 4.6 billion years of the Earth's history, one idea to propose a view of the gas in the context of crustal and atmospheric cycles.
- ✓ We expect the CRF to support the promotion of technologies, human resources, and achievements required for implementing both CN and CR in society.
- ✓ We want the CRF to summarize the technologies and initiative subjects of individual member companies briefly and distribute the summary.
- ✓ We expect the CRF to connect CR technologies.
- ✓ We will continue to deploy "The Tale of Carbo and Risa" internally, Our employees look forward to watching the next episode, so we would like the series to continue.
- ✓ We would like to use valuable information from the CRF because we are now gathering information on CR.
- ✓ We expect strong lobbying activities in the public interest from the CRF.

Attachment 3. Overview of the Carbon Recycling Fund Institute

(1) Vision

We coordinate with the national government to provide support for the real-world implementation of carbon recycling and the conduct of carbon recycling business by the private sector.

(2) Organization structure

Chairperson: Tugio MITSUOKA (Representative Director and Chairman of the Board, IHI Corporation)

Vice-Chairperson: Masayoshi KITAMURA (Special Counselor, Electric Power Development Co., Ltd.)

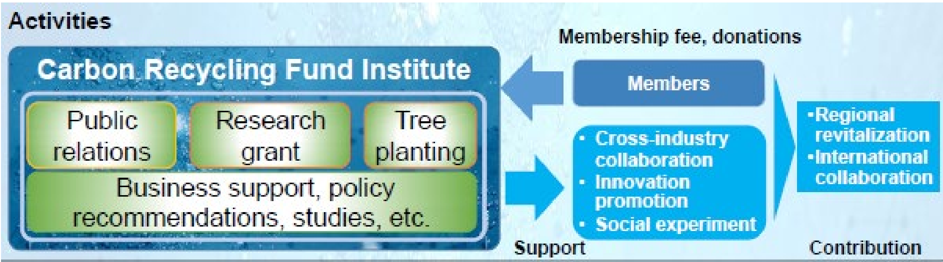
Vice-Chairperson: Kouji EGUCHI (Representative Corporate Executive Officer, Senior Vice President, Chief Supply Chain Officer, Mitsubishi Chemical Group Corporation)

(3) Activities

① Public relations: Raising awareness regarding carbon recycling

② Research grant: Offering grants to researchers, etc.

③ Tree planting: Supporting efforts to expand CO_2 sinks



(4) Members (as of 1st November, 2023)

128 corporate members, 26 individual members, 14 local government members, and 19 academic members

Corporate members

<Chemicals>
- AGC Inc.
- ASAHI KASEI CORPORATION
- BASF Japan Ltd.
- Cabot Japan K.K.
- Denka Co., Ltd.
- DIC Corporation
- JSR Corporation
- Lion Corporation
- Maruzen Industry Co., Ltd.
- Mitsubishi Chemical Group Corporation
- MITSUBISHI GAS CHEMICAL COMPANY, INC.
- Mitsui Chemicals, INC.
- TODA KOGYO CORP.
- Toray Industries, Inc.

<Electric power>
- Electric Power Development Co., Ltd. (J-POWER)
- The Chugoku Electric. Power CO., Inc
- Tokyo Electric Power Company Holdings, Inc.

<Precision, Electronics>
- Furukawa Electric Co., Ltd.
- Orbray Co., Ltd.
- SHIMADZU Corporation
- Ushio Inc.

<Energy>
- ENEOS Holdings, Inc.
- GWSOLAR West Japan CORPORATION
- Hitachi, Ltd.
- Idemitsu Kosan Co., Ltd.
- INPEX CORPORATION
- ITOCHU ENEX CO.,LTD
- Japan Petroleum Exploration Co., Ltd.
- NIPPON COKE & ENGINEERING COMPANY, LIMITED
- Osaka Gas Co., Ltd.
- Tokyo Eco Service Co., Ltd.
- TOKYO GAS CO.,LTD.
- TOSHIBA ENERGY SYSTEMS & SOLUTIONS CORPORATION
- SANIN-SANSO CO., LTD.

<CO_2 Utilization, Renewable energy, Recycling>
- euglrna Co., Ltd.
- Geothermal Energy Research and Development Co., Ltd.
- JCCL, Inc.
- KANKYOU SYSTEMS, INC.
- Utilization of Carbon Dioxide Institute Co., Ltd.
- REVCELL Co., Ltd.

<Iron, Metal, Non-ferrous metal, Cement>
- AIZAWA Concrete Corporation
- Kobe Steel, Ltd.
- Mitsubishi UBE Cement Corporation
- MITSUI MINING & SMELTING CO., LTD.
- Nippon Steel Corporation
- SUMITOMO OSAKA CEMENT CO.,LTD.
- TAIHEIYO CEMENT CORPORATION

<Trading company>
- ITOCHU Corporation
- JFE Shoji Corporation
- Marubeni Corporation
- Mitsubishi Corporation
- MITSUI & CO., LTD.
- SEIKA CORPORATION
- Sojitz Corporation
- Sumitomo Corporation
- Tokyo Boeki Holdings Corporation
- TOKYO SANGYO CO.,LTD
- Toyota Tsusho Corporation

<Heavy industries>
- IHI Corporation
- Kawasaki Heavy Industries, Ltd.
- Mitsubishi Heavy Industries, Ltd.
- Sumitomo Heavy Industries, Ltd.

<Engineering>
- ARVOS K.K.
- Chiyoda Corporation
- Ebara Corporation
- FUSO Corporation
- Hitachi Power Solutions Co., Ltd
- KUBOTA Corporation
- JFE Engineering Corporation
- JGC HOLDINGS CORPORATION
- NGK INSULATORS,LTD.
- NIPPON STEEL ENGINEERING CO., LTD.
- Yokogawa Electric Corporation
- Toyo Engineering Corporation

<Printing, Visual creation, Translation>
- Dai Nippon Printing Co., Ltd.
- SunFlare Co., Ltd.
- Toppan Inc.

<Automotive>
- AISAN INDUSTORY., LTD..
- Nissan Motor Co., Ltd.
- Niterra Co., Ltd.
- TOYODA GOSEI CO., LTD.

<Air, traffic, transportation>
- JAMCO Corporation
- SENO KISEN CO., LTD.

<Construction, Real estate>
- Dome Gold Mines Ltd.
- FKG Corporation
- FUTURE ESTATE Co., Ltd.
- Hitachi Plant Services Co., Ltd.
- Hulic Co., Ltd.
- HOUSEI
- KAJIMA CORPORATION
- Kumagai Gumi Co., Ltd.
- Mitsui Fudosan Co., Ltd
- OBAYASHI CORPORATION
- Ohmori Construction Co., Ltd.
- SHIMIZU CORPORATION
- Shin Nippon Air Technologies Co., Ltd.
- Social Welfare Research Corporation, Inc
- TAIHEI DENGYO KAISHA, LTD.
- TAISEI CORPORATION
- TAKENAKA CORPORATION
- TOA CORPORATION
- Vertex Corporation
- WAKACHIKU CONSTRUCTION CO.,LTD.

<Banks, Financing>
- Daiwa Securities Group Inc.
- FUKOKU MUTUAL LIFE INSURANCE COMPANY
- Mizuho Financial Group, Inc.
- MUFG Bank, Ltd.
- Nippon Life Insurance Company
- Sumitomo Mitsui Banking Corporation
- Sumitomo Mitsui Trust Panasonic Finance Co., Ltd.
- Tokio Marine & Nichido Fire Insurance Co., Ltd.

<Food>
- ASAHI QUALITY & INNOVATIONS, LTD.

<IT, Analysis, Assessment>
- Boston Consulting Group G.K.
- FUJITSU LIMITED
- Information Services International-Dentsu, LTD.
- KDDI Research, Inc.
- Mitsubishi Research Institute, Inc.
- Mizuho Research & Technologies, Ltd.

<Retail & Consumer goods>
- TMB Co., LTD.

<Others>
- Central Research Institute of Electric Power Industry
- JAPAN COAL FRONTIER ORGANIZATION
- JX Metals Research Institute for Technology & Strategy CO., Ltd.
- Nagoya Industrial Science Research Institute
- Organization for Industrial Complex Transformation
- SUMISEKI TRADING
- The Institute of Energy Economics, Japan

Individual members
- 26 persons

Local government members
- Akita Prefecture
- Annaka City (Gunma Prefecture)
- Hiroshima Prefecture
- Hokkaido Prefecture
- Kagawa Prefecture
- Omuta City (Fukuoka Prefecture)
- Osakikamijima town (Hiroshima Prefecture)
- Sakata City (Yamagata Prefecture)
- Saikai City (Nagasaki Prefecture)
- Takehara City (Hiroshima Prefecture)
- Tomakomai City (Hokkaido Prefecture)
- Yamagata Prefecture
- Yamaguchi Prefecture

Academic members
- Consortium for Satellite Earth Observation
- NAGASAKI UNIVERSITY
- Tokyo University of Science Foundation
- 16 researchers

Note: by sector / in alphabetical order

As of 1st November 2023