Carbon Recycling 3C Initiative
Progress Report

October 2020

Ministry of Economy, Trade and Industry

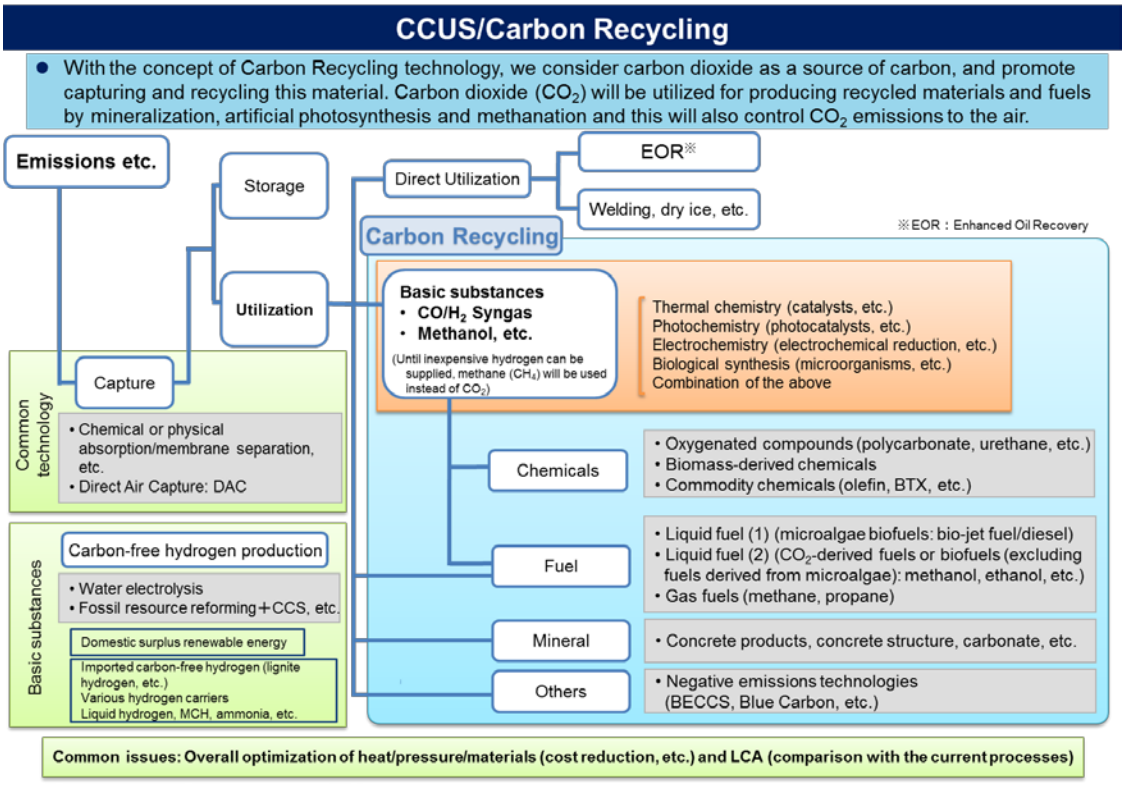
New Energy and Industrial Technology Development Organization

1. Introduction

Global awareness of the global warming issue has been on the rise as the entry into force of the Paris Agreement further strengthened the momentum for combating global warming. Meanwhile, approximately one billion people in the world still do not have access to electricity. Global demand for energy is expected to continue to increase in the future, especially in Asia, in line with improvements in access to electricity and economic growth. A major challenge for us is to achieve a virtuous cycle of environmental protection and economic growth through disruptive innovation, while ensuring a stable and affordable supply of energy.

In order to solve this problem, it is imperative that we pursue all options. In this context, Carbon Recycling is one of the most important and promising means, along with energy saving and renewable energy. Carbon Recycling is an initiative that captures CO2, which is regarded as a resource, to be reused as fuels or raw materials. The reasons for conducting Carbon Recycling are: (1) Carbon Recycling can directly contribute to the reduction of greenhouse gas emissions; (2) Carbon Recycling can produce synergy effects with related technologies through the utilization of hydrogen and renewable energy; and (3) Carbon Recycling can be introduced in various industries in their respective business fields by making use of the existing infrastructure.

With the aim of accelerating this momentum, Japan held the first International Conference on Carbon Recycling in September 2019 and formulated the “Carbon Recycling 3C Initiative” at the conference. This initiative is utilized to promote the development and commercialization of Carbon Recycling technologies through international collaboration among industry, academia and government. This report provides an overview of Carbon Recycling technologies and the status of efforts based on this initiative, which will be shared with partners around the world towards the next step forward.



1st International Conference on Carbon Recycling (September 2019)

2. Progress of the Carbon Recycling 3C Initiative

(1) Overview of the Carbon Recycling 3C Initiative

(i) Objectives of the Carbon Recycling 3C Initiative

As mentioned above, Japan formulated the “Carbon Recycling 3C Initiative” in September 2019 to accelerate the development and commercialization of Carbon Recycling technologies through international cooperation. This is an initiative that seeks to accelerate innovation based on the "Roadmap for Carbon Recycling Technologies" (hereinafter referred to as the "Technology Roadmap"), which was announced in June last year at the “G20 Ministerial Meeting on Energy Transitions and Global Environment for Sustainable Growth**.”**

(ii) Overview of the Carbon Recycling 3C Initiative

The Carbon Recycling 3C Initiative, which aims to accelerate innovation based on the Technology Roadmap, contains three actions: (1) Promotion of mutual exchange (Caravan); (2) Establishment of R&D and demonstration base (Center of Research); and (3) Promotion of international joint research (Collaboration).

First is the promotion of mutual exchange (Caravan). The significance and importance of Carbon Recycling and the progress of its development will be shared and disseminated both domestically and internationally through international conferences related to Carbon Recycling including the International Energy Agency (IEA)’s CCUS summit. Efforts will be made to build a network through exchanges based on participation in academic conferences and visits to R&D and demonstration bases by researchers. In addition, information provision and public relations campaigns will be carried out with businesses, universities and research institutes in charge of development, as well as local governments, which are one of the providers of initial demand.

Second is the establishment of R&D and demonstration base (Center of Research). Research and technological development of Carbon Recycling technologies will be promoted, mainly at R&D and demonstration bases that have already begun CO2 capture, while preparing an environment for scale expansion and commercialization including the examination of test beds and standardization studies. As an initial step, the Osakikamijima

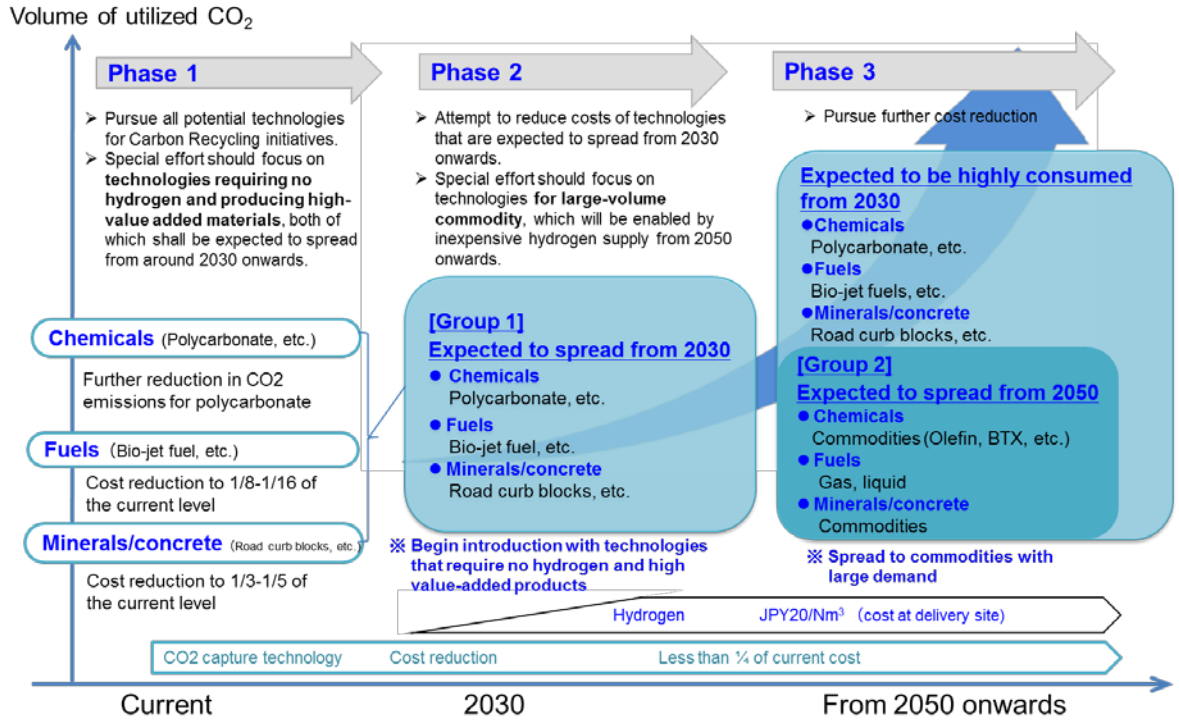
facility in Hiroshima Prefecture, which began the demonstration of CO2 capture in December 2019, and Tomakomai facility in Hokkaido, which is working on the CCUS project, will be developed ahead of others as core R&D demonstration bases. In September 2020, Tomakomai reorganized the "Tomakomai CCS Promotion Council" into the "Tomakomai CCUS / Carbon Recycling Promotion Council" in anticipation of future developments in Carbon Recycling.

Third is the promotion of international joint research (Collaboration). Collaboration with potential partners in industry, academia, and government will be expanded through the provision and sharing of information on Carbon Recycling through mutual exchanges noted in (1), while pursuing international joint research that complements each other's characteristics and strengths. In addition, the results obtained through these collaborations will be actively disseminated.

(iii)About the Roadmap for Carbon Recycling Technologies

The Technology Roadmap shows the path to development and commercialization in the three main strategic fields of chemicals, fuels, and minerals. The Roadmap will move ahead in three stages and the technologies and products are divided into two groups according to their characteristics: Group 1 that includes technologies and products whose commercialization is expected to proceed ahead of others and Group 2 whose commercialization is scheduled to proceed in the full-scale implementation stage. The examples cited in Group 1 include products that do not require hydrogen in their manufacture and high value-added products (polycarbonate, road curb blocks, jet fuel, etc.). Group 2 is expected to include high-demand commodities (olefins, BTX, etc.) that are manufactured on the premise of inexpensive hydrogen supply (about 20 yen/Nm^3) that is to be achieved through disruptive innovation. The Phase 1 (2020 onwards) will involve the start of the initial stage comprising research, technological development and demonstration that contribute to Carbon Recycling, and the establishment of a base to promote these activities. In the subsequent Phase 2 (around 2030), the commercialization of Group 1 and progress in Group 2 manufacturing technology are scheduled while in Phase 3 (2050 onwards), products and technologies in both Group 1 and Group 2 will have become more widespread with cost reduction.

Figure Roadmap for Carbon Recycling Technologies



(2) Progress of Carbon Recycling 3C Initiative

(i) Progress in the development and commercialization of Carbon Recycling technologies

First of all, this section provides an overview of the progress of the Carbon Recycling technologies covered by the Carbon Recycling 3C Initiative. In Phase 1, research and technological development are well underway by a wide range of business enterprises including existing major companies and startups, primarily in the three main fields of chemicals, fuels, and minerals. As for Group 1, some early examples of commercialization are beginning to emerge.

There are high expectations for the realization of CO2-derived chemicals as a Carbon Recycling technology due to their ability to replace existing fossil fuel-derived chemicals and contribute to CO2 reduction and fixation, their potential for use in the manufacture of high value-added products and possibilities for efficiency improvement and cost reduction with the introduction of new technology. At the same time, however, many of the technologies are still at the basic research level, and this is an area that should be

prioritized in future for technological development. For this reason, the synthesis of CO2-derived chemicals is founded on the technology to produce synthetic CO and H2 gases, the basic substances or methanol, etc., from CO2 and H2O, technology to manufacture commodities such as olefin and BTX (benzene, toluene, and xylene) from these basic substances, and technology to produce biomass-derived chemicals. Highly efficient manufacturing technologies will be developed and the overall system will be optimized in reference to these technologies.

Specifically, the New Energy and Industrial Technology Development Organization (NEDO) has launched technological development projects with the University of Toyama and Nippon Steel Corporation for paraxylene synthesis, with Mitsubishi Chemical Corporation, The University of Tokyo and others for artificial photosynthesis (development of a process technology for manufacturing basic chemicals from carbon dioxide raw materials) and with multiple corporations including Kao Corporation, Taiyo Vinyl Corporation, and Nippon Paper Group for cellulose nanofibers (CNF) technology.

Also, precedent cases of commercialization have begun to emerge for Group 1 technologies and products. For example, Asahi Kasei Corporation has developed and commercialized a non-phosgene polycarbonate production process that uses CO2 as a raw material. The polycarbonate production capacity of this technology's licensees reached 790,000 tons in 2019, expanding to 17% of global production capacity. In addition, the company has conducted a mass-production demonstration of a newly developed process for diphenyl carbonate production that uses polycarbonate as a raw material and launched the development of a technology to manufacture urethane materials (isocyanates) from urea, which is produced from CO2.

(Reference) Major technological development projects that utilize Carbon Recycling budget Ⅰ (FY2020)

Chemicals	Commodity/Product	Development stage
University of Toyama, Nippon Steel Corporation, Nippon Steel Engineering, HighChem, Chiyoda Corporation, Mitsubishi Corporation	Paraxylene	Basic (NEDO)
Mitsubishi Chemical Corporation, The University of Tokyo, etc. (artificial photosynthesis project)	Methanol/olefin	Basic (NEDO)
AIST, Kobe University, Kazusa DNA Research Institute, Ajinomoto (Smart Cell project)	Bioplastic Pharmaceutical ingredients	Basic –Demonstration (NEDO)
Kao Corporation, Taiyo Vinyl Corporation, Nippon Paper Industries, Ube Industries, Tosoh Corporation, Daio Paper Corporation, Sugino Machine Limited, AIST, Panasonic, Sumitomo Rubber Industries, University of Fukui, etc.	Cellulose nanofiber	Basic –Demonstration (NEDO)
AIST, NITE, Environmental Health and Science Institute of Shizuoka, The University of Tokyo, Ehime University, Shimadzu Techno-Research, Nisshinbo Holdings	Marine biodegradable plastic	Basic –Demonstration (NEDO)

Minerals	Commodity/Product	Development stage
Idemitsu Kosan, Ube Industries, Ltd., JGC Corporation, Seikei University, Tohoku University	Cement materials	Basic -Demonstration (NEDO)
Takenaka Corporation	Soil improvement material	Basic -Demonstration (NEDO)
Tokuyama Corporation, Sojitz Corporation, NanoMist Technologies Co., Ltd.	Sodium carbonate, baking soda	Basic -Demonstration (NEDO)
The Chugoku Electric Power CO.,INC., Hiroshima University, Chugoku Koatsu Concrete Industries	Greening infrastructure material, etc.	Basic -Demonstration (NEDO)
Waseda University, Sasakura Engineering, JGC Corporation	Cement materials, etc.	Basic -Demonstration (NEDO)
Taiheiyo Cement	Cement materials	Basic -Demonstration (NEDO)

Fuels	Commodity/Product	Development stage
IHI Corporation, Mitsubishi Power, Euglena, bits, Chitose, J-POWER	Jet fuel (microalgae)	Basic -Demonstration (NEDO)
INPEX CORPORATION, Hitachi Zosen Corporation	Methane	Basic -Demonstration (NEDO)
JPEC	Survey of e-fuel production technology	Basic (NEDO)

Development of Osaki Base	Commodity/Product	Development stage
Osaki CoolGen Corporation, JCOAL	Base development, research support	–
The Chugoku Electric Power CO.,INC., Kajima Corporation, Mitsubishi Corporation	Improved type carbon absorption concrete	Basic (NEDO)
Kawasaki Heavy Industries, Osaka University	Paraxylene	Basic (NEDO)
The Chugoku Electric Power CO.,INC., Hiroshima University	Diesel fuel, etc. (fungi)	Basic (NEDO)
Institute of Microalgal Technology(IMAT)	Jet fuel (microalgae)	Basic (NEDO)

There are great expectations on realizing the Carbon Recycling technology for CO2-derived liquid fuels, given the possibility of utilizing the existing oil supply chain and promoting a transition to low-carbon liquid fuels. On the other hand, further technological development is required to resolve the issues that exist at present in terms of production efficiency and cost and promote their widespread use. For this purpose, efforts are under way to improve the production process of liquid fuels, such as FT synthesis, and to optimize syngas manufacturing processes using microorganisms such as bioethanol.

Specifically, IHI and others have continued the development of bio-jet fuel production technology using microalgae while efforts to build the bases for the improvement and standardization of microalgae technology have begun. As for e-fuel (liquid synthetic fuel), the Japan Petroleum Energy Center (JPEC) is conducting a preliminary survey for the development of low-cost production technology. The results of this survey will be used to promote technological development in 2020.

Regarding the development of methanation technology to produce methane from CO2, INPEX CORPORATION (INPEX) and Hitachi Zosen Corporation are planning to conduct a demonstration test on a scale 50 times larger than at present.

In the mineral field, there are high expectations for the realization of Carbon Recycling technologies, thanks to the high potential of CO2 fixation in the use of CO2 in carbonates,

concrete products and structures, the stability of the products, and the potential for their application to soil improvement. For all these reasons, this is a field where early social implementation is desired. The key technologies include energy-saving pretreatment such as pulverization and separation of active components (Ca and Mg compounds) from industrial by-products including waste concrete and coal ash, waste minerals, and brine, energy-saving pretreatment in the wet processes, and development of elemental technologies to develop aggregates and admixtures. In addition, measures will be taken to enhance the business feasibility of the cement manufacturing process through the development of an integrated system from CO2 emission sources to production and supply, process optimization, expansion of applications, and cost reduction. The technological development engages leading businesses and universities including Idemitsu Kosan, Ube Industries, JGC Holdings, Takenaka Corporation, Tokuyama Corporation, The Chugoku Electric Power Co., Inc., Kajima Corporation, Taiheiyo Cement Corporation, Seikei University, Tohoku University, Hiroshima University and Waseda University.

In the field of minerals, the precedent cases of Group 1 technologies and products are beginning to emerge as well. One example is the CO2-absorbing concrete (CO2-SUICOM) developed mainly by The Chugoku Electric Power Company and Kajima Corporation. CO2-SUICOM is already shipped as a product, and development and demonstration will be carried out to further reduce costs and expand applications.

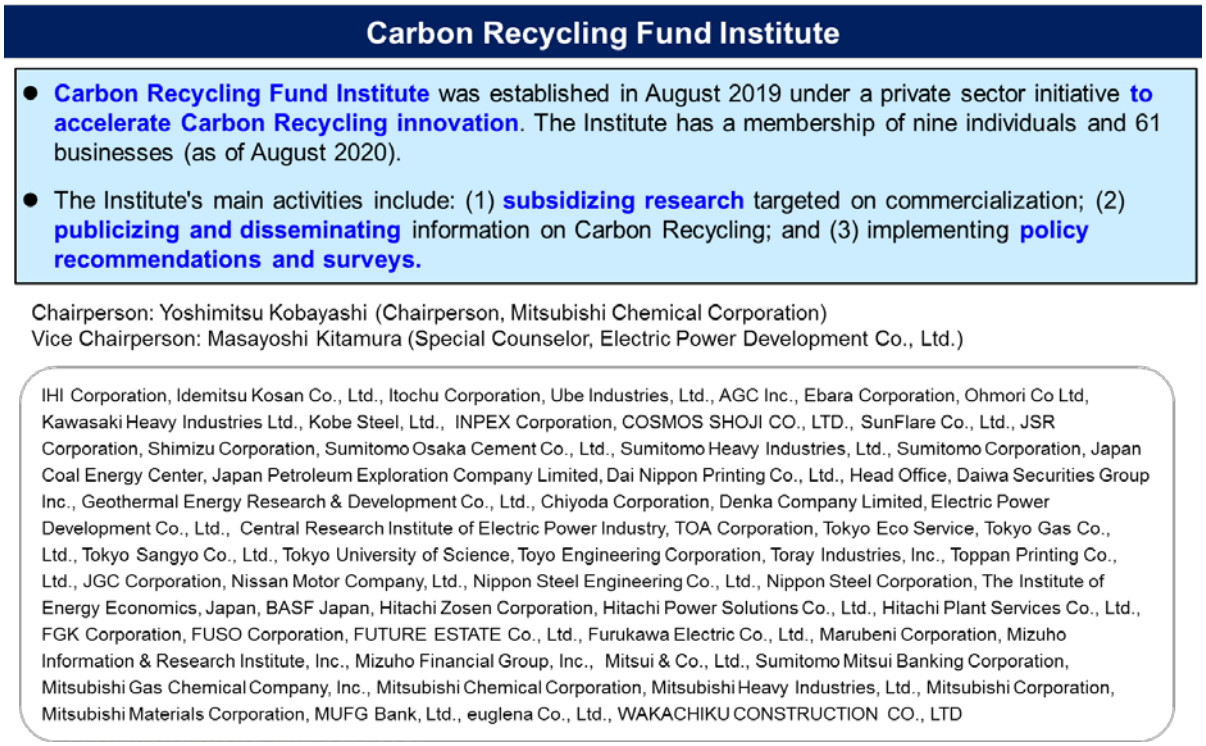
(Reference) Major technological development projects that utilize Carbon Recycling budget Ⅱ (FY2020)

Basic and pilot research	Commodity/Product	Development stage
JCOAL, Keio University, Tokyo University of Science	Utilization of diamond electrodes Production of basic materials with CO2 electro-reduction	Basic (NEDO)
Central Research institute of Electric Power Industry, Tokyo Institute of Technology	Development of CO2 electrolysis reversible solid oxide cell	Basic (NEDO)
AIST, Doshisha University	CO2 reduction and decomposition using high temperature soluble salt electrolysis	Basic (NEDO)
Toshiba Energy Systems & Solutions, Kyushu University	CO2/H2O co-electrolysis	Basic (NEDO)
Tokai National Higher Education and Research System, Sawafuji Electric, Kawada Industries	CO2 reduction and decomposition by electric discharge plasma	Basic (NEDO)
Central Research institute of Electric Power Industry, Keio University	Urea electrolysis synthesis using low temperature ionic liquid	Basic (NEDO)
Sumitomo Osaka Cement, Yamaguchi University, Kyushu University	Calcium extraction from calcium-containing waste, CO2 mineralization	Basic (NEDO)
MHPS, Central Research institute of Electric Power Industry, Toyo Construction, JCOAL	CO2 fixation and utilization by coal ash and biomass ash	Basic (NEDO)
Kobelco Eco-Solutions, Okayama University, RIKEN	Synthesis of carboxylic acids using metal sodium dispersions	Basic (NEDO)
Mitsubishi Gas Chemical, Nippon Steel, Nippon Steel Engineering, Tohoku University	Intermediate for the production of polycarbonate using CO2	Basic (NEDO)

CO2 capture	Commodity/Product	Development stage
Osaki CoolGen Corporation	Physical absorption	Demonstration (NEDO)
Kawasaki Heavy Industries, RITE	Chemical absorption (solid)	Demonstration (NEDO)
Sumitomo Chemical, RITE	Membrane separation (organic membrane)	Demonstration (NEDO)
Nippon Steel, Nippon Steel Engineering, Kobe Steel, JFE Steel	Chemical absorption CO2 capture from blast furnace	Demonstration (NEDO)

Others	Commodity/Product	Development stage
Japan CCS, Mitsubishi Power, Ltd., Mitsubishi Chemical Engineering, Mitsubishi Gas Chemical	CCS demonstration／methanol	Demonstration／Survey (NEDO)
Japan CCS	Survey of CO2 storage potential	Survey
Applications currently accepted	Identification and survey of projects that utilize low-carbon technologies including JCM	Survey
JGC, JXTG, TCV	CO2 separation technology for expanding crude oil production with CO2 injection	Demonstration
Applications currently accepted	Carbon neural technology	Basic
Applications currently accepted	International joint research	Basic

Furthermore, the Carbon Recycling Fund Institute (CRF) was established in August 2019 under a private sector initiative to accelerate Carbon Recycling innovation (Chairperson: Yoshimitsu Kobayashi, Chairperson of Mitsubishi Chemical Holdings). Reflecting the diverse potential of Carbon Recycling, CRF has a membership of nine individuals and 61 businesses (as of August 2020) including financial institutions, trading companies, and universities, in addition to manufacturers in chemicals, steel, construction materials, fuel, engineering, and other fields. CRF's main activities include: (1) subsidizing research targeted on commercialization; (2) publicizing and disseminating information on Carbon Recycling; and (3) implementing policy recommendations and surveys.



In FY2020, the first round of research grants was adopted for 12 research projects, mainly from universities and other organizations (development of new catalysts, synthesis of oxygen-containing chemicals, research for the realization of Carbon Recycling complexes, etc.). These projects are expected to translate into early commercialization or be deployed in international joint research.

(Reference) Projects adopted by Carbon Recycling Fund Institute(FY2020)

Adoption	Field of application	Name of research theme	Name of senior researcher (affiliated organization)
Adoption	Recycling (chemicals)	Adaptation of new low-temperature methanol synthesis catalyst to IGCC+CCS	Yoshiharu Yoneyama (University of Toyama)
		Synthesis of oxygen-containing chemicals from biomass and CO_2	Jun-Chul CHOI（National Institute of Advanced Industrial Science and Technology)
		Discovering Inexpensive, Effective Novel Catalysts for Electrochemical CO_2 Conversion: Towards Value-Added Chemical Production	Song Juntae（Kyushu University）
		High-efficiency CO_2 conversion using biomass, lignite and metallic media	Ryuichi Ashida (Kyoto University)
	Recycling (fuels)	Development of a new membrane reactor for low temperature CO_2 hydrogenation reaction	Takeshi Furusawa (Utsunomiya University)
	Recycling (utilization of organisms)	Parachlorella breeding for simultaneous production of biofuels and high value-added products	Shigeaki Harayama (Chuo University)
		Bioelectrochemistry technology for converting carbon dioxide into organic acid	Arata Katayama (Nagoya University, Tokai National Higher Education and Research System)
		Development of basic technology for growing early-growth trees by heavy ion beam irradiation	Tomoko Abe (RIKEN)
	Social science (CR introduction and promotion scenario)	Scenario analysis of carbon recycling technology Innovation for Zero Net Emissions	Etsushi Kato (The Institute of Applied Energy)
Conditional adoption	CO_2 capture, etc. (CO_2 absorption material)	Development of CO_2 adsorbent from inferior carbon sources	Yuki Mochizuki (Hokkaido University)
	Social science (CR introduction and promotion scenario)	Research for the realization of the Setouchi Carbon Recycling Complex	Takayuki Ichikawa (Hiroshima University)
	Social science (others)	Survey and evaluation of GHG emissions accompanying hydrogen supply	Atsushi Inaba (Japan Life Cycle Assessment Facilitation Centre)

(ii) Progress of Carbon Recycling 3C Initiative

1) <u>Caravan (Promotion of mutual exchanges)</u>

The “G20 Ministerial Meeting on Energy Transitions and Global Environment for Sustainable Growth” was held in June 2019 in Karuizawa, which provided a forum for mutual exchanges under a multilateral framework. At this meeting, Japan, as the chair country, advocated the concept of Carbon Recycling. Participants at the meeting agreed on the importance of innovation as a driving force for energy transition and shared understanding on the importance of promoting innovation in diverse fields such as hydrogen, CCUS, and especially Carbon Recycling proposed by Japan. In the back-to-back bilateral talks with other countries, Japan actively referred to the possibility of Carbon Recycling, which obtained approval from the participating countries.

Global cooperation continued to expand following the spread of the circle of Carbon Recycling at the G20. In September 2019, the “International Conference on Carbon Recycling” the world's first conference dedicated to Carbon Recycling, was held in Tokyo. Bringing together the wisdom of those involved in Carbon Recycling from industry, academia and government, the conference that was attended by 20 countries and

numerous organizations discussed the importance of innovation and international cooperation in Carbon Recycling to achieve a virtuous cycle of environmental protection and economic growth in view of the urgent need to address global warming. In particular, as mentioned above, Isshu Sugawara, former Minister of Economy, Trade and Industry, announced the "Carbon Recycling 3C Initiative," which consists of “Promotion of mutual exchange (Caravan)", "Establishment of R&D and demonstration base (Center of Research)" and "Promotion of international joint research (Collaboration)". Especially with regard to Collaboration, the international conference provided an opportunity for the first collaboration project between former Minister Sugawara and Hon Matt Canavan, former Minister of the Ministry of Resources and Northern Australia, who signed a memorandum of understanding on cooperation on holding regular consultations, sharing research and development, and cooperation in international forums, among others.

In December 2019, a CCUS side event was held to coincide with the IEA Ministerial Council, which was co-chaired by Yohei Matsumoto, former State Minister of Economy, Trade and Industry and Theodore J. Garrish, Assistant Secretary for the Office of International Affairs at the Energy Department of U.S. Active discussions on Carbon Recycling took place with the attendance of IEA member countries headed by Dr. Fatih Birol, the Executive Director of the IEA, and related companies. The discussions reaffirmed the importance of innovation and creating solutions with the cooperation of different countries.

In January 2020, the World Future Energy Summit held in the UAE provided an opportunity for Japan to bring together and globally exhibit its Carbon Recycling technologies. The process of capturing CO2 and transforming it into minerals, fuels, chemicals and other products with value drew the attention of many participants and was well received. These efforts are expected to provide a foundation for new collaborations in the future.

In March 2020, the Ministry of Foreign Affairs of Japan organized a CCUS/Carbon Recycling Study Tour for Diplomatic Corps in Tokyo, which was attended by some 30 participants from embassies in five countries, university faculty members and students, and business representatives. The participants toured sites and studied the latest research on Carbon Recycling in Japan and engaged in lively discussions.

Against this backdrop, Japan reaffirmed the importance of Carbon Recycling through bilateral talks with the United States, Australia, Saudi Arabia, Canada, Poland and other countries.

2) Center of Research (Establishment of R&D and demonstration base)

In August 2020, the Ministry of Economy, Trade and Industry (METI) and NEDO began the process of establishment R&D and demonstration bases. Specifically, works to develop the facility in Osakikamijima, Hiroshima Prefecture, which had already been engaged in CO2 capture, into a R&D and demonstration base started. The facility will conduct R&D on a wide range of areas including biofuels, chemicals and carbonates so that it may be showcased to the nation and the rest of the world. The project is scheduled to last five years, from FY2020 to FY2024, and the total cost of the project, including the development of the base and technology, is expected to be around 8.5 billion yen.

First, from FY2020 to FY2021, Osaki CoolGen Corporation and Japan Coal Energy Center (JCOAL) will play a central role in developing the infrastructure of the R&D and demonstration base. The process will involve the construction of pipelines to transport the CO2 captured by Osaki CoolGen to the demonstration base, installation of utilities, and land levelling. Three areas are planned for the demonstration base: “Basic Research Area,” “Demonstration Research Area,” and “Algae Research Area.”

In the “Basic Research Area” and “Demonstration Research Area,” a wide range of research and development will be carried out including the development of technologies for carbonate and chemicals manufacturing using CO2 and the application of bioprocesses.

In the chemicals field, Kawasaki Heavy Industries and Osaka University will play a central role in constructing a manufacturing process for paraxylene, a chemical product whose demand is expected to increase in the future. The aim is to develop a technology with a lower CO2 emission load compared with petrochemical-derived paraxylene by developing a catalyst that synthesizes methanol from CO2 and then selectively synthesizes paraxylene from methanol to increase the yield.

In the mineral field, research and development will be carried out on concrete that effectively uses CO2, which can be applied to on-site casting and reinforcement bars that command a large market. Since the existing CO2-absorbing concrete (CO2-SUICOM) has limited applications due to its technical constraints, the aim is to use technological

development, such as the optimization of carbonization, to promote the expansion of applications and cost reduction.

In addition, a system for CO2 fixation technology using microorganisms will be established. Specifically, this involves the development of a two-step fermentation technology consisting of a process to produce acetic acid by fixating CO2 using microorganisms and a process to synthesize high value-added lipids and chemical materials from acetic acid.

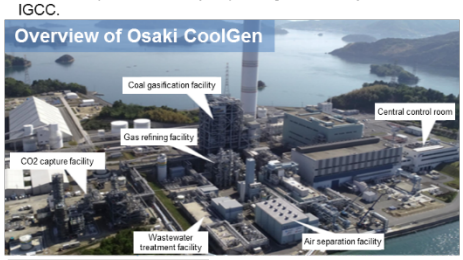
The “Algae Research Area” will involve the establishment of a research base for microalgae, which includes a technology to produce bio-jet fuel by culturing CO2-absorbing microalgae on a large scale and extracting oil from the algae. This is a fundamental project undertaken by the Institute of Microalgal Technology (IMAT), which is comprised of companies working on microalgae. In order to steadily translate the results of this basic technology into products and markets, efforts will be made to develop test beds for scale expansion, establish standards and specifications, and take other steps that lead to industrialization.

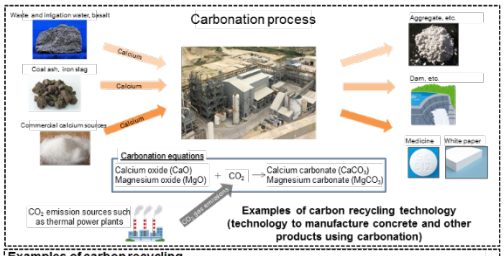
A total of 43.7 billion yen has been committed to Carbon Recycling-related technological development including the above projects. The R&D and demonstration base at Osakikamijima is expected to serve as a node for all these projects and play a role in accelerating innovation in the Carbon Recycling field and disseminating the achievements through mutual exchange and matching among domestic and international research institutions (such as the Global Zero Emission Research Center (GZR) of the National Institute of Advanced Industrial Science and Technology (AIST)) and businesses.

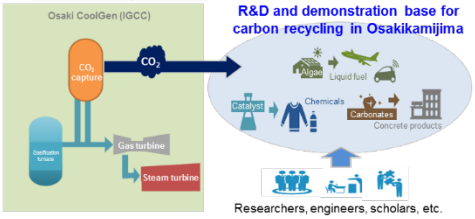
"R&D and Demonstration Base for Carbon Recycling" in Osakikamijima, Hiroshima

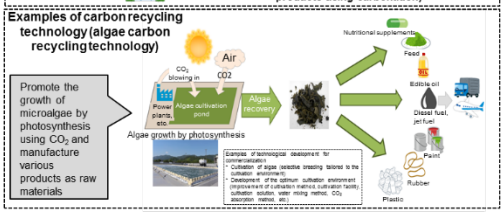
- The demonstration of Integrated Gasification Combined Cycle (IGCC) and Integrated Gasification Fuel Cell (IGFC)* is underway in Osakikamijima, Hiroshima. In December 2019, **a demonstration to capture CO2 form IGCC was started**.
- The Plan to **establish R&D and demonstration base to develop Carbon Recycling technologies by utilizing CO_2** captured in the demonstration are underway.
  - ✓ Concrete and other products are manufactured by using CO2 carbonation
  - ✓ Chemicals and fuels are manufactured from CO_2 using microalgae and catalysts

(※) IGCC is a technology that burns gasified coal to generate electricity. Higher efficiency can be achieved by combining gas turbine and steam turbine power generation.
IGFC is a triple combined cycle power generation system that combines IGCC with fuel cells, enabling power generation at a higher efficiency than IGCC.







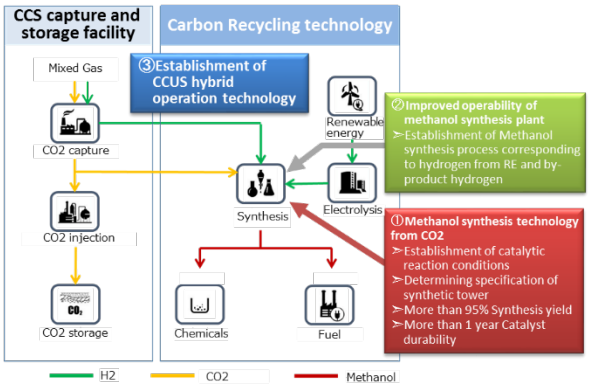


In addition, METI and NEDO have promoted a large-scale demonstration project to store captured CO2 underground in Tomakomai City, Hokkaido, which led to the injection of 300,000 tons of CO2, the target figure. Currently, the monitoring of the CCS site is being continued and studies on the effective use of the captured CO2 (including the synthesis of basic substances such as methanol) are underway.

Tomakomai CCS/Carbon Recycling Demonstration Project

- **Japan's first large-scale CCS demonstration project** aiming to **establish practical CCS technology**.
- Reached the goal of **300,000 tons of CO2 injection in total** from April 2016 to November 2019.
- Conducting **a feasibility study of methanol synthesis carbon dioxide demonstration** to promote the development of Carbon Recycling by effectively utilizing the Tomakomai CCS facility.
- Conducting reorganized "Tomakomai CCS Promotion Council" chaired by the Mayor of Tomakomai into **the "Tomakomai CCUS / Carbon Recycling Promotion Council"** in September 2020.

Tomakomai CCS/Carbon Recycling Demonstration Project



3) Collaboration (Promotion of international joint research)

Japan is expanding international joint research on Carbon Recycling against the backdrop of mutual exchange based on the Caravan.

For instance, as mentioned above, Japan signed a Memorandum of Understanding on cooperation with Australia on the occasion of the First International Conference on Carbon Recycling. The scope of cooperation includes the establishment of regular consultations, sharing of research results, discussions aimed at revising the Technology Roadmap, and examination of the possibility of joint projects between Japan and Australia. In June 2020, INPEX and Commonwealth Scientific and Industrial Research Organization (CSIRO), a governmental research institution in Australia, signed an agreement on methanation prior to feasibility studies. INPEX is currently conducting a demonstration on a scale of 8Nm^3-CO2/h in Nagaoka, Niigata Prefecture, and will continue to research and study the use of CO2 emitted from gas fields while working on their scale expansion.

In September 2020, as part of the efforts to develop an environment for further deepening these discussions, a workshop designed to share the fruits of the research was held online to strengthen collaboration with the participation of the industry, academia and government in the two countries (METI, NEDO and theResearch Institute of Innovative Technology for the Earth (RITE) from the Japanese side and the Department of Industry, Science, Energy and Resources (DISER) and CSIRO from the Australian side). Discussions at the workshop will be used to further deepen joint research in the future.

Japan has shared energy strategies including the use of fossil fuels with the U.S. to promote concrete collaboration. In June 2019, an MOU on Carbon Recycling cooperation was signed between JCOAL, State of Wyoming and Columbia University. By building on these examples, collaboration on international joint research is expanding and deepening with different countries including those participating in the International Conference on Carbon Recycling.

3. Future development of Carbon Recycling

Trends to adopt Carbon Recycling are rapidly gaining momentum as one of the realistic solutions to achieve the goals of the Paris Agreement. A feature of Carbon Recycling that it utilizes the existing infrastructure has helped invigorate the efforts involving various industries, businesses, and fields. To further expand this momentum, Japan will strategically work on the development and commercialization of Carbon Recycling technologies while deepening international collaboration based on the "Carbon Recycling 3C Initiative."

In the field of “Caravan”, METI and NEDO will hold the Second International Conference on Carbon Recycling on October 13, 2020 on the web as part of Tokyo “Beyond-Zero” Week as an opportunity for multilateral exchanges. The conference will provide an opportunity for front-line officials in industry, academia and government from around the world to share awareness and information and accelerate the efforts toward the development and commercialization of Carbon Recycling technologies.

Based on its first theme, "Pursuit of Zero Emissions by Carbon Recycling," the conference will bring together the wisdom from all over the world to address issues related to policy, technology, and marketization, and transmit information. Building on the first theme, the second theme, "The Possibility of Carbon Recycling as a Realistic Solution for Global Warming," will be used to deepen discussions on the operationalization of Carbon Recycling in the key areas. In addition to discussions at the conference, information on the relevant industry-academic-government activities will be disseminated to the world on the website and other means. At the same time, the conference will be used to expand bilateral cooperation, conclude MOCs and hold workshops and other events based on these agreements, and promote information sharing and exchanges.

Regarding “Center of Research”, the R&D and demonstration bases at Osakikamijima in Hiroshima and Tomakomai in Hokkaido will be developed ahead of others, while the overall status and results of the development of Carbon Recycling technologies both domestically and internationally will be widely disseminated. In the process of development and commercialization, collaboration with local governments will be strengthened to pursue synergy with regional development. In addition, collaboration with domestic and international technology development centers related to Carbon Recycling (Tokyo Zero-emission Innovation Bay, Fukushima Hydrogen Energy Research Field (FH2R) in Namie, etc.) will be promoted.

As for “Collaboration”, international joint research related to Carbon Recycling will be expanded and promoted on the back of mutual exchanges through the Caravan and development of bases for the Center of Research. Japan signed a new MOC with the U.S. on the occasion of the second international conference, in addition to Australia, with which an MOC was concluded last year, to expand opportunities for joint research in industry, academia and government.

As mentioned earlier, Carbon Recycling is an innovative field that creates new value by combining various elemental technologies. By taking advantage of this characteristic, Japan will seek to accelerate the development and commercialization of Carbon Recycling through international collaboration between industry, academia, and government based on the “Carbon Recycling 3C Initiative”. Through these efforts, we will contribute to the realization of a virtuous cycle between environmental protection and economic growth through disruptive innovation, while ensuring a stable and affordable supply of energy.