Carbon Recycling Fund Institute
Progress Report 2022

- Making Progress

Towards the Realization of a Sustainable Carbon Society -

August 2022

Carbon Recycling Fund Institute

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Main points

■ **Carbon recycling trends**

The report of the results of COP26 (held in October and November 2021) clearly indicated ongoing resolve to achieve the 1.5°C target and demanded that 2030 greenhouse gas level reduction targets be re-considered and reinforced by the end of 2022

* Moves towards achieving carbon neutrality are accelerating worldwide

* In Japan, as well, the basic policy of the Green Innovation Fund Project was revised and government policies aimed at promoting carbon recycling, such as green energy strategies, were prepared and updated. Companies, local governments, and members of academia have made progress in developing concrete measures.

■ **The importance of carbon recycling, the roles of the Carbon Recycling Fund Institute (CRF), and the progress that has been made so far**

* Through measures for reducing CO_2 emissions and carbon recycling, using CO_2 as a resource, will be vital for achieving carbon neutrality

* The creation of a sustainable carbon society, which lies at the core of carbon recycling, is the optimal means of achieving carbon neutrality and going beyond that to create truly sustainable social and economic systems

* Roles of CRF:

The CRF is a platform for coordination between stakeholders in the creation of sustainable carbon societies. It facilitates activities, supporting innovation that contributes to carbon recycling

* Activity progress:

・ Of the 12 research grants selected in 2021, two were selected by the New Energy and Industrial Technology Development Organization (NEDO) and the Green Innovation Fund

・ In addition to accepting public applications in 2022, a support framework was also established for start-ups. 14 of the 55 public applications were selected, and 2 of the 29 start-up applications were selected

・ The Chairperson and Vice-Chairperson have given speeches at international conferences, etc., regarding the importance of carbon recycling and the activities of the CRF

・ The CRF has focused on nurturing the next generation of people who will be involved in carbon recycling by holding "Carbon Recycling University" training for junior employees in member companies and developing "The Tale of Carbo and Risa" digital content for junior high and high school students

・ The CRF has formulated a medium-term plan for 2022-2025

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

* Examples of progress made in concrete activities by CRF members to deploy carbon recycling technologies in society

・ Comprehensive measures in Hiroshima Prefecture such as carbon recycling verification research

・ Soma IHI Green Energy Center

・ Methanol conversion of CO_2 recovered from factory exhaust gas

・ Development of innovative methanation technologies

・ Green hydrogen production

・ Manufacture of carbonate from calcium and CO_2 derived from industrial waste

・ Plastic chemical cycle
・ Offshore wind power generation
・ Carbon recycling through marine biomass production
・ Planting and growth of forests of fast-growing trees
・ CCUS value chain digital platform, etc.

■ **Three core recommendations for realizing a sustainable carbon society:**

Develop and promote innovation, develop human resources

・ The CRF and its members should develop carbon recycling technologies and products aimed at achieving carbon neutrality by 2050, verify these technologies and products, deploy them in the real world, and promote investment in them. To accelerate the speed with which this is performed, we should engage in cross-industry coordination, including coordination with start-up companies, and make maximal use of open innovation. We should utilize the verification opportunities provided by the national government, such as Expo 2025 Osaka, Kansai, Japan.

・ To support the activities of these industries, the national government should enrich its measures, including providing greater support, and provide solid support for the development and promotion of innovation in order to accelerate green transformation. Support should be provided for the advancement and expansion of measures that highly motivated companies can voluntarily take part in, such as the GX League.

・ Between 2030 and 2050, personnel who can implement carbon neutrality measures and carbon recycling should be developed.

・ A deeper greater understanding of carbon neutrality and carbon recycling should be fostered among the general public in order to promote greater adoption by society.

CO_2 value chain creation

・ 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.

・ To maintain and enhance Japan's international competitiveness, the national government should promote measures which provide incentives, such as providing premiums for products and services that use CO_2 value chains.

・ The quantitative evaluation of 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 regarding matters with major impacts which would transform the social structure, such as emission trading, carbon taxes, and carbon pricing, should be promoted. Unified systems which ensure fairness between industries should be prepared and implemented without delay.

・ Leadership should be provided with respect to evaluating CO_2 sinks such as oceans and vegetation, and with respect to the creation of international rules.

・ The national government should accelerate carbon recycling promotion measures and deliberations regarding CO_2 capture and storage. Laws should be developed, solid support should be provided for active private measures, and the division of roles between the public and private sector should be clarified with respect to the bearing of risks and costs.

Integration with regional revitalization and expansion to the global market

・ CRF members should create case examples that leverage the strengths and features of communities by collaborating with local governments. The agriculture, forestry, and fishing industries should be vitalized from the

perspective of carbon recycling. For example, this could include combining offshore wind power generation with fishing reefs. Multifaceted investigation and coordination will also be necessary in order to create carbon neutral ports.

・ Efforts should be expanded to the global market, including licensing business. For Asian countries, especially, carbon neutrality technologies should be introduced to grow carbon recycling into one of Japan's growth industries, contributing to carbon neutrality throughout Asia.

■ Summary

In order to create sustainable social and economic systems based on carbon neutral despite the instability and lack of transparency produced by international affairs, all stakeholders must collaborate together and steadily implement concrete measures.

However, this cannot be allowed to lead to a hollowing out of Japanese industry by shifting industry overseas.

A variety of measures must be implemented together, including the creation of carbon recycling societies by clearly defining the value of CO_2, capturing and storing CO_2, and using CO_2 and carbon compounds as resources.

Carbon recycling is a field that spans all domains. The Carbon Recycling Fund Institute includes not only cooperation between members of private industry, but also cooperation between industry, academia, the public sector, and overseas organizations with the aim of creating sustainable carbon societies, in Japan and around the world.

1. Carbon recycling trends

The movement of working to achieve carbon neutrality is accelerating worldwide in order to achieve shared global objectives such as curbing global warming and engaging in sustainable procurement of resources and energy. The report of the results of COP26 (held in Glasgow, Scotland from October 31 to November 13, 2021) clearly indicated ongoing resolve to achieve the 1.5°C target and demanded that 2030 greenhouse gas level reduction targets be re-considered and reinforced by the end of 2022.

In order to cut global CO_2 emissions by 45% vs. 2010 levels by 2030, required to achieve the 1.5°C target, and to achieve carbon neutrality/net zero carbon emissions by 2050, numerous countries, companies, and organizations are formulating roadmaps and action plans based on fundamental policies for solving environmental and social issues while maintaining economic development. In order to achieve carbon neutrality and net zero CO_2 emissions while balancing both environmental considerations and economic development, it will be vital to implement thorough emissions reductions and carry out carbon recycling, using CO_2 as a resource.

In Japan, led by the 2050 carbon neutral declaration in October 2020, the government formulated a "Green Growth Strategy Through Achieving Carbon Neutrality in 2050." This strategy identifies 14 industrial fields with growth potential that will serve as drivers that promote both environmental protection and economic growth, and sets forth action plans. Among these 14 fields is the field of carbon recycling. These 14 fields are fields which will be significantly affected by policies and which will require long-term ongoing support leading up to societal deployment. Because of that, a 2 trillion yen Green Innovation Fund was created to support companies and other organizations committed to achieving ambitious targets. In April 2021, Japan announced its new emissions target for 2030 of reducing greenhouse gas emissions by 46% compared to 2013 levels. It has become clear that green transformation (GX) and digital transformation (DX) will be central to efforts to transform industrial structures and socioeconomic systems into ones with carbon neutrality at their core, and in 2022, various policies were formulated

and updated with the aim of encouraging measures aimed at achieving carbon neutrality. These included making revisions to the basic principles of the Green Innovation Fund Project and defining related policies such as clean energy strategies as comprehensive strategies that include not only technology development but also infrastructure, industrial complexes, market creation, and more. Measures by companies, local governments, and academia are being refined and detailed at an accelerating rate.

Russia's invasion of Ukraine has manifested energy security risks. At the same time, it has also had a major impact on the procurement of foodstuffs and industrial materials, increasing the level of instability and reducing the amount of transparency in the business environment and living conditions. With regard to COVID-19, advances in vaccinations and the accumulation of related knowledge and experience has led to the relaxation of restrictions on peoples' activity. Against this backdrop, decentralization and digitalization have irreversibly changed peoples' behaviors and values.

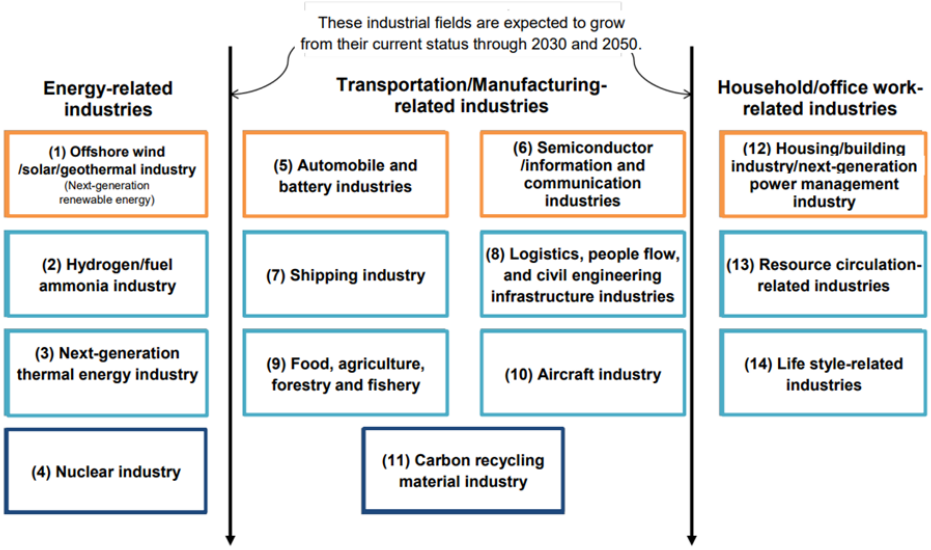


Figure 1. Ministry of Economy, Trade and Industry - Green Growth Strategy fields
Source: Ministry of Economy, Trade and Industry website

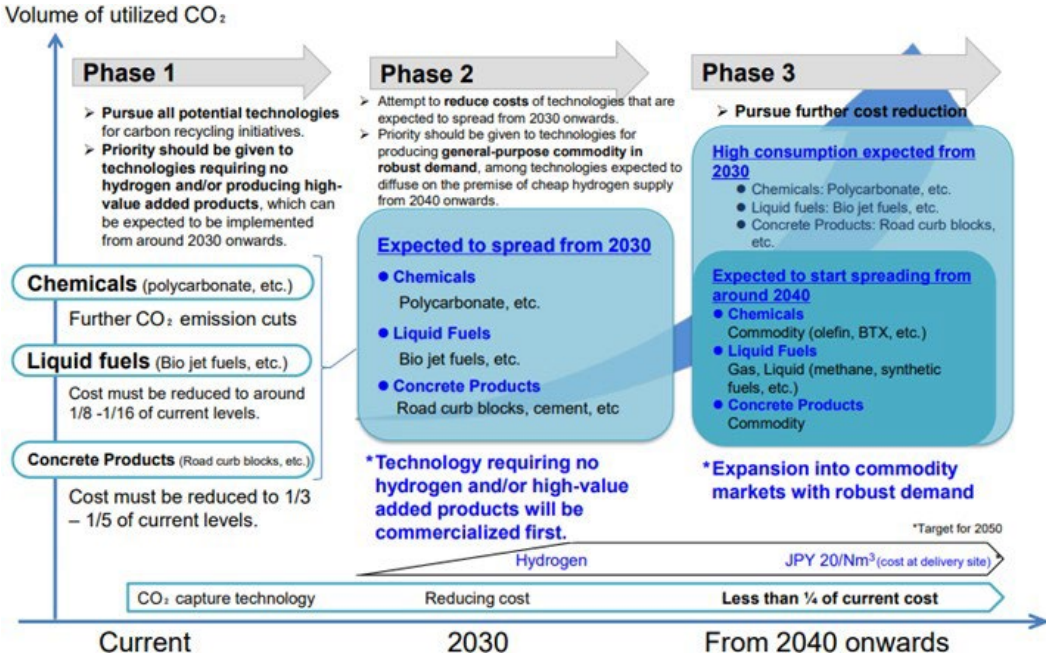


Figure 2. Carbon recycling technology roadmap
Source: Ministry of Economy, Trade and Industry website

The Nobel Prize in Physics 2021 was awarded to Dr. Syukuro Manabe for his groundbreaking research into the forecasting of the effects of CO_2 on global warming using weather models based on simulations. His research showed that climate change must be seen in terms of physical cycles on a global scale, and that it involves every domain.

2. The importance of carbon recycling, the roles of the Carbon Recycling Fund Institute, and the progress that has been made so far

（1） The importance of carbon recycling

Several measures have been formulated with the aim of achieving the 1.5°C target. Global CO_2 emissions levels are to be cut by 45% by 2030 in comparison to 2010 emissions. In addition to this, carbon net zero emissions measures will seek to offset CO_2 emissions that cannot be prevented by even stringent emissions reduction measures by absorbing and eliminating CO_2. All excess CO_2 emissions are to be offset by the year 2050, resulting net zero CO_2 emissions.

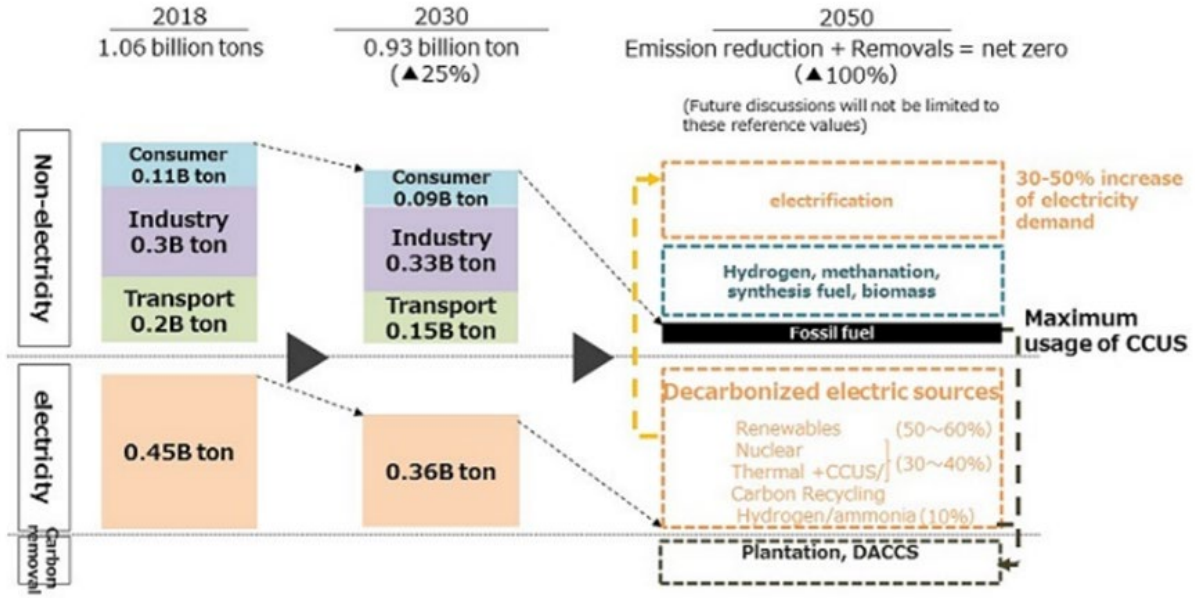


Figure 3. CO_2 emissions forecasts by energy source, formulated by the Ministry of Economy, Trade and Industry

Source: Ministry of Economy, Trade and Industry website

Many carbon compounds containing CO_2 are essential matter needed to maintain the Earth's systems, including life itself. For example, greenhouse gasses which contain CO_2 protect the Earth's environment from the harsh environment of space. Plants use CO_2 to synthesize carbon compounds and provide them to nature. Our own bodies are made up of carbon-based substances. The carbon system is made up of all of the Earth, including its atmosphere, land, and seas.

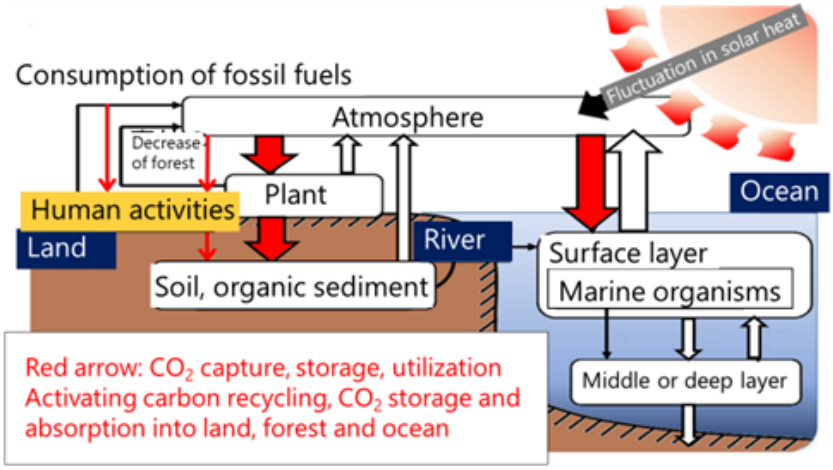


Figure 4. Model of the Earth's carbon cycle

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 to achieve the 1.5°C target and go beyond that to creating truly sustainable socioeconomic systems. To achieve this, we must not look at CO_2 as an enemy but must instead restore and maintain our planet's health by creating carbon recycling societies which 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 recover CO_2 produced by 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 added-value materials for the materials that are indispensable for our societies and economies, such as concrete and chemicals. Furthermore, we must use the power of nature in industries such as the agriculture, forestry, and fishing industries while we fix CO_2 and turn it into a resource by capturing and storing it. We must transform it into a value-added product and create a market for it, promoting integrated initiatives that take into consideration the entire CO_2 value chain, including CCS and hydrogen.

Figure 5. Conceptual image of CO_2 value chain used in realizing carbon recycling societies

Source: Carbon Recycling Fund Institute materials

(2) The roles of the Carbon Recycling Fund and the progress that has been made so far

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

Now, three years after its establishment, the CRF has over 130 members who support its goals and participate in its activities (106 corporate members, 8 local governments, three academic members, and 17 individuals, as of August 1, 2022). Its activities have deepened, and 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 in 2050 announced by the Japanese government.

This document presents recommendations regarding the refinement of the activities discussed in the recommendations issued in June 2021, together with policy recommendations. It does so from the following three perspectives: 1) promoting the development of innovation and the cultivation of personnel, 2) preparing the market environment, and 3) addressing public issues involved in commercialization in conjunction with the progress made by the CRF based on expansion into the global market.

- [Example of progress: research grant activities]

  Through its research grant activities, the CRF supports the discovery of new ideas and personnel within companies, universities, and the like, fundamental carbon recycling research that is 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 fixing using mineralization, conversion to fuel usage, conversion to chemicals, CO_2 separation and capture, social science-related research, research related to CO_2 sinks (soil; forests; blue carbon; biological usage; agriculture, forestry, and fishing industries), hydrogen creation, geoengineering, functional materials, medical fields, and more. In addition to accepting public applications in 2022, a support framework was also established for start-ups.

	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)
Attribution of research results	Research results basically belong to researchers
Number of applications and accepted cases	FY2020: 39 applications → 12 accepted FY2021: 46 applications → 12 accepted FY2022: 55 applications → 14 accepted and 29 applications for startup support → 2 accepted

Figure 6. Overview of Carbon Recycling Fund Institute research grant activities

Source: Carbon Recycling Fund Institute materials

In 2020, 12 of the 35 applications were selected, and in 2021, 12 of the 46 applications were selected. In 2022, there were 55 public applications and 29 start-up company applications (with an overlap of 6 applications). Of these, 14 public applications and 2 start-up company applications were accepted.

Over the three years since the launch of the research grant activities in 2020, the CRF has provided roughly 26 million yen in grants. From the applications selected to receive grants by the CRF, two* have been selected and are currently receiving NEDO research grants and national project grants such as Green Innovation Fund grants, etc.

* NEDO project

"Research and Development of CO2 Mineralization Method Using Sea Water and Biogenic Amine" Head researcher: Ko Yasumoto

(The Kitasato Institute, Kitasato University)

* Green Innovation Fund Project

Development of Ultra-efficient Method of Manufacturing Polyurethane Raw Material Using CO_2" Head researcher: Katsuhiko Takeuchi

(National Institute of Advanced Industrial Science and Technology)

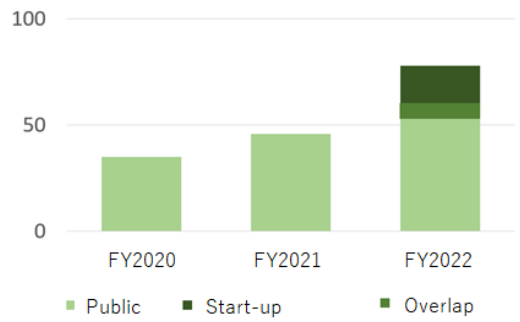


Figure 7. Number of Carbon Recycling Fund Institute research grant applications

Source: Carbon Recycling Fund Institute materials

■ [Example of progress: Local government collaborative working group]

The CRF plans working group activities in which it coordinates with local governments to connect loops of CO_2 emissions sources and CO_2 uses, striving to create CO_2 value chains. Its goal is to build a model that leverages the strengths of the community while providing a space to perform societal pilot testing of carbon recycling technologies, whose elements are falling into place through the connection of CO_2 emitters and latent CO_2 users, while looking ahead to the 2030 commercialization of CCS, to which the Japanese government has announced its commitment.

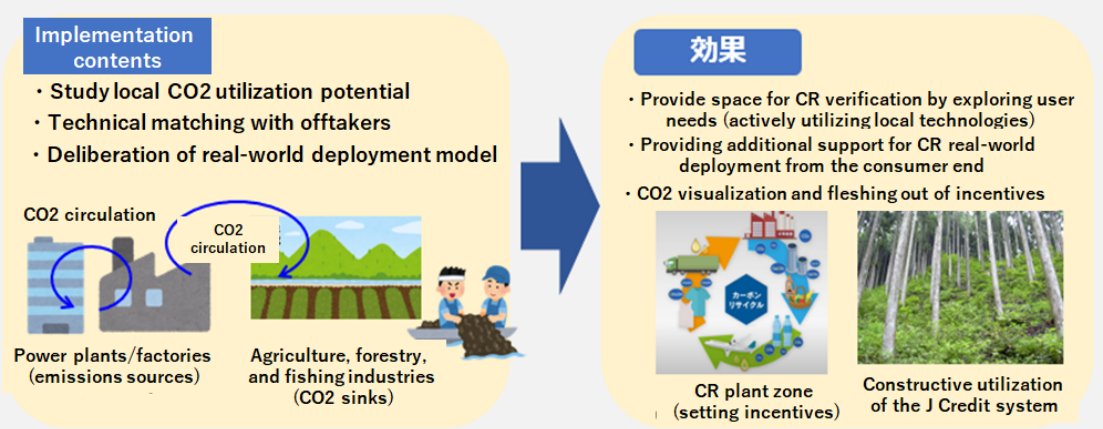


Figure 8. Overview of the CO_2 value chain creation working group
Source: Carbon Recycling Fund Institute materials

■ [Example of progress: Carbon Recycling University - Nurturing the Next Generation of People Who Will Be Involved in Carbon Recycling]

Carbon neutrality-oriented R&D and commercialization requires a major, global-scale mission and long-term efforts involving complex systems. That's why it's 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. The CRF holds 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 approaches and values. These skills and mindsets are cultivated through discussions with management personnel from blue-chip startup companies and colleagues. In 2021, the first year of the courses, 20 young employees from member companies participated. They engaged in group work on four themes selected from their own recognitions of issues: ① energy, ② upcycling, ③ decentralized societies, and ④ CO_2 visualization and valuation.

Participants shared many positive impressions of the Carbon Recycling University through a follow-up questionnaire. They said they reaffirmed the importance of cross-industry cooperation in order to create carbon recycling and carbon neutrality solution businesses. They cultivated their recognition of the need to be proactive and not simply wait for systems to be put in place. They also felt anew the need for reforms in order to further social acceptance, and developed the mentality that would be needed when junior colleagues issued proposals in the future.

We plan to continue this initiative in 2022 as well.



■ [Activity progress: Messages from top leaders]

Top leaders give discussions at international symposia and exhibitions regarding the importance of carbon recycling and call for collaboration. In October 2021, the CRF's Chairperson, Yoshimitsu Kobayashi (now the CRF's top advisor) gave a presentation during the International Conference on Carbon Recycling, and in March, Vice-Chairperson Masayoshi Kitamura gave a presentation during World Smart Energy Week 2022.


■ [Activity progress: "The Tale of Carbo & Risa" - digital content for the next generation

Due to the importance of reaching the younger generation, we created the "Tale of Carbo & Risa" series of digital content for junior high and senior high school students. The fascinating story conveys the importance of carbon recycling to restoring the health of our planet. Carbo and Risa, high school students in the year 2222, when sustainable carbon societies are commonplace, together with Ninja Owl, travel through time to 2022 and learn about the passion and effort devoted to innovation. It is available for viewing on the CRF website.

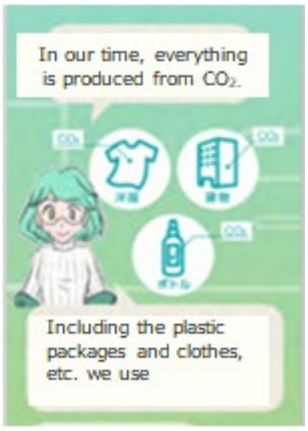


Figure 9. Excerpts from the Tale of Carbo & Risa

Source: Carbon Recycling Fund Institute materials

■ [Example of progress: Formulation of the CRF Medium-term Plan (2022-2025)]

Carbon recycling has made a great deal of progress towards the goal of carbon neutrality by 2050. The CRF will continue to build even greater trust among its members and the Japanese government as it becomes an indispensable part of the real-world implementation of carbon recycling aimed at achieving carbon neutrality, making the tide of carbon recycling a permanent one. To this end, it has formulated an action plan for the years leading up to 2025 and a medium-term plan which includes KPI for measuring progress. The entire CRF is working to carry out these plans and implement carbon recycling throughout society.

* The roles of the CRF:

- Provide a space for high-level information sharing and coordination
- Serve as a catalyst and facilitator that connects diverse stakeholders
- Stimulate measures related to carbon recycling with a broad and long-term perspective rooted in restoring the health of our planet

Critical Issues		Action Plan	KPI and Targets	
(1) Provide collaborative opportunities and promote concrete implemenation of CR in society	• Enrich research grant system and reinforce utilization	· Prepare an environment that attracts promising projects	▷ Number of WG meetings (as pilot studies)	Hold one WG involving member-local government cooperation per year. Have one project selected for a pilot study project by the nation government or a local government by FY2023 and another by FY2025
		· Support the development of initiative results		
	• Contribute to creation of CO2 value chains	· Identify CO2 utilization demand and promote the creation of value for CO2		
		· Coordinate with local governments	▷ No. of matches (Number of meetings and dialogs set up through CRF intermediaries)	Maintain 10 matches or more per year (same as current level)
		· Participate in creation of international rules regarding CO2 sinks		
	• Leverage opportunities to give policy recommendations	· Collect opinions and input from members and communicate industry requests		
(2) Enrich and refine member services	• Refine the provision of information and promote greater utilization	· Regularly share information regarding the latest CR trends around the world	▷ Member questionnaires	Raise member questionnaire recovery rate to 80% in FY2023 (Currently 55%)
		· Enrich online salons and stimulate discussion		
		· Share information regarding CR-related seeds and needs and promote matching		Establish and improve member satisfaction level
	• Refine public relations activities (including selection and concentration)	· Enrich website content	▷ No. of website visits	Increase number of daily website visits to 700 by FY2023 and to 1,000 by FY2025 (currently 500)
		· Leverage opportunities to exhibit in shows and present lectures		
		· Appeal to the younger generation through CR university programs and the use of digital technology		Increase number of page views to 2,100 by FY2023 and to 4,000 by FY2025 (currently 1,000)
(3) Stabilize and reinforce operation platform	• Stabilize financial foundation	· Increase the number of members	▷ No. of members	Increase number of members to 150 by FY2023 and to 200 by FY2025
		· Expand support for public relations and research grant activities		
		· Secure other revenue sources		
	• Strengthen operating structure	· Strengthen the Council ~~Meeting~~ (又は"Strengthen council meetings"	▷ Financial status	Eliminate cumulative loss by end of FY2022
		· Carry out stable operation of secretariat		

Figure 10. Overview of the Carbon Recycling Fund Institute's medium-term plan (2022-2025)

Source: Carbon Recycling Fund Institute materials

3. Progress made by CRF members towards the realization of carbon recycling societies

Carbon recycling technologies and products establish their importance and roles in society through their deployment and application. That is why CRF members promote verification and real-world deployment through cross-industry cooperation and cooperation between industry, academia, and the public sector that contributes to the creation of CO_2 value chains that leads to CO_2 valuation. CRF members are working to promote greater understanding and usage of CR technologies and products.

Below, we report on the progress of several concrete initiatives being conducted by CRF members to deploy carbon recycling in the real world.

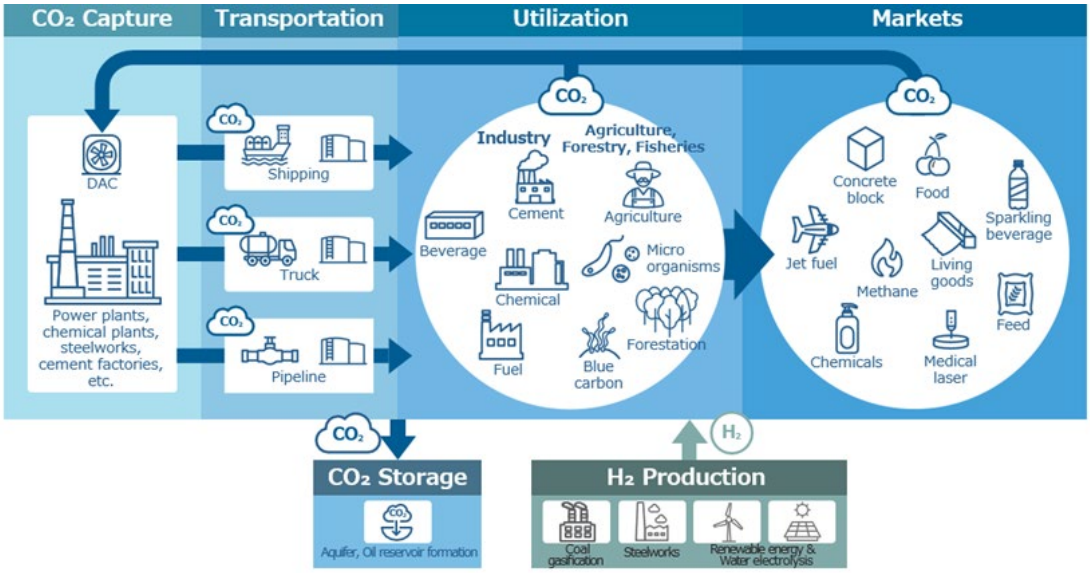


Figure 11. CO_2 value chain

Source: Carbon Recycling Fund Institute materials

■ [Example of member progress: Comprehensive carbon recycling verification research measures in Hiroshima Prefecture]

Keywords: Regional cooperation, CO_2 value chain

Implementation member(s): Hiroshima Prefecture, Osakikamijima (Hiroshima Prefecture), Electric Power Development Co., Ltd., Chugoku Electric Power Co., Inc.

In May 2021, Hiroshima Prefecture established the Hiroshima Prefecture Carbon Circular Economy Promotion Council. The goal of the Council is to promote the real-world deployment of carbon recycling technologies, stimulate local economies, and create "carbon circular economies*". To achieve this, the prefecture coordinated with a national project being conducted in Osakikamijima to create a verification and research center for carbon recycling. By promoting the gathering of companies, research organizations, and researchers involved in the research of carbon recycling and similar areas, it hopes to make the area a leading carbon recycling R&D site.

(* Carbon circular economies are regional economies in which carbon is sustainably circulated by using it in the natural world and in industrial activity by converting it into various forms, including living organisms, chemicals, and fuel.)

In May 2022, Hiroshima Prefecture launched the HIROSHIMA CARBON CIRCULAR PROJECT. This carbon recycling technology research and verification support project provides support to people engaged in the research, development, and verification of carbon recycling-related technologies and to companies within the prefecture who deal with carbon recycling issues. Its goals increasing the number of carbon recycling research and verification projects in the prefecture and the promotion of the real-world deployment of carbon recycling technologies.

Following the Ministry of Economy, Trade and Industry announcement in 2019 of the Carbon Recycling 3C Initiative, in July 2020, NEDO began preparing a carbon recycling verification and research site (composed of a verification research area, a fundamental research area, and an algae research area). This site was established in conjunction with the Osaki CoolGen Corporation, which was founded through joint

investment by the Electric Power Development Co., Ltd. and the Chugoku Electric Power Co., Inc., on the grounds of Chugoku Electric Power Co., Inc.'s Osaki Power Plant (located in Osakikamijima, Hiroshima Prefecture). The Osaki Power Plant had previously been used as a verification research site for CO_2 capture-based oxygen-blown integrated coal gasification combined cycle (IGCC) and integrated coal gasification fuel cell combined cycle (IGFC). At the verification research site, Osaki CoolGen Corporation plans to provide captured CO_2 to companies and organizations researching carbon recycling technologies.

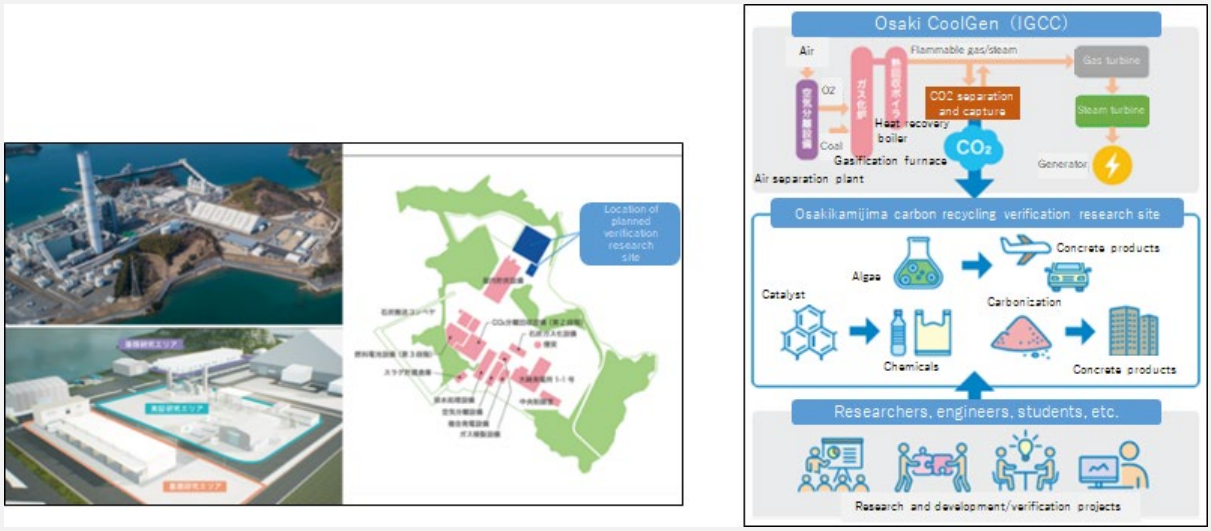


Figure 12. (Left) Carbon recycling verification research site
(Right) Conceptual image of effective CO_2 utilization and how it relates to the research, development, and verification project
Source: NEDO materials

In July 2020, three research projects being conducted by CRF members (Chugoku Electric Power Co., Inc., Mitsubishi Corporation, and Kawasaki Heavy Industries Ltd.) were selected as research to be carried out in the verification research area.

The Institute of Microalgal Technology's project, "Establishment of a Research & Technology Center for Industrialization of Bio-Jet Fuel and Improvement of CO_2 Utilization Efficiency with Microalgae," which was selected in October 2020, is being performed in the algae research area.

In April 2022, six research projects were selected to be carried out in the fundamental research area, as shown in the table. Of these six, three are being implemented by CRF members or related organizations (Tokyo University of Science, Japan Coal Frontier Organization, ENEOS GLOBE Corporation, and Nippon Steel Corporation).

Projects selected by NEDO	Planned implementation members
Manufacture of Basic Substances from CO_2 Captured from Coal-Fired Exhaust Gas Using Diamond Electrodes	Keio University Tokyo University of Science Japan Coal Frontier Organization
Research and Development of New CO2 Decomposition and Reduction Processes Using Atmospheric Pressure Plasma	Tokai National Higher Education and Research System Kawada Industries, Inc.

Development of Technologies for Algal Biomass Production and Utilization Capable of High Efficiency CO_2 Usage	Nippon Steel Corporation
Industrial Waste-Derived Silicon Carbide Synthesis Using CO_2 as Its Carbon Source	University of Toyama
Research and Development of Carbon Recycling LPG Production Technologies and Processes	ENEOS GLOBE Corporation Nippon Steel Corporation University of Toyama
Research and Development Related to the Capture of CO_2 and Effective Use in Chemicals Through the Use of Microbial Algae	Algal Bio Co., Ltd. Kansai Electric Power Co., Inc.

Figure 13. Contents of research and development being conducted in the fundamental research area

Source: NEDO materials

Hopes are high for these carbon recycling verification projects which aim to contribute to carbon neutrality by 2050 through cooperation between industry, academia, and the public sector, and through cooperation with local governments, which leverage the features and strengths of their areas.

■ [Example of member progress: Soma IHI Green Energy Center]

Keywords: Regional cooperation, CO_2 value chain

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 in the form of solar power and using the energy within the area (local production and local consumption), reinforcing the area's disaster prevention functions, and revitalizing the area.

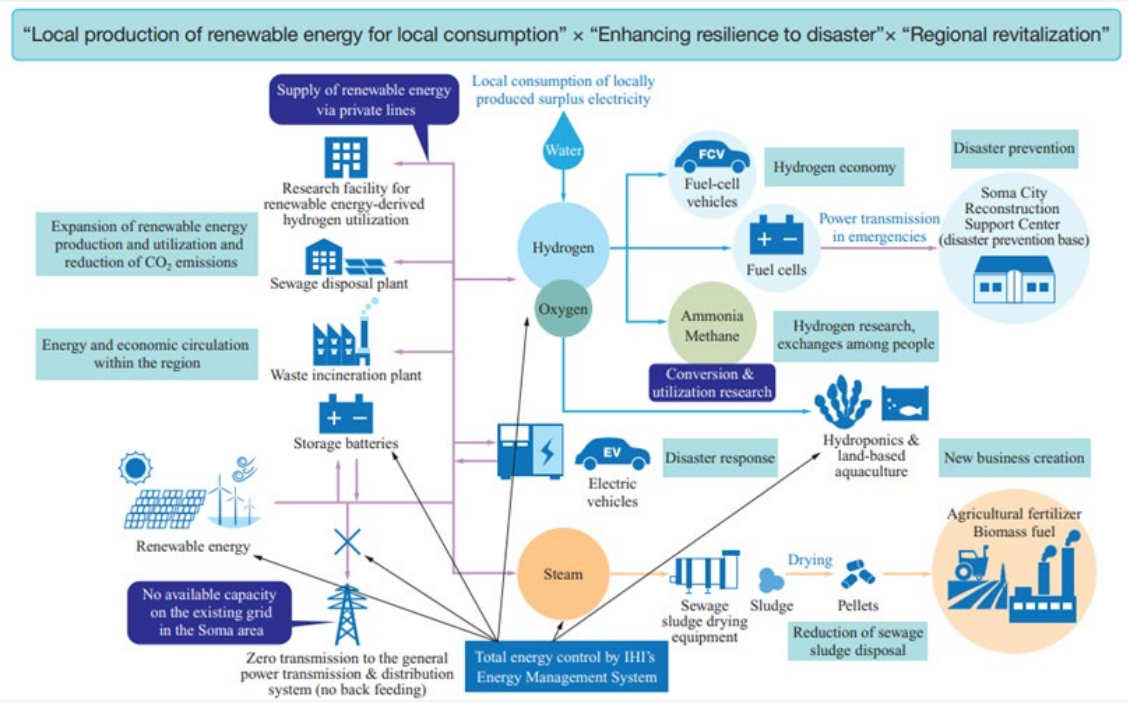


Figure 14. Smart community model

Source: IHI materials

The SIGC, which covers 54,000 m^2, uses solar power generation equipment with an output of 1.6 MW, a large-scale battery system with an output of 1 MW and a capacity of 5.5 MWh, and electrolyzers that use electricity to generate hydrogen from water (an alkaline hydrolysis device from Asahi Kasei Corporation and a PEM hydrogen generator from Hitachi Zosen Corporation). The power that is generated at the site is supplied to a sewage treatment plant and incinerator in nearby Soma City, and any power shortfalls are made up for by purchasing grid power. When the facility generates power at full capacity during good weather, the amount of power even exceeds battery charging capabilities, resulting in surplus power. This surplus power is used to generate hydrogen using hydrolysis devices. The two tanks at the site can store up to 400 Nm^3 of hydrogen. Power supply and demand within the site, and the site's equipment, are centrally controlled by a local production, local consumption energy management system. Information about the amount of power generation, offsite power consumption, offsite power storage, and the like are aggregated in real-time and displayed on monitors in SIGC and in Soma City. Even if a grid power outage occurs, solar power and battery power can be operated independently, providing resilience functions by supplying electricity.

Figure 15. Equipment used at SIGC: (from left to right) 1.6 MW solar power generation facilities, battery system, hydrogen tanks, energy management system screen

Source: Nikkei BP

In September 2020, "Soma Lab" was created. This hydrogen research facility is used to perform technical verification for the carbon-free hydrogen produced and stored at SIGC. Soma Lab is expected to perform verification of "Power to X" technology, which synthesizes methane, ammonia, olefin, and the like from carbon-free hydrogen, etc. The methane synthesis testing equipment installed in Soma Lab can be used to synthesize 12 Nm^3/h of methane from CO_2 and hydrogen generated through water electrolysis.

Figure 16. (Left) The Soma Lab (Right) the lab's 12 Nm^3/h methanation equipment

Source: IHI materials

We believe that the effective use of regional renewable energy and the creation of carbon-free hydrogen value chains will play important roles in achieving carbon neutrality by the 2050 date declared by the government. The local production, local consumption energy management technologies and Power to X technologies developed by SIGC will be key technologies for these measures, so IHI is working to popularize and expand the smart community model.

■ [Example of member progress: Methanol conversion of CO_2 recovered from factory exhaust gas]

Keywords: Chemical conversion, methanol

Implementation member(s): Mitsubishi Gas Chemical Company, Inc.

Mitsubishi Gas Chemical Company, Inc. is promoting the Environmental Circulation-based Methanol Framework, an initiative which seeks to use methanol production technologies based on the company's own catalysts to convert CO_2, waste plastic, biomass, and the like into ethanol, recycling it for use as a chemical and in fuel and power generation applications.

Mitsubishi Gas Chemical was the first company in Japan to successfully convert CO_2 recovered from cleaning plant exhaust gas into methanol conversion. It achieved this in verification testing, conducted in conjunction with JFE Engineering Corporation, of processes for synthesizing methanol from CO_2. It also concluded a memorandum of agreement with Tokuyama Corporation to deliberate regarding the commercialization of the production and sale of methanol made from CO_2 and hydrogen produced by the Tokuyama Factory. If this commercialization is carried out, the plant is expected to become Japan's first commercial plant that manufactures methanol from CO_2 plant emissions.

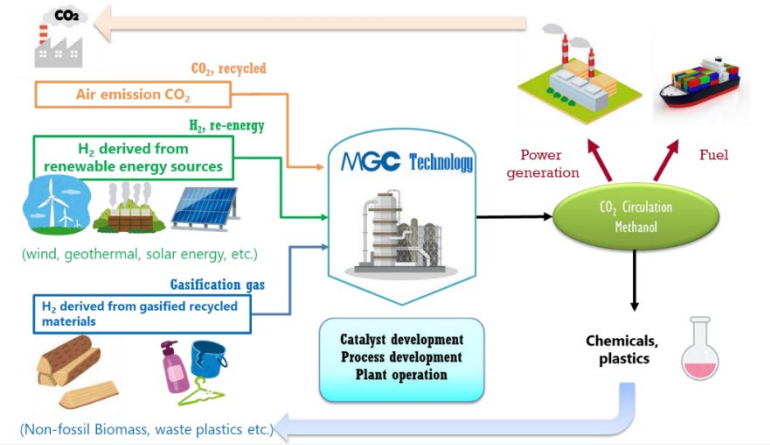


Figure 17. Environmental Circulation-based Methanol Framework and pilot facilities
Source: Mitsubishi Gas Chemical website

■ [Example of member progress: Development of innovative methanation technologies]
Keywords: Methanation, hydrogen and ammonia production, fuel conversion
Implementation member(s): Osaka Gas Co., Ltd.

Osaka Gas Co., Ltd. is engaged in fundamental research regarding solid oxide electrolysis cells (SOECs), a technology that contributes to innovative methanation with the potential for synthesizing methane with a high level of energy conversion efficiency using CO_2 and renewable energy. It has successfully created prototypes of actual size cells. SOEC technology has the potential for use not only in the manufacture of methane but also in the highly efficient production of hydrogen, liquid fuel, ammonia, and other chemicals, and the company aims to establish these production technologies by the year 2030.

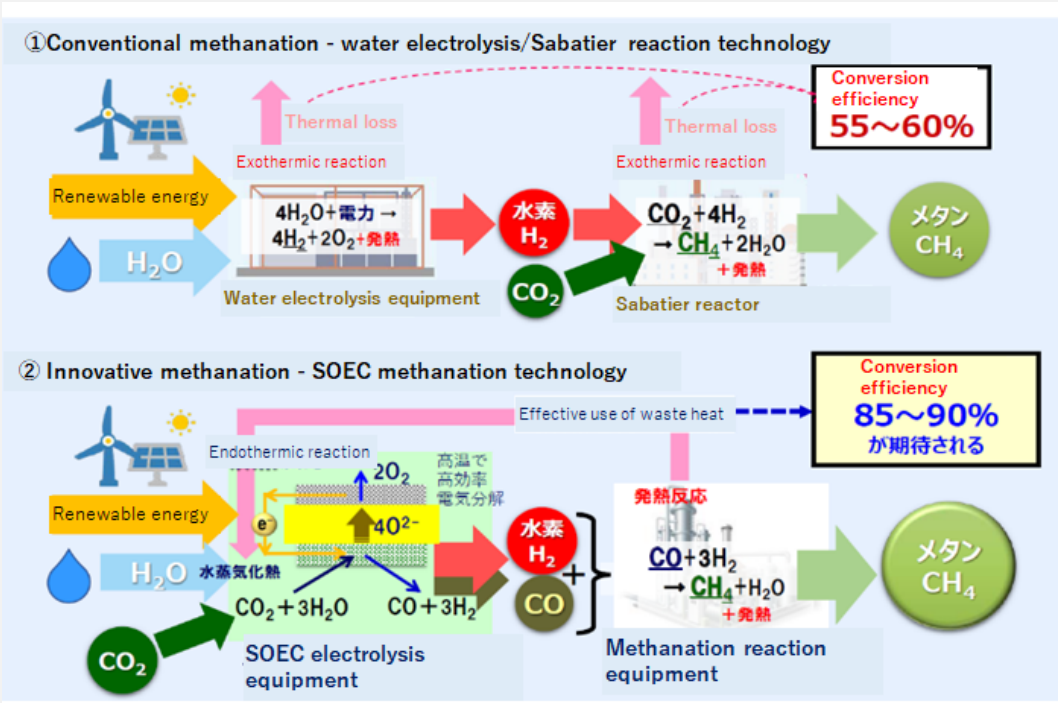


Figure 18. Comparison of conventional methanation and innovative methanation processes
Source: Osaka Gas website

■ [Example of member progress: Green hydrogen production]

Keywords: Carbonatization, mineralization, concrete

Implementation member(s): ITOCHU Corporation

As it works to build green hydrogen supply chains, ITOCHU Corporation has signed a memorandum of agreement to engage in strategic operational cooperation in the hydrogen field with Nel ASA (Norway), which supplies industries around the world with hydrogen production, storage, and delivery technologies. The two companies have agreed to jointly promote hydrogen-related business (October 2021). Nel ASA is one of the world's top manufacturers of water electrolysis equipment, vital for green hydrogen production, in terms of production capacity, equipment scale, units sold, and net sales. In 2021, it announced that it was the first water electrolysis equipment manufacturer to receive orders for a 20 MW-class system. The primary methods currently used in commercial water electrolysis are alkaline and PEM (solid polymer) water electrolysis. Nel is one of the few countries in the world that produces both types of equipment.
Furthermore, in 2021, ITOCHU reached an agreement with three companies (Dalrymple Bay Infrastructure Limited (Australia), North Queensland Bulk Ports Corporation Limited (Australia), and Brookfield Asset Management Inc. (Canada) to perform a joint commercialization study regarding green hydrogen production, storage, and supply chain creation in Australia, including the exporting of green hydrogen.

Figure 19. (Left) Nel water electrolysis equipment (alkaline) (Right) Nel water electrolysis equipment (PEM)
Source: ITOCHU website

■ [Example of member progress: Manufacture of carbonate from calcium and CO_2 derived from industrial waste]

Keywords: Carbonatization, mineralization, concrete

Implementation member(s): Idemitsu Kosan Company, JGC Holdings Corporation

Idemitsu Kosan Company, JGC Holdings Corporation, and others conducted a research and development project on consignment for NEDO from 2020 to 2024, in which they worked to practically apply processes for developing and popularizing technologies for extracting calcium from industrial waste such as concrete and reacting it with CO_2 in exhaust gas to solidify it. Carbonation has promise for purposes such as conventional product filler usage, but also for building material uses such as concrete admixture, for which there is a large market. Because of this, it has tremendous potential for reducing greenhouse gas emissions, so testing and evaluation are underway for accelerated carbonation technologies that can increase the efficiency of calcium extraction and carbonation. Through this technical development project, participants

are actively working towards real world deployment in a wide range of fields, from material procurement to application development.

Furthermore, Idemitsu Kosan has reacted CO_2 in boiler exhaust gas with waste water with a high concentration of calcium, a concrete waste product, to solidify it and produce synthetic calcium carbonate, which it used as an admixture in asphalt. This asphalt was then used to perform test paving of the area in front of the entrance of the company's Coal & Environment Research Laboratory (4 cm thick pavement covering an area of 500m^2), and the company is currently performing verification testing.

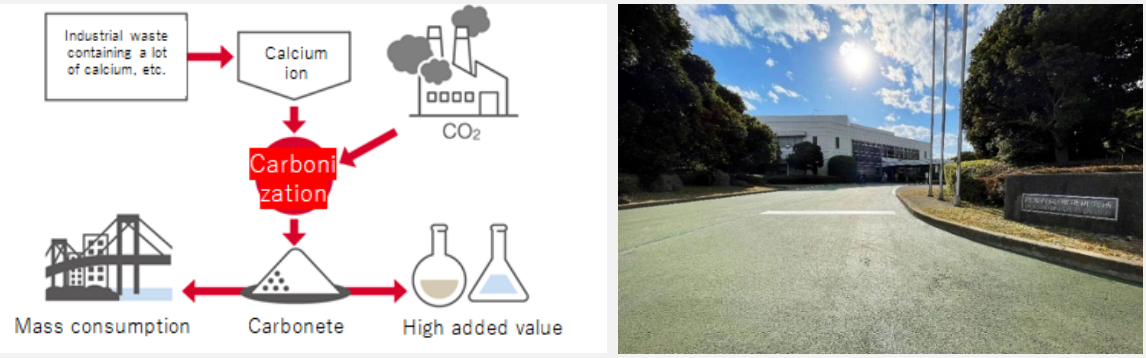


Figure 20.(Left) Conceptual image of CO_2 recycling through carbonation
(Right) Asphalt test paving using CO_2-solidified carbonate
Source: Idemitsu Kosan materials

■ [Example of member progress: Plastic chemical cycle]

Keywords: Circular economy, resource circulation, waste plastic liquefaction

Implementation member(s): Mitsubishi Chemical Group Corporation, ENEOS Corporation

The Mitsubishi Chemical Group Corporation and ENEOS Corporation are engaging in a joint plastic chemical recycling project. They are liquefying waste plastic and using it to create recycled oil, which is used by the two companies' existing petroleum refining equipment and naphtha pyrolyzing equipment. Through this process, it is recycled and reused in petroleum products and plastic products, resulting in a high efficiency chemical recycling process. The project uses waste plastic liquefaction processing technologies from U.K.-based Mura Technology. The facility they have constructed at Mitsubishi Chemical's Ibaraki Plant is the largest commercial facility of its kind in Japan, with a processing capacity of 20,000 tons per year. In fiscal year 2023, they plan to begin the liquefaction of waste plastic. In the future, the project's participants will strive to create products that offer greater added value by obtaining certifications for stable waste plastic procurement, the use of chemical recycling for plastic products, and the reduction of greenhouse gas emissions from petroleum product production.

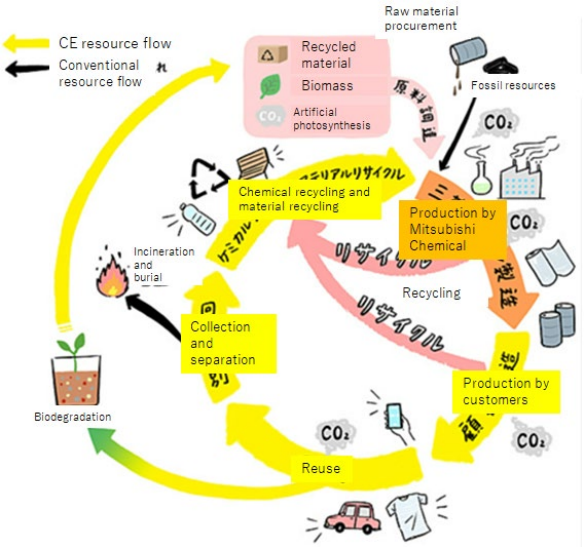


Figure 21. Conceptual image of plastic recycling
Source: Mitsubishi Chemical Group website

■ [Example of member progress: Offshore wind power generation]
Keywords: Renewable energy, offshore wind power generation, green hydrogen
Implementation member(s): Marubeni Corporation

Marubeni Corporation joined SSE Renewables Limited, a renewable energy subsidiary of major U.K. power company SSE plc and Danish investment company Copenhagen Infrastructure Partners P/S in bidding on offshore lease rights related to the development of an offshore wind power generation project in Scotland conducted by a Scottish governmental organization (popularly referred to as "ScotWind"). In January 2022, they were selected by the government organization as winning bidders for the project. The project involves the development of the largest floating offshore wind power generation site off the eastern coast of Scotland, with a maximum capacity of 2.6 GW. It is expected to be one of the first projects in the world involving large-scale floating offshore wind power generation, and operation is scheduled to begin in roughly 2030. The Scottish government aims to reduce greenhouse gas emissions dramatically by 2030, cutting them by 75%, and to achieve net zero emissions by 2045. It is also actively pursuing a strategy of converting to a hydrogen society with the goal of large-scale green hydrogen production using offshore wind power by 2045.

Marubeni owns and operates roughly 12 GW of power generation assets in 21 countries, including Japan. It has been a pioneer in floating offshore wind power generation, participating in verification research such as the Fukushima floating offshore wind farm verification research project. Based on the knowledge and experience gathered through these power generation projects, it will contribute to carbon neutrality in Scotland, to the creation of offshore wind power generation supply chains, and to regional economic development.

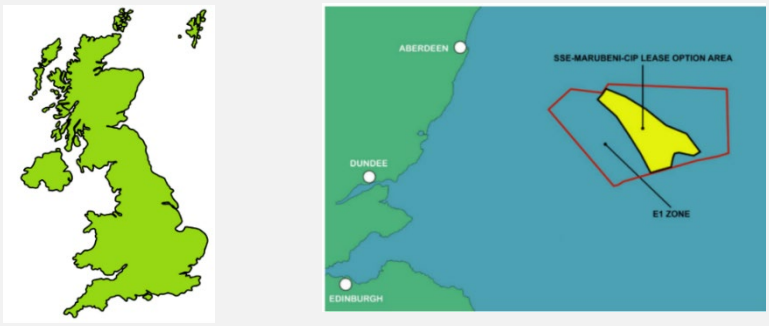


Figure 22. Planned development area

Source: Marubeni website

In the agriculture, forestry, and fishing fields, expectations are high for blue carbon, forest planting, and soil fixation. In the agricultural field, carbon recycling contributes to the improvement of food self-sufficiency levels. Pioneering farmers are managing production in plant factories, etc., by managing CO_2 concentration levels. In the forestry field, large amounts of CO_2 fixing are being achieved by the creation and improvement of forests, which are CO_2 sinks, and planned logging of appropriately aged trees through the use of robots on steep slopes, etc. In the area of civil engineering and construction, the use of lumber is contributing to CO_2 fixing as it is being actively used in some regions in the construction of public facilities such as schools and community centers because of its CO_2 fixing qualities. In the fishing field, blue carbon has tremendous potential. There have been several examples of projects consisting of collaboration with the agricultural and construction sectors, such as sinking concrete made primarily from materials such as coal ash, an industrial by-product, into the ocean to increase seaweed growth and produce fish reefs. Projects such as these have major potential for CO_2 capture and storage.

■ [Example of member progress: Carbon recycling through marine biomass production]
Keywords: CO_2 sinks, blue carbon, seagrass bed creation, fishing industry support
Implementation member(s): Nippon Steel Corporation

Nippon Steel Corporation is aiming to create a new supply chain in which it produces marine biomass (seaweed) and then uses it in steel production processes in a "marine biomass local production, local consumption" model. It is working to use marine biomass as a carbon source for steel production processes, and is actively growing seaweed by levering its technologies for creating seagrass beds from steel slag generated through the steel production process. These initiatives are based on a project selected for the "NEDO Feasibility Study Program/Energy and Environmental New Technology Pioneering Research Program/Development of Technologies Related to the Creation of Supply Chains Focused on Blue Carbon (Marine Ecosystem Carbon Sink)," implemented by NEDO with the aim of creating supply chains that contribute to blue carbon (a joint project by Nippon Steel Corporation, Nippon Steel Chemical & Material Co., Ltd., and the Japan Research and Development Center for Metals).

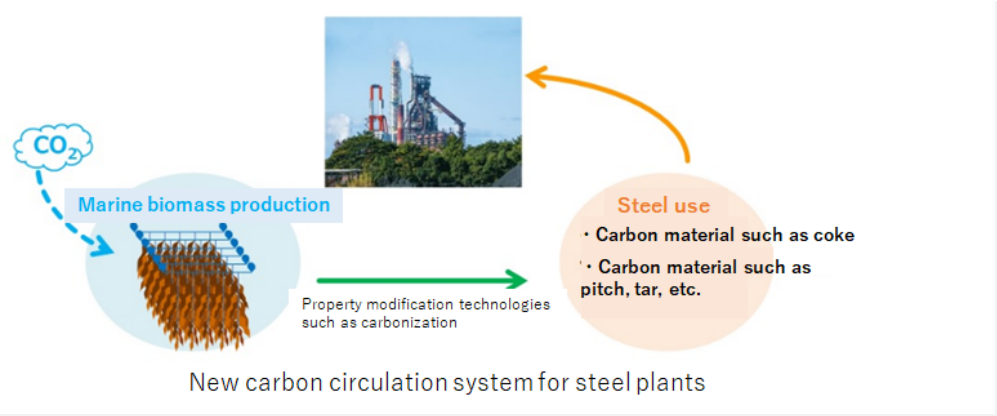


Figure 23. New carbon circulation system for steel plants
Source: Nippon Steel website

■ [Precedent set by CRF member: Planting and growth of forests of fast-growing trees]
Keywords: CO_2 sink, forestry support
Implementation member(s): Sojitz Corporation/Cool Earth, Inc.

Sojitz Corporation and Tokyo University's venture company Hongo Research Institute Inc. jointly established Sojitz Morinomirai Corporation, which will produce Japanese aspen tree saplings that can reach maturity for logging five years after planting. These saplings are currently being grown by Hongo Research Institute on a trial plantation in Miyazaki Prefecture. Japanese aspen is notable for its ability to provide a stable supply of fuel for biomass power generation. In parallel with the production of the tree saplings, Sojitz is also considering the early commercialization of the forest planting project. Sojitz seeks to provide solutions to the region's issues through the realization of a forest resource cycle in close cooperation with the regional community. It has also begun test planting of Japanese aspen in deserted agricultural land, undeveloped forest land, and the like in the prefectures of Miyazaki, Yamaguchi, Okayama, and Hokkaido.

Figure 24. The Hongo Research Institute's Japanese aspen trial plantation (one year after planting)
Source: Sojitz website

Cool Earth, Inc. aims to restore forest and denuded land while helping remove greenhouse gasses from the atmosphere by planting and growing "*Japaulownia*," a fast growing Japanese species of paulownia. *Japaulownia* can be felled after five years, and over that time, 10,000 *Japaulownia* trees can absorb 420 to 600 tons of CO_2 (according to calculations performed together with the Seikei University Faculty of Science and Technology, Department of Materials and Life Science). Expectations are high for its potential in the environmental conservation industry, as it can not only be used as fuel for biomass power generation,

but thanks to its light weight humidity control effectiveness, it can also be used in furniture and as a construction material. *Japaulownia* growth management does not require the use of chemical fertilizers or other agricultural chemicals. Instead, organic growing techniques using mycorrhizal fungus, its partner bacteria, and partner plant vulpia myuros can be used to create safe, dependable, and sustainable *Japaulownia* production systems. Since 2021, Cool Earth has collaborated with companies to plant hundreds of tree saplings at a time. It plans to have planted over 30,000 saplings by June 2023.

Figure 25. Japaulownia tree saplings, planting, and furniture made from Japaulownia
Source: Cool Earth materials

The creation of CO_2 value chains will be essential for capture and storage in Japan. As discussed during the interim summary of the CCS long-term roadmap announced by the Ministry of Economy, Trade and Industry in May 2022, systematically and rationally implementing the CCS will contribute to the advancement of the Japanese economy and industry and the stable supply of energy. In preparation for commercialization in 2030, it is important that overall system design and policy support be linked to clean energy strategies, new material industry visions, the carbon neutral plans of local governments, and other plans with the same objectives, and that they be led by the national government. Collaboration with the agriculture, forestry, and fishing industries can also be enhanced by broadly interpreting CO_2 capture and storage, expanding it to include the use of bio-organisms, such as soil fixing and blue carbon.

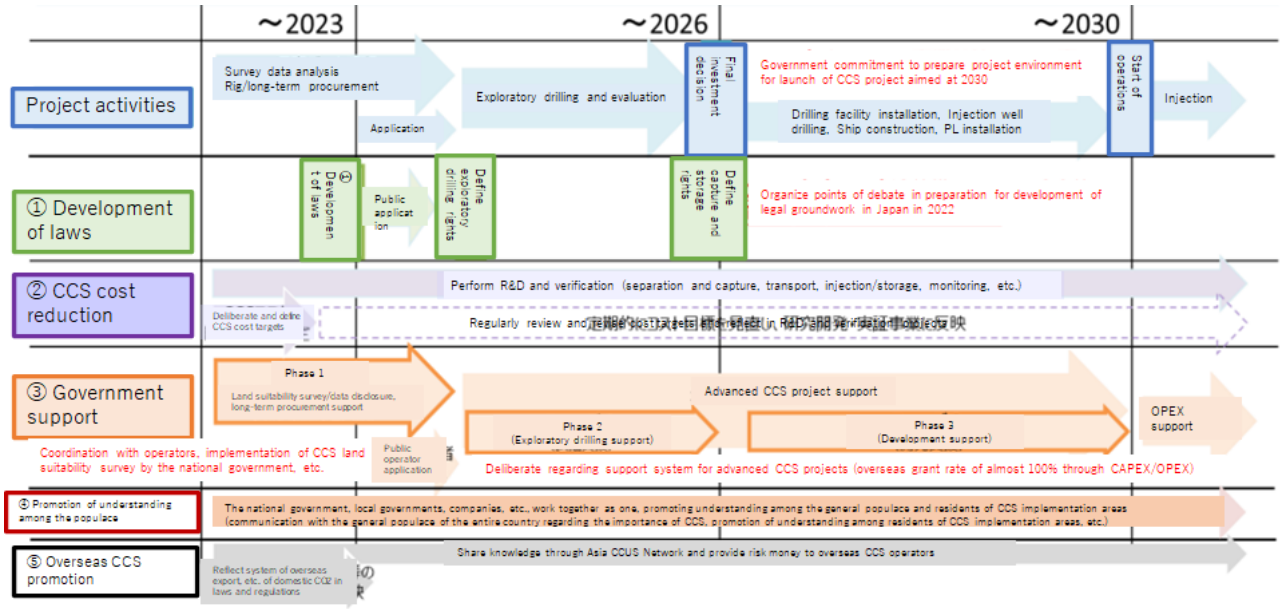


Figure 26. CCS long-term roadmap (draft)
Source: Ministry of Economy, Trade and Industry materials

■ [Example of member progress: CCUS value chain digital platform]

Keywords: CCU, CCS, CO_2 value chain

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

Mitsubishi Heavy Industries, Ltd., together with IBM Japan, Ltd., is developing CO_2NNEX, a CCUS value chain digital platform. The goal of this platform is to connect the valuation of CCUS, in which captured CO_2 is transported, reutilized, and stored, with the IoT and blockchain technology. Through this, they aim to make visualization, tracking, transactions, and optimization possible, helping invigorate the use of CO_2 ecosystems and contributing to environmental conservation.

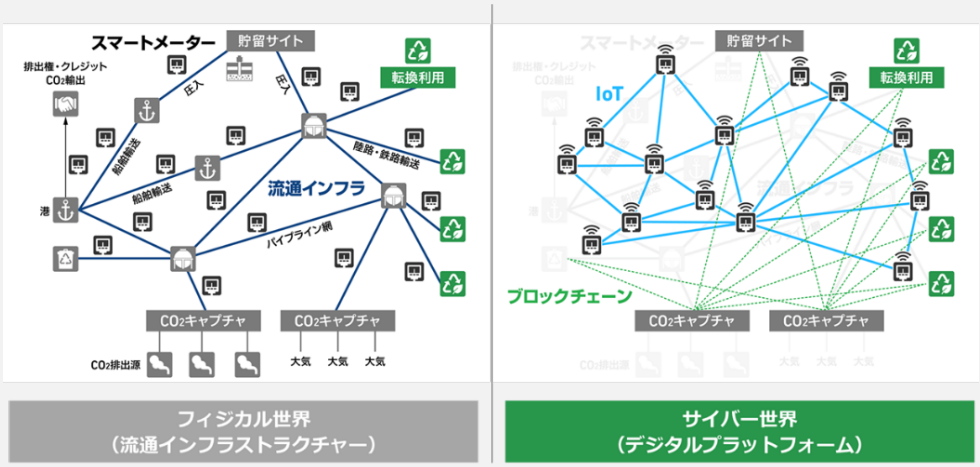


Figure 27. CO_2 capture technology process flow
Source: Mitsubishi Heavy Industries website

The fundamental platform will be completed in 2022, and, based on this, there are plans to start digital verification testing together with the stakeholders of various CCS/CCU projects, both inside Japan and abroad. The CCUS data collected in CO_2NNEX will be used to create an open platform that allows various service providers to provide their own unique value, and they aim to put the platform into operation from 2023.

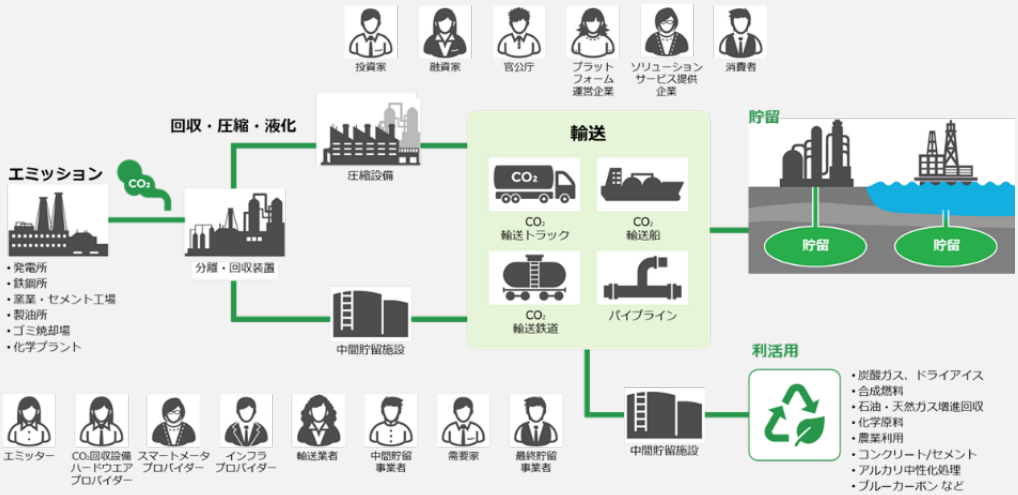


Figure 28. CO_2 capture technology process flow
Source: Mitsubishi Heavy Industries website

CRF members are engaged in a variety of other projects, some of which are introduced on the following page.

Keyword(s)	Initiative	Implementation member(s)	Initiative Stage	Overview
Chemical conversion	Manufacture of polyurethane using CO_2 chemistry	Asahi Kasei Corporation	Operationalization	Establish process for manufacturing special polyurethane raw material from CO2 derivative. Use this material for the clear coating of vehicle top coat. Aim to start test marketing in 2022 and to start commercial facility operation and commercialization in 2025.
Chemical conversion	Development of innovative system for large-scale development of CO2 sources focused on electrochemical processes	Shimizu Corporation Furukawa Electric Co., Ltd. Chiyoda Corporation	Research and development	Develop an integrated system that captures CO2 in the air (including indoor air in office buildings) (urban DAC) uses renewable energy to electrochemically reduce CO2, and then generates useful chemicals such as ethylene from water and CO2. NEDO-COMMISSIONED project
Fuel conversion	Development of innovative methane production technologies using low temperature processes	Asahi Quality & Innovations, Ltd. (AQI) Toshiba Energy Systems & Solutions Corporation IHI Corporation	Verification	Use a CO2 separation and collection device (manufactured by Toshiba Energy Systems & Solutions Corporation) to capture CO2 from boiler exhaust gas within the AQI plant and supply the CO2 to a methanation device (manufactured by IHI Corporation) in the Japanese food industry's first methanation verification test.
Fuel conversion	Synthesis of liquid hydrocarbon from synthetic gas containing carbon dioxide	Sumitomo Heavy Industries, Ltd.	Research and development	Together with the Gunma Industrial Technology Center, this project is developing technology for synthesizing diesel fuel with a high cetane number and zero sulfur content by performing FT synthesis on hydrogen and CO2. Use Co/SiO2 catalyst to confirm the generation of liquid hydrocarbon from a mixture of CO2 and synthetic gas.
Mineralization	CO2 absorption concrete	Aizawa High Pressure Concrete Co., Ltd.	Operationalization	Began Japan's first real-world deployment of CarbonCure Concrete, CO2-trapping concrete from Canada's CarbonCure Technologies, in November 2021.
Mineralization	Low CO2 cement "CARBOFIX®"	Taiheiyo Cement Corporation	Verification	Cement-based material made using a production process that emits less CO2 than ordinary portland cement. This material hardens through a chemical reaction with CO2, trapping the CO2 and further reducing the total CO2 emissions from concrete.
Hydrogen and ammonia	Verification project for the creation of a large-scale sea transport supply chain for hydrogen derived from unutilized lignite	Kawasaki Heavy Industries, Ltd. Electric Power Development Co., Ltd. Marubeni Corporation ENEOS Corporation (ENEOS Holdings, Inc. Group)	Verification	Complete a verification test of the marine transport and cargo handling of liquid hydrogen between Japan and Australia using hydrogen created from lignite with the goal of creating a hydrogen supply chain. NEDO-COMMISSIONED project
Hydrogen and ammonia	Development of large-scale PEM water electrolysis equipment	Toray Industries, Inc. Hitachi Zosen Corporation	Verification	Expand and modularize PEM water electrolysis equipment. Develop technologies related to the creation of films with superb durability and conductivity, etc. NEDO-COMMISSIONED Green Innovation Fund project
Absorption	Bell pepper production using CO2 for agricultural purposes	VEGI-Dream Kuriihara Corporation (Toyota Tsusho Corporation Group)	Operationalization	Since the farm was created, it has contributed to the reduction of CO2 emissions by reducing the heating fuel consumed by this environmentally-friendly bell pepper by reusing waste heat from an adjacent plant. The CO2 emitted during boiler operation is also captured and reused to promote plant photosynthesis.
CCS/CCUS	Cross-industry coordination using CCS/carbon recycling Hub-and-cluster CCUS project	Japan Petroleum Exploration Co., Ltd.	Verification	This project aims to establish CCUS business through the NEDO-commissioned study on the feasibility of carbon recycling leveraging cross-industry collaboration in Tomakomai (2021-2022). A JOGMEC-commissioned study of CO2 emissions sources in Japan and the capture and transport of CO2 for specific regions in Japan (2022) is being carried out to study the feasibility of hub-and-cluster CCUS connecting multiple CO2 emissions sources in the eastern Niigata area with storage locations.
Start-up	Start-up support	Mitsubishi Corporation	Other	Together with NYK Line, Startupbootcamp Australia is being used to discover promising future start-up companies with new low carbon and decarbonizing technologies and business ideas.

Figure 29. Projects by CRF members

Source: Carbon Recycling Fund Institute materials

4. Recommendations for realizing a sustainable carbon society

The Carbon Recycling Fund Institute (CRF), carrying out the roles described in Section 2, has updated the recommendations it issued last year for achieving carbon neutrality led by carbon recycling and creating carbon recycling societies. These updates to its recommendations were made from the following three perspectives, and the CRF, together with its members, is actively working to put the recommendations into practice.

Develop and promote innovation, develop human resources

- The research, development, and verification of carbon recycling technologies and products are accelerating. Overseas, in particular, start-up companies with the seeds of technologies with future potential are attracting funding, and research and development are making speedy progress. In the U.S., Germany, and other countries, massive amounts of funding are being invested, and these countries are poised to take the initiative in development competition. Given this environment, CRF members should develop, verify, deploy, and actively invest in carbon recycling technologies and products with the aim of achieving carbon neutrality by the year 2050 through green transformation (GX). In doing so, they should engage in cross-industry coordination, including coordination with start-up companies, and make maximum use of open innovation in order to accelerate these activities. Utilizing the verification opportunities provided by the national government, such as Expo 2025 Osaka, Kansai, Japan, would be an efficient approach.
- In order to support these industrial activities, the Japanese government must strive to enrich its measures, such as providing additional support in order to accelerate development and verification related to green innovation (carbon recycling, hydrogen and ammonia production, the usage of biological resources, coordination with the agriculture, forestry, and fishing industries, CCS, and the creation of CO_2 value chains which include financial coordination). It must provide solid support for the development and promotion of innovation. Expectations are high for its support for the advancement and expansion of measures that highly motivated companies can voluntarily take part in, such as the GX League.
- Measures for developing personnel that can lead innovation and real world deployment will also be important. CRF members should make wide-ranging efforts to develop personnel that will implement carbon neutrality and carbon recycling measures, and, especially, the core personnel that will lead implementation between 2030 and 2050.
- We hope that the Japanese government will provide greater opportunities in schools to learn about carbon neutrality and carbon recycling and that, along with nurturing the personnel that will be responsible for these efforts in the future, it will carry out measures for fostering a greater understanding of carbon neutrality and carbon recycling among the populace, which will lead to greater adoption.

CO_2 value chain creation

- Carbon recycling technologies and products establish their importance and roles in society through their deployment and application. Because of this, 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.
- To maintain and enhance Japan's international competitiveness through the real-world deployment of carbon recycling technologies and products, the national government should strive to provide incentives, such as

providing premiums for products and services that use CO_2 value chains.

- Companies and the national government should acquire and collect data regarding CO_2 separation, capture, and utilization through real world deployment, and prepare the groundwork for quantitative evaluations. When doing so, efforts should be made to further the overall optimization of the effects and impact of introducing carbon recycling through the use of objective investigation based on lifecycle assessments (LCAs).
- The national government should promote the visualization of the flow of CO_2 based on LCAs and engage in active discussion regarding matters with major impacts which would transform the social structure, such as emission trading, carbon taxes, and carbon pricing,. Unified systems which ensure fairness between industries should be prepared and implemented without delay.
- We hope that the Japan will provide leadership and take initiative with respect to evaluating CO_2 sinks such as oceans and vegetation, and with respect to the creation of international rules.
- Carbon recycling promotion measures and deliberations regarding CO_2 capture and storage must be accelerated, and discussions have begun regarding enacting laws within Japan related to the implementation of CCS projects. The government should provide solid support for active measures by the private sector working towards the commercialization of CCS by 2030. Furthermore, it would be best if it were to divide the roles, risks, and costs of these measures between the private and public sectors.

Integration with regional revitalization and expansion to the global market

- If carbon neutrality and carbon recycling are to be linked to the revitalization of Japan and the enhancement of its competitiveness, integration with regional revitalization will be essential. CRF members should create CR case examples that leverage the strengths and features of communities by collaborating with local governments. When doing so, they should keep the creation of CO_2 value chains, including the aforementioned CO_2 capture and storage, in mind, and they should focus on discovering CO_2 consumers and coordinating with the agriculture, forestry, and fishing industries from a carbon recycling perspective. Coordination with multifaceted investigations will also be necessary in order to create carbon neutral ports.
- The local production and local consumption of energy Is also a key concept linked to the carbon recycling and regional revitalization. It is important to carry out measures that leverage natural local assets such as offshore wind power, small-scale hydropower, and geothermal energy. Offshore wind power generation also has the potential to contribute to the creation of fish reefs. There are high expectations for measures that help improve food self-sufficiency rates by revitalizing agriculture, forestry, and fishing industries that make use of carbon recycling.
- Global standards are being developed for carbon neutrality initiatives, and CRF members should see these as excellent opportunities, actively expanding into the global market, including licensing business.
- We hope that the Japanese government will demonstrate a strong presence in international deliberations in order to support these efforts. The government can expand carbon recycling into a growth industry for Japan by keeping in mind that Japan is part of Asia and deploying Japanese carbon neutrality technologies in Asian countries, contributing to carbon neutrality throughout Asia. It will also be important to conclude memorandums of agreement with the International Conference on Carbon Recycling and the governments of individual countries, and to conduct joint research and other work based on these memorandums of agreement, thereby strengthening Japan's international cooperation.
- Industry, academia, and the public sector must work together as one to advance the effectiveness and progress of carbon recycling, enhancing their sharing of information around the world. As part of this, the carbon recycling technology roadmap defined by the Japanese government must be revised as further progress is made.

5. Summary

With COP26, the global community launched into action, working to achieve the shared goals of cutting CO_2 emissions by 45% from 2010 levels by 2030 and achieving carbon neutrality by 2050. To build sustainable social and economic systems founded on carbon neutrality in the face of international political instability and a lack of global transparency, every stakeholder must work together to steadily implement concrete measures.

However, this cannot be allowed to lead to a hollowing out of Japanese industry by shifting industry overseas. Furthermore, achieving carbon neutrality is not feasible simply through decarbonizing or striving to reduce carbon footprints, rejecting all emission of CO_2 produced by using fossil fuels.

A variety of measures must be implemented together, including the creation of carbon recycling societies by clearly defining the value of CO_2, capturing and storing CO_2, and using CO_2 and carbon compounds as resources.

Carbon recycling is a field that spans all domains. The Carbon Recycling Fund Institute includes not only cooperation between members of private industry, but also cooperation between industry, academia, the public sector, and overseas organizations with the aim of creating carbon recycling societies, in Japan and around the world.

[Attachment 1]

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

Top Advisor: Yoshimitsu Kobayashi (Chairman, Tokyo Electric Power Company Holdings)

Advisor: Takeo Kikkawa (Vice-President, International University of Japan)

Chairperson: Nobuo Fukuda (Representative Corporate Executive Officer, Executive Vice President, Mitsubishi Chemical Group Corporation)

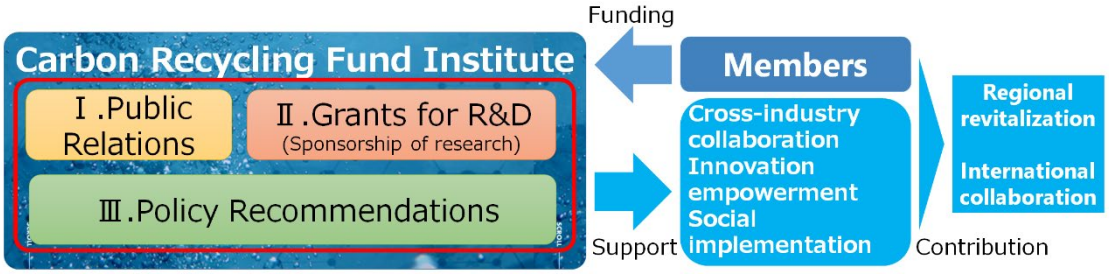
Vice-Chairperson: Masayoshi Kitamura (Special Counselor, Electric Power Development Co., Ltd.)

(3) Activities

① Public relations: Raising awareness regarding carbon recycling

② Research sponsorship: Offering grants to researchers, etc.

③ Other activities: Issuing recommendations, performing studies of domestic and international carbon recycling technology trends, etc.



Members (as of August 1, 2022)

106 corporate members, 17 individual members, 8 local government members, and 3 academic institute members

Corporate members

<Chemicals>
- AGC Inc.
- ASAHI KASEI CORPORATION
- BASF Japan Ltd.
- Denka Co., Ltd.
- DIC Corporation
- JSR Corporation
- Mitsubishi Chemical 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.

<Precision, Electronics>
- Furukawa Electric Co., Ltd.
- Shimadzu corporation
- Ushio Inc.

<Energy>
- ENEOS Holdings, Inc.
- 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.
- KANKYOU SYSTEMS, INC.
- Utilization of Carbon Dioxide Institute Co., Ltd.

<Iron, 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>
- Cosmos Shoji Co., Ltd.
- 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>
- Chiyoda Corporation
- Ebara Corporation
- FUSO Corporation
- HITACHI ZOSEN CORPORATION
- Hitachi Power Solutions Co., Ltd
- 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 Printing CO., LTD.

<Automotive>
- AISAN INDUSTORY., LTD.
- NGK SPARK PLUG CO., LTD.
- Nissan Motor Co., Ltd.

<Air, traffic, transportation>
- JAMCO Corporation

<Construction, Real estate>
- Dome Gold Mines Ltd.
- FKG Corporation Fukuoka.K.Gouzai. Inc
- FUTURE ESTATE Co., Ltd.
- Hitachi Plant Services Co., Ltd.
- Hulic Co., Ltd.
- HOUSEI
- 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
- 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 Consultiong Group G.K.
- Mizuho Research & Technologies, Ltd.
- NTT Data Institute of Management Consulting, Inc.

<Others>
- Central Research Institute of Electric Power Industry
- JAPAN COAL FRONTIER ORGANIZATION
- The Institute of Energy Economics, Japan

Individual members
- Einaga Yasuaki
- Katsu Kinichi
- Hanawa Moriyuki
- Minemura kenji
- Sakurai Shigetoshi
- Takeishi masayuki
- Terashima Chiaki
- Yamada Hidetaka
- Yoshihara Tomomichi
- Kaku sen
- Kawamura Hiroyuki
- Hashimoto kazuyo
- Ohno Yotaro
- Takahashi Tsuneo
- Takeuchi Aya
- Ueno Hiromoto
- Yoshida Taiji

Local government members
- Akita Prefecture
- Hiroshima Prefecture
- Hokkaido Prefecture
- Kagawa Prefecture
- Osakikamijima town (Hiroshima Prefecture)
- Saikai City (Nagasaki Prefecture)
- Takehara City (Hiroshima Prefecture)
- Tomakomai City (Hokkaido Prefecture)

Academic members
- NAGASAKI UNIVERSITY
- Sakanishi Kinya
- Tokyo University of Science Foundation

Summary of 2021 Carbon Recycling Fund Institute member questionnaire

Questionnaire period: February 10 to March 17, 2022

Questionnaire scope: 89 corporate members and 15 individual members * Includes prospective members planning to join in 2022

Number of respondents: 53

1. We administered a multiple-choice questionnaire covering the following items.
   - ① Carbon recycling technology fields for which respondents had high hopes or wished to implement measures, expectations regarding promising technologies, stages of measures, and challenges faced during real-world deployment (see figures below)
   - ② Participation in national projects
   - ③ Countries/regions in which participants were considering taking part in international cooperation

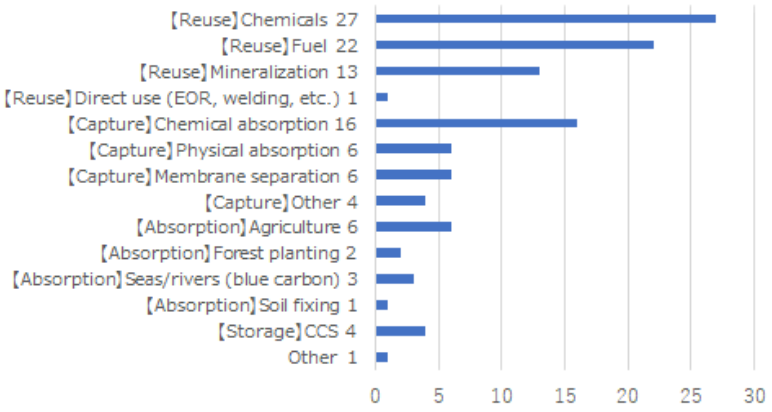


Figure 1　Carbon recycling technology areas for which members had high hopes or wished to implement measures

(including areas in which members had already implemented measures and areas of interest to members, whether or not their own organizations possessed those technologies)

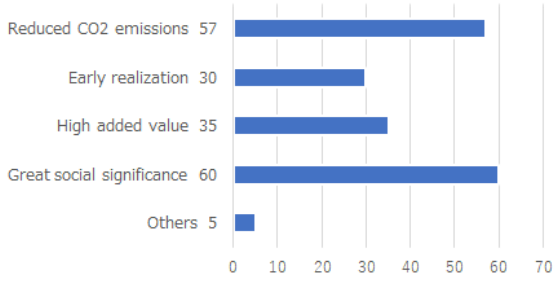


Figure 2 Expectations regarding promising technologies

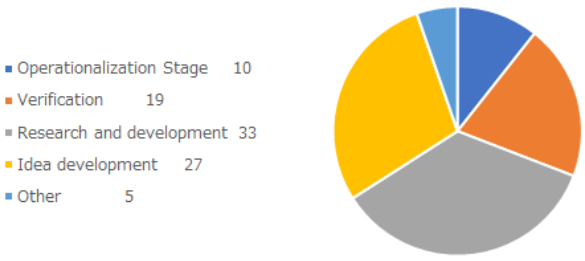


Figure 3 Stages of measures in technology areas for which members had high hopes or wished to implement measures

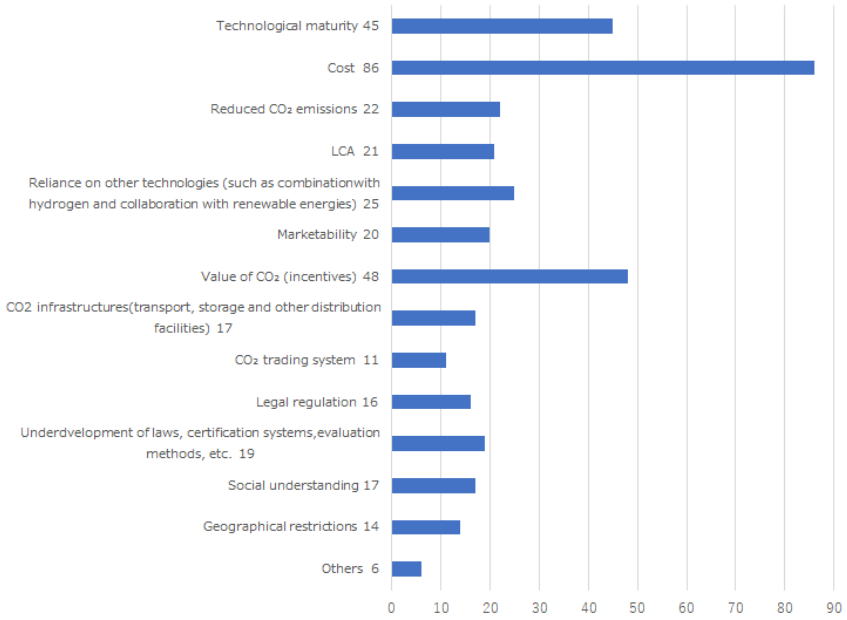


Figure 4 Challenges faced during real-world deployment

2. We also administered a free response questionnaire covering the following items. Below were the main responses.

① Expectations for carbon recycling

- ✓ Carbon recycling technologies will be essential to maintaining growth while achieving carbon neutrality
- ✓ Comprehensive global strengths will need to be leveraged
- ✓ This will also be important for increasing the societal value of companies

② Opinions regarding the establishment of the carbon recycling throughout society

- ✓ It will be important to develop and promote new technologies in order to thoroughly and widely establish the fact that CO_2 is a resource
- ✓ We must communicate that this is not merely a concept but an actual system that can be implemented as a product
- ✓ We should focus on the development and verification of research technologies that contribute to real-world deployment

③ Carbon recycling measures other than technology development

- ✓ Forest planting
- ✓ Funding of start-up companies, development of measurement methods that can be used to evaluate CO_2 absorption and fixing amounts
- ✓ Carbon credit business

④ Comparison of Japanese and foreign technology development

- ✓ Japan is superior with respect to catalyst technologies, electrochemical technologies such as hydrogen fuel cells, artificial photosynthesis, etc.
- ✓ Japan lacks sufficient national support for verification and real-world implementation
- ✓ Other countries have the lead with respect to market establishment, the development and widespread use of

decarbonization technologies, and the verification testing of seeds

- ✓ Inexpensive renewable energy is widely used overseas

⑤ Industrial fields in which members wish to engage in collaboration aimed at real-world deployment

* Responses covered a wide range of industrial fields, including the petrochemical industry and the construction industry

⑥ Expectations of industry members/academic organizations in collaborations between industry and academia

- ✓ Establish and improve system for fostering exchange between researchers in the industrial and academic spheres
- ✓ Target technologies should be clarified and efforts should be focused on research technology development fields in which participants are internationally competitive
- ✓ Information should be communicated and shared through open innovation regarding technologies in high demand in industry

⑦ Challenges with implementing CCS in Japan

- ✓ There is little land suited to it
- ✓ It is absolutely vital to secure the understanding of local members of the community, such as fishing cooperatives
- ✓ Society must be made aware of the potential and impact of CCS

⑧ Comments regarding CO_2 sinks such as blue carbon

- ✓ Absorption amounts must be evaluated based on scientific evidence and using measurement methods
- ✓ Japan should take the lead in creating rules regarding blue carbon, based on scientific assessments
- ✓ Awareness needs to be raised and legal systems need to be put in place so initiatives can be advanced both on land and at sea
- ✓ Global utilization and international collaboration are important

⑨ Opinions regarding reforms to regulations that present impediments to R&D, product manufacturing, etc. (regulatory relaxation and the tightening of regulations, etc.)

- ✓ Support for adding value to carbon negative products/technologies, support for the global use of CO_2 and conversion of CO_2 into a resource
- ✓ Standardization of products that fix CO_2, introduction of incentive systems, tax benefits
- ✓ Creation of systems that are prioritized for use in public procurement, such as green procurement

⑩ Opinions regarding what approaches should be used to create systems that provide CO_2 with value

- ✓ There need to be systems in which final consumers seamlessly and naturally bear CO_2 costs
- ✓ CO_2 reductions through the use of CR technologies should be one of the reduction items in CO_2 emissions reductions from carbon pricing
- ✓ Care needs to be given to prevent a loss of competitiveness in comparison to overseas companies

⑪ Improvements to address challenges in real-world deployment of carbon recycling technologies

[Chemicals]

- ✓ System of premiums for developed products (such as compensation for increases in prices), tax breaks, etc.
- ✓ Cost reduction through technology development

[Fuel]

- ✓ Creation of systems and rules through wide-ranging collaboration and collaborative creation
- ✓ Expand market by providing incentives for base usage of hydrogen

[Mineralization]

- ✓ Appropriate design of carbon pricing systems, relaxation of regulations and development of legal systems involved in use of carbonate in construction and civil engineering applications
- ✓ Standardization of concrete products made using carbon recycling technologies (JIS, etc.)

[Capture]

- ✓ Creation of systems and rules through wide-ranging collaboration and collaborative creation
- ✓ Collaboration in the form of supply chains, from capture to utilization and storage, total LCA activities, etc.

[Absorption]

- ✓ Active desert greening, creation of seagrass beds in oceans, etc.
- ✓ Creation of blue carbon credits, incentives for developed material providers, etc.

[Storage]

- ✓ Design of appropriate carbon pricing system, development of laws promoting CCS