Japan’s Action toward Public Implementation of Carbon Recycling 【Progress over the Past Year】

October 4, 2021

Ministry of Economy, Trade and Industry

Progress over the Past Year【Overview of Japan's Action】

◆ 2050 Carbon Neutral Declaration

- In October 2020, the Japanese government declared its plan to achieve the goal of "2050 Carbon Neutral". In December of the same year, the "Carbon Recycling Implementation Plan" was established, which **positioned carbon recycling as a key technology to realize carbon neutrality**. The plan clarifies **the path of technological development and demonstration for public implementation**.

Action 1. Establishment of Carbon Recycling Industry Implementation Plan; Show the path of industrialization

- In June of this year, the **"Carbon Recycling Industry Implementation Plan" was revised**, and new carbon recycling technology aimed at public implementation was added in the fields of concrete/cement, fuel and chemicals. Cost targets and schedules were specified in the revised plan.

Action 2. Revision of Carbon Recycling Technology Roadmap; Communication of technological trends

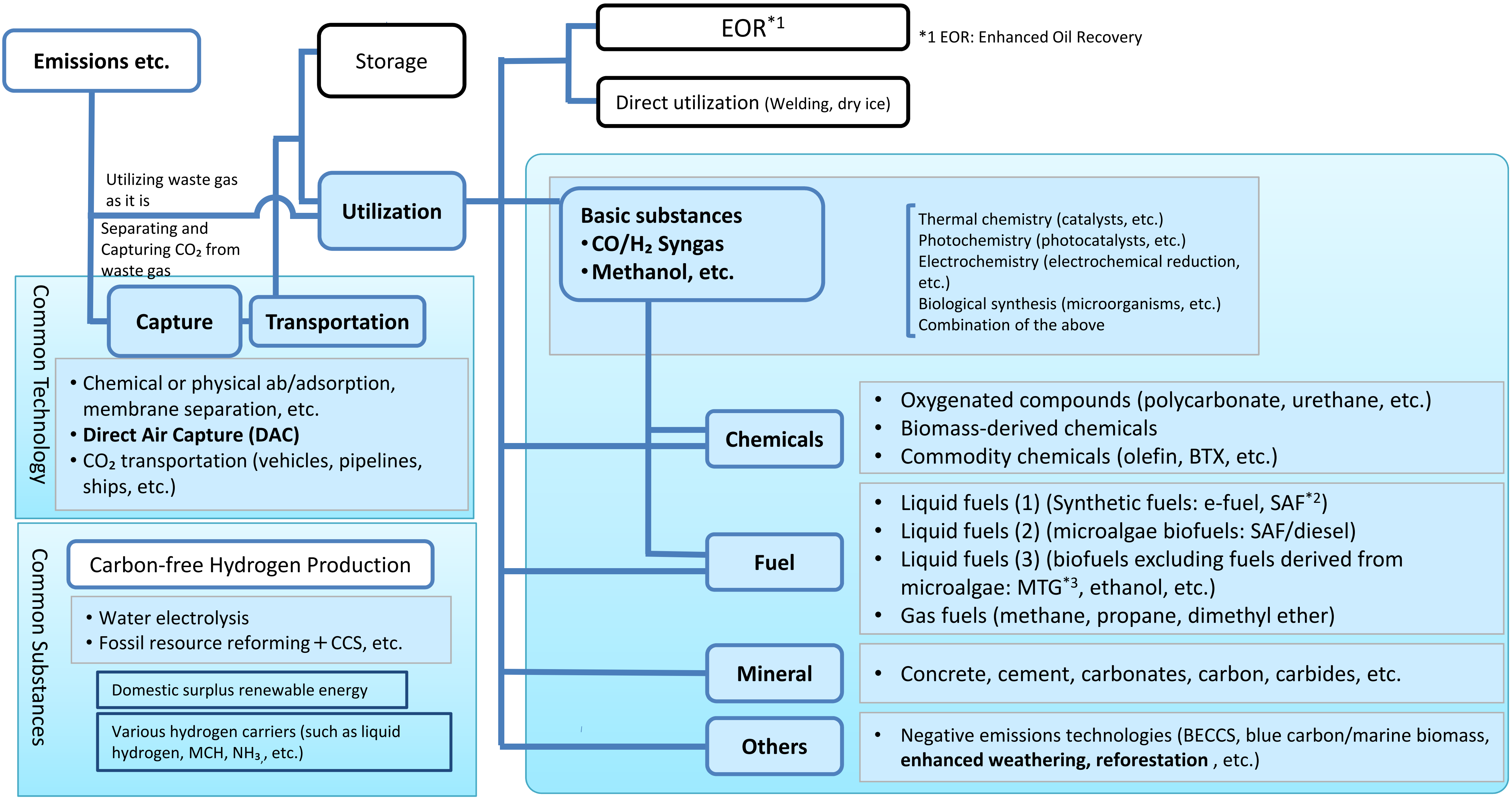
- In July of this year, the **"Carbon Recycling Technology Roadmap" was revised for the first time in two years**, and DAC and synthetic fuel were added as new technical fields. In addition, a detailed schedule for public implementation was stipulated, which stated that as international cooperation was strengthened, the period of dissemination of carbon recycled products (general-purpose products) will be advanced to 2040.

Action 3. Acceleration of public implementation through the Green Innovation Fund

- This year, technological development and demonstration for public implementation will **accelerate through the utilization of the "Green Innovation Fund"** totaling 2 trillion yen. It will start the process for open recruitment and adoption in the fields of concrete/cement, fuel, chemicals and CO2 separation and capturing.

CCUS/Carbon Recycling

- **Carbon Recycling**: Under the concept of Carbon Recycling technology, we consider carbon dioxide as a source of carbon, and promote separating, capturing, and recycling of this raw material. Carbon dioxide (CO_2) will be recycled into concrete through mineralization, into chemicals through artificial photosynthesis, and into fuels through methanation, in order to reduce CO_2 emissions into the atmosphere.



*2 SAF: Sustainable aviation fuel

*3 MTG: Methanol to Gasoline

Action1. Revision of Carbon Recycling Industry Implementation Plan

◆ Carbon recycling is a technology that effectively utilizes CO2 as a resource and is important for the realization of a carbon-neutral society. In order to **aim for global expansion**, **technological development and public implementation** aimed at **cost reduction** and application development will be promoted through **international conferences on Carbon Recycling**.

	Current status and tasks	Future actions
Concrete・Cement	**Concrete made by absorbing CO2 has been put into practical use, but the market is limited** ・The current cost of CO_2-SUICOM is high. (＝About 3 times the cost of existing concrete = 100 yen/kg) ・Amount of CO_2 absorption is limited, high oxidation/rusting of steel frame in the concrete (it is easily oxidized due to CO2 absorption), limited use	**Expand sales channels and reduce costs by utilizing public procurement** ・As a cost target, aim for the same price (= 30 yen/kg) as existing concrete by expanding demand by 2030. In 2050, new products with rust prevention performance will be available for construction purposes. ・The market size is expected to be about 15-40 trillion yen worldwide as of 2030. ① Expansion of sales channels through public procurement ・Register CO2 absorption type concrete in the Ministry of Land, Infrastructure, Transport and Tourism database (NETIS) on new technology. Expand **public procurement** by national and local governments. Consider introduction at the 2025 Japan International Exposition. Furthermore, through **international standardization**, sales channels to Asia will be expanded. ② Further expansion of sales channels ・Develop a new product with rust prevention performance. Expand applications to buildings and concrete blocks. Consider expanding demand in the private sector by **supporting the introduction of standardization.** ・Develop new technologies and products that combine increased CO2 absorption and cost reduction. Share acquisition and expansion by utilization of license business form through intellectual property strategy.
	CO2 is generated when limestone is burned, but a sufficient amount of CO2 capturing technology has not been established ・Thousands of tons of CO2 are generated per day from the kiln, which is large-scale with current technology (chemical absorption method). ・Carbon dioxide technology also consumes less CO2 and has a limited calcium source.	**Establishing a new manufacturing process and expanding the use of carbonates** ・Aim to **establish a technology which captures nearly 100%** of CO2 emitted from limestone by 2030. Establish carbonate and carbon recycled cement technology using waste, etc. to expand the use of carbonate. ・Aim to **introduce it to domestic factories**, technical cooperation with plants in Southeast Asia, and **expand the spread of carbon recycled cement** by 2050.

		Current status and tasks	Future actions
Carbon recycled fuel	ALTERNATIVE AVIATION FUEL (SAF) (※1)	**Large-scale demonstration to overcome the issues of stable supply and high costs** ・Elemental technology development is progressing and demonstrations have begun. It is necessary to establish technologies that enables algae to grow stably, while improving the absorption efficiency of CO_2 in the cultivation of microalgae, gasification FT(※2) synthesis to make the quality of various raw materials uniform, and ATJ(※3) to control catalytic reaction. (※1) SAF (Sustainable Aviation Fuel) (※2) Technology for producing SAF by steaming (gasifying) organic matter such as wood chips and liquefying it with a catalyst (Fischer-Tropsch process)。 (※3) Abbreviation for Alcohol to jet. Technology for reforming bioethanol into SAF using catalysts, etc.	**Cost reduction and supply expansion through large-scale demonstration** ・As a cost target, aim for the same price as existing jet fuel (= 100 yen level/L) in 2030. ・As for the market size, as of 2030, total demand at domestic airports is expected to be approximately 250 billion yen to 560 billion yen. ・Regarding international aviation, ICAO (International Civil Aviation Organization) introduced a policy in 2021 that "**prevent[s] an increase in CO_2 emissions compared to 2019**". The international market for SAF is expanding. ①Implement large-scale demonstrations and reduce costs to the same level as existing jet fuel. It will be put into practical use around 2030 ahead of other countries. ②According to the trends in the international SAF market, SAF which is competitive to alternative fuels will expand in Japan and overseas (**international certification acquired**).
	SYNTHETIC FUEL (※4)	**Establish manufacturing technology and cost reduction for commercialization** ・Decarbonized fuel produced by synthesizing CO_2 and hydrogen ・Features: it has high energy density and portability, since it's liquid fuel like fossil fuel. ・Integrated manufacturing process for commercialization has not been established (※4) liquid fuel made by synthesizing CO_2 and hydrogen recovered from power plants and factories.	**Support technological development for large-scale synthetic fuel production** ・Increase efficiency of existing technology (reverse shift reaction+FT synthesis process) and design and develop manufacturing equipment. ・Develop innovative new technologies and processes (co-electrolysis, Direct-FT, etc.). ・Establish high-efficiency and large-scale manufacturing technology by 2030, expand introduction and reduce costs in the 2030s, and aim for commercialization (※5) by 2040. ・Aim to achieve costs below gasoline prices in 2050 (※5) The cost of synthetic fuel in the self-sustaining commercialization phase is assumed to be the cost including its environmental value.
	SYNTHETIC METHANE	**Develop technology for practical use and cost reduction** ・Develop basic technology for Methanation and leading basic technology for more efficient and innovative technologies. ・Develop technology to enlarge the equipment of Methanation and improve efficiency, build a supply chain to procure hydrogen and CO_2, and consider counting the amount of CO_2 reduction that contributes to CN.	**Cost reduction and supply expansion through technological development such as upsizing of methanation equipment and building overseas supply chain** ・In 2030, 1% synthetic methane will be injected into the existing infrastructure, and 5% gas will be CN-ized together with other means. In 2050, 90% synthetic methane will be injected, and the gas will be CN-ized together with other means. ・Develop technology for larger plants and higher efficiency of methanation, build overseas supply chain and proceed with a study of the necessary amount of CO_2 reduction that will contribute to CN. ・25 million tons of synthetic methane will be supplied by 2050, aiming for the same level as the current LNG price (40-50 yen / Nm3).
	GREEN LPG	**Establish technology for commercialization** ・Demand for LP gas is expected to remain constant in 2050 ・Even from a global perspective, technological development aimed mainly at green LP gas synthesis has not been implemented, and it is aimed to establish the technology and implement it in society at an early stage ahead of the rest of the world.	**Demonstration projects for large-scale production** ・Develop basic technologies such as catalysts that can be commercialized ・Develop technology to integrate basic technologies such as catalysts and peripheral basic technologies to be utilized at demonstration plants. Through these actions, commercialize green LPG in 2030.

	Current status and tasks	Future actions
Carbon recycling chemicals **Plastic raw materials by artificial photosynthesis**	**Large-scale demonstrations** ・Basic, lab-scale research has been successful, and the demonstration will be carried out. (*The plastic materials are produced by CO_2 and hydrogen which is separated from water with photocatalysts) ・Since the current efficiency of photocatalysts is low, the manufacturing cost is high. ・Japanese companies have advanced technology. There are few foreign competitors.	**Accelerate the development of photocatalysts with high conversion efficiency for practical use** ・Develop photocatalysts with high conversion efficiency and aim to reduce the manufacturing cost by about 20% by 2030. Implement a large-scale demonstration and as a cost target, aim for the same price (=100 yen/kg) as existing plastic products by 2050. ・ In order to implement large-scale demonstration of artificial photosynthesis and promote its public implementation, we will work to formulate new safety and security standards and take measures against related regulations such as the High Pressure Gas Safety Act to confirm the safety in the process of separating hydrogen and oxygen.
Plastic raw materials made from waste plastic, waste rubber and CO_2	**Need to reduce CO2 emissions significantly** ・Take measures to address CO_2 which is emitted when waste plastic and waste rubber are incinerated. ・Add higher value such as weight reduction to functional chemicals in addition to reducing CO_2 emissions. ・Consider taking measures against the heat source required in naphtha cracking furnaces.	**Establish the technology to convert waste plastic, waste rubber, and CO_2 into plastic raw materials** ・Aim to establish manufacturing technology by 2030 and to achieve the same price as existing products by 2050 for functional chemicals based on CO2 (oxygen-containing compounds such as polycarbonate) and chemicals derived from biomass and waste plastics ・Further functional improvement such as heat resistance, impact resistance, and weight reduction will enable products with higher added value (automobiles, electronic devices, etc.) to be produced at the same cost. ・ In addition, we consider upgrading naphtha cracking furnaces by using carbon-free heat sources. ・The global market size is expected to be roughly several hundred trillion yen and the Japanese market is expected to be ten trillion yen as of 2050.
Utilization of bio-manufacturing technology	**Establish elemental technologies toward commercialization.** ・The challenge with bio-manufacturing using biomass resources is that the cost is higher than that of existing chemicals and the type of products is limited. ・The challenge with bio-manufacturing using atmospheric CO_2 is to establish the elemental technologies such as the development of genetically modified microorganisms and cultivation technologies.	**Establish bio-manufacturing technologies** ・As for bio-manufacturing using biomass resources, by developing industrial microorganisms through genome editing, etc., and by demonstrating production processes, we aim to reduce costs to a level of existing products and to expand the types and functions of chemicals that can be produced on a commercial basis by 2035. ・As for bio-manufacturing using atmospheric CO_2 as a raw material, we will establish basic technology by developing microbial strains suitable for cultivation, etc., and aim for practical use from around 2040.

	Current status and tasks	Future actions
CO_2 separation and capture facilities (Separation and capture of CO_2 in exhaust)	**Reduce the cost of CO_2 separation and capture technology in order to acquire a large share of the market.** • Separation and capture facilities for concentrated CO_2 emited from power plants have been completed for use in EOR and chemical applications. (Japanese companies have the largest share of construction contracts for CO_2 separation and capture plants. Japanese industries and academia have a number of patents.) • A future technological development issue is low-cost capture of CO_2 from various emission sources with different concentrations and characteristics.	**Expand demand by cost reduction** ・The market size will expand to about 6 trillion yen/year in 2030 and to about 10 trillion yen/year in 2050. ・Aim to realize further cost reduction of separation and capture technology and expand applications other than EOR. ・Develop highly efficient CO_2 separation and capture technology to reduce costs. ・Establish a standard evaluation technology for CO_2 separation and capture, and consider the introduction of international standardization in order to accelerate global development. ・Consider a demonstration at the Japan International Exposition in 2025 toward public implementation. ・Aim to reach 30% share of the global CO_2 separation and capture market of 10 trillion yen per year which is equivalent to about 2.5 billion CO_2 tons.

［Reference］ Direct atmospheric capture of CO_2 (Direct Air Capture)

Current status and issues

・It's still in the stage of elemental technology development around the world. In Japan as well, development at the laboratory level started in 2020.

・Energy efficiency is low and the cost of capturing CO_2 from the atmosphere is high.

Future actions

Develop a highly efficient atmospheric CO_2 capturing technology, and aim at practical use through cost reduction by 2050.

Action2. Revision of Carbon Recycling Technology Roadmap

Volume of utilized CO_2

Phase 1

- **Pursue all potential technologies** for carbon recycling initiatives.
- **Priority should be given to technologies requiring no hydrogen and/or producing high-value added products**, which can be expected to be implemented from around 2030 onwards.

Chemicals (polycarbonate, etc.)

Further CO_2 emission cuts

Liquid Fuels (Bio jet fuel, etc.)

Cost must be reduced to around 1/8 -1/16 of current levels.

Concrete Products (Road curb blocks, etc.)

Cost must be reduced to 1/3 – 1/5 of current levels.

Phase 2

- Attempt to **reduce costs** of technologies that are expected to spread from 2030 onwards.
- Priority should be given to technologies that produce **high-demand, general purpose commodities**, among technologies that are expected to spread on the premise of cheap hydrogen supply from 2040 onwards.

Expected to spread from 2030

- **Chemicals**
  Polycarbonate, etc.
- **Liquid Fuels**
  Bio jet fuel, etc.
- **Concrete Products**
  Road curb blocks, cement, etc

*** Technology requiring no hydrogen and/or high-value added products will be commercialized first.**

Phase 3

- **Pursue further cost reduction**

High consumption expected from 2030

- Chemicals: Polycarbonate, etc.
- Liquid Fuels: Bio jet fuels, etc.
- Concrete Products: Road curb blocks, etc.

Expected to start spreading from around 2040

- **Chemicals**
  Commodities (Olefin, BTX, etc.)
- **Liquid Fuels**
  Gas, Liquid (methane, synthetic fuels, etc.)
- **Concrete Products**
  Commodities

*** Expansion into commodity markets with robust demand**

*Target for 2050

Hydrogen — JPY 20/Nm^3 (cost at delivery site) *

CO_2 capture technology — Reducing cost — **Less than ¼ of current cost**

Current — 2030 — From 2040 onwards

Action2. Revision of Carbon Recycling Technology Roadmap

◆ Added **DAC** and **synthetic field** as new technical fields, and specified **detailed schedule** for public implementation

DAC

<Technological challenge: DAC>

- Development of air contactor technology for contact between absorbers/adsorbents/membranes and air
- Development of distributed (small-scale) systems
  Development of large-scale (highly efficient) systems

<Technological challenges: common with other CO_2 separation and capture technology>

- Reduction of equipment/operation costs and energy consumption
  Development of new materials (absorbers, adsorbents and separation membranes) (improve selectivity, capacity and durability)
  Reduction of material production costs
  Optimization of processes (e.g., heat, mass, power, etc.), etc.

<Other challenges>

- Development of technologies to raise capture efficiency and cut energy consumption to improve CO_2 separation and capture
- JPY 30,000-60,000/t-CO_2

* In the absence of large-scale demonstration tests, costs vary significantly depending on the system and technologies as well as on scales

- DAC technology should utilize renewable energy and other non-fossil power sources, considering storage and utilization of captured CO_2.
- Selection of DAC locations (suitable climate for CO_2 capture, proximity to energy sources and CO_2 utilization demands)
- Establishing assessment baseline for energy consumption and cost

<Specific initiatives>

- Moonshot Research & Development Program
  Chemical absorption, physical absorption, solid absorption, physical adsorption, and membrane separation methods

Target for 2030

<Development of CO_2 separation and capture systems>

- Achieve competitive costs for CO_2 separation and capture in the 2030s market
  Example targets
  JPY 10,000/t-CO_2: ICEF (Innovation for Cool Earth Forum) roadmap
  JPY 10,000/t-CO_2: Published as corporate target for 2025 or 2030
- Confirm the effectiveness from the lifecycle assessment (LCA) through pilot projects

Target from 2040 onwards

<DAC system commercialization>

- Achieve capture costs less than JPY 2,000/t-CO_2
- Improve DAC system durability and reliability
- Full-fledged spread of DAC system

Action2. Revision of Carbon Recycling Technology Roadmap

Synthetic fuels（e-fuel、SAF）

<Technological challenges>
- Challenges towards the introduction of synthetic fuels include the reduction of costs and the establishment of production technologies (synthetic fuel production costs with current technologies are estimated at about JPY300-700/L).
- The hydrogen cost accounts for a major part of synthetic fuels production costs. Need to tackle technological development and demonstrations for improving production efficiency without waiting for reduction of hydrogen cost.

<Other challenges>
- Need to establish an international assessment of synthetic fuels as decarbonized fuels and develop a framework for offsetting CO_2 generated during their consumption with CO_2 used for their overseas production.

<Specific initiatives>
- Developing innovative technology to integrally produce synthetic fuels from CO_2 emitted by power and other plants and hydrogen from renewable energy.

Target for 2030

<Establishment of production technology>
- Establish highly efficient, large-scale production technology by 2030
- To this end, intensify technological development and demonstration regarding synthetic fuels by 2030. The following are specific targets:

(1) Development of technology to improve the efficiency of the existing synthetic fuels production technology (reverse conversion reaction + Fischer-Tropsch (FT) synthesis process), and design development and demonstration of equipment to realize large-scale production

(2) Development of innovative production technologies (CO_2 electrolysis, co-electrolysis, direct synthesis (Direct FT)

<Technological goals>
- Achieve a liquid fuels yield of 80% with a pilot-scale (assumed at 500 BPD) plant
- Upgrade electrolysis syngas production technology, improve production performance with next-generation FT catalysts, conduct demonstration operation tests for optimization, scale up pilot plant capacity (semi-plant demonstration), and proceed to the commercialization stage

Target from 2040 onwards

<Synthetic fuels commercialization>
- Increase diffusion of synthetic fuel use and cut their costs in the 2030s for independent commercialization (based on environmental values) by 2040

<Costs>
- Realize synthetic fuels costs below gasoline prices in 2050

Action3. Utilization of Green Innovation Fund

- Implement **technological development, demonstration, and base development** of carbon recycling technology (concrete/cement, fuel, chemical CO2 separation and capturing, etc.) through **NEDO**.
- In addition, **by utilizing the Green Innovation Fund**, **technological development and demonstration** for public implementation toward 2050 carbon neutrality **will accelerate**.

Carbon recycling-related budget （NEDO project）

Budget amount for FY 2021, 47.9 billion yen

Development and demonstration of highly efficient CO2 separation and capturing technology and carbon recycling technology for effective use of CO2.

＜Business Examples＞

- Technological development of concrete that absorbs CO2
- Development of bio-jet fuel made from microalgae mass-produced by intensively injecting CO2
- Development of synthetic fuel (e-fuel) manufacturing technology using CO2
- Technology development of artificial photosynthesis to manufacture chemicals from CO2
- Development of highly efficient CO2 separation and capturing technology etc.

※**DAC (Direct Air Capture)** is carried out by Moonshot Research and Development (NEDO).

Green innovation fund （NEDO project）

Supplementary budget for FY 2020 2 trillion yen

R&D/demonstration and public implementation of 14 fields including carbon recycling will be supported for 10 years.

Energy	Transport/manufacturing	Home/office
1.Offshore wind power, PV, Geothermal (Next generation RE)	5. Mobility, batteries	12 Housing and building, Next generation electricity management
2. Hydrogen, fuel ammonia	6. Semiconductors, ICT	13 Resource circulation
3. Next generation heat energy	7. shipping	14 lifestyle related industries
4. Nuclear power	8. Logistics, People flow and infrastructure	
	9. Foods, agriculture, forestry and fisheries	
	10. Aviation	
	11. Carbon recycling and material	

Action3. Utilization of Green Innovation Fund（Field of concrete・cement）

◆ While making the best use of the results of the NEDO grant projects, etc., **technological development and demonstration will be accelerated** in the related **green innovation fund projects** such as those of concrete and cement, **international cooperation will be strengthened**, and **the results will be disseminated**.

Cases of green innovation fund utilization in the field of concrete and cement

Material development ＜NEDO grant project＞

- Technology for efficiently **extracting and chlorinating magnesium in seawater**
- Technology to efficiently **extract and carbonate calcium in waste concrete**
- Technology to **directly carbonate calcium in waste concrete**

Utilize **elemental technology such as aggregate manufacturing, etc.**

Utilize **rust prevention efficiency**

Add performance ＜NEDO grant project＞

- Add **rust prevention technology** to concrete that absorbs CO2

Green innovation fund project

【R&D items 1】
Develop materials and manufacturing technology for maximizing CO2 emission reduction/absorption of concrete

【R&D items 2】
Develop evaluation and quality control method for maximized CO2 emission reduction/absorption of concrete

【R&D items 3】
Design and develop innovative CO2 capture technology in the cement manufacturing process

【R&D items 4】
Develop carbonated chloride technology using various calcium sources

→ Other green innovation fund projects

Integrate and accelerate the development of elemental technologies (lab level)

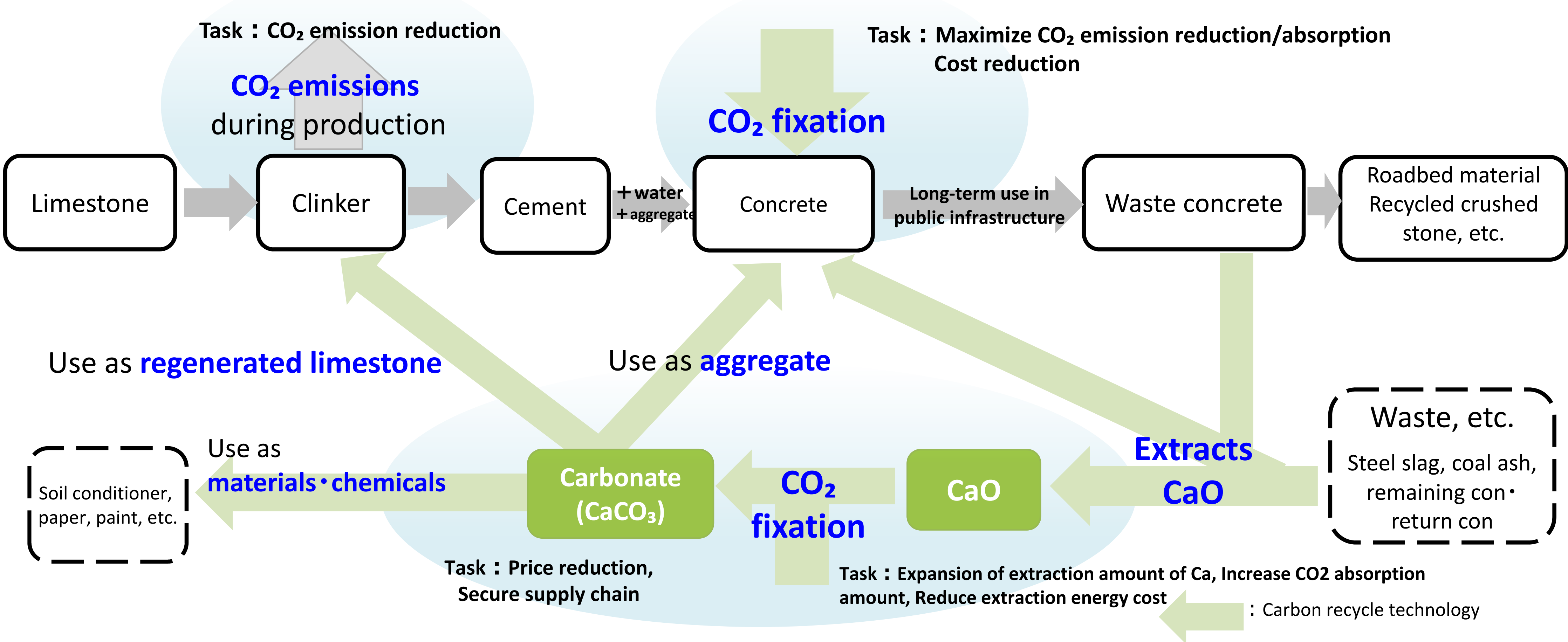
Material development ＜NEDO grant project＞

- Technology to **capture (chemically absorb) CO2** in the cement manufacturing process and **use it as a raw material for cement**
- Technology to extract **calcium in garbage incinerator ash** and **use it as a raw material for cement**

Action3. Utilization of Green Innovation Fund（Field of concrete・cement）

- In the field of concrete and cement, a variety of companies including start-ups have started to work on **R&D and demonstrations,** mainly in **Japan, US and Europe.**
- As for technological field, it covers various technologies that effectively extract and reuse calcium, etc. from wastes containing calcium and **incorporate CO2 into concrete and cement products.**
- **It is necessary to maximize CO2 emission reduction/absorption, reduce costs, and establish a sustainable resource recycling system** by combining various technologies.

Overview of concrete and cement



(1-1) R&D Projects within Carbon Recycling Budget of NEDO（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 HOLDINGS CORPORATION, Seikei University, Tohoku University	Cement materials	Basic -Demonstration (NEDO)
Takenaka Corporation	CO_2 fixed aggregates	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 HOLDINGS 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)

Sector coupling	Commodity/Product	Development stage
Yokogawa Electric Corporation	Carbon recycling cooperation project in Chiba Goi area	F/S (NEDO)
Idemitsu Kosan Co., Ltd, Idemitsu Engineering Co., Ltd.	Carbon recycling cooperation business at Chiba Refinery	F/S (NEDO)
RING, JCOAL	Carbon recycling cooperation business of petrochemical complex nationwide	F/S (NEDO)
JAPEX, Deloitte	Carbon recycling cooperation project in Tomakomai area	F/S (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	High-value added lipids, Chemical raw materials (microorganisms)	Basic (NEDO)
Institute of Microalgal Technology(IMAT)	Jet fuel (microalgae)	Basic (NEDO)

(1-2) R&D Projects within Carbon Recycling Budget of NEDO（FY2020)

CO_2 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 CO_2 capture from blast furnace	Demonstration (NEDO)

DAC (Direct Air Capture)	Commodity/Product	Development stage
Kanazawa University, RITE	DAC Chemical absorption (solid)	Basic (NEDO)
Nagoya University, TOHO GAS CO., Ltd.	DAC （Chemical absorption・Cryogenic energy utilization)	Basic (NEDO)
Tokyo University, Osaka University, Ube Industries, Ltd., Shimizu Corporation, The Furukawa Electric Co., Ltd.	DAC (Physical adsorption, Chemical absorption)	Basic (NEDO)
AIST,Tokyo Institute of Technology, Nagoya University	DAC（microbial CO_2 fixation)	Basic (NEDO)
Tokyo University, Hokkaido University	DAC（CO_2 fixation through mineralization)	Basic (NEDO)
Tohoku University, Osaka Metropolitan University	DAC（Membrane separation)	Basic (NEDO)
Kyushu University, Kumamoto University, Hokkaido University	DAC（Membrane separation)	Basic (NEDO)

Basic and pilot research	Commodity/Product	Development stage
JCOAL, Keio University, Tokyo University of Science	Utilization of diamond electrodes Production of basic materials with CO_2 electro-reduction	Basic (NEDO)
Central Research institute of Electric Power Industry, Tokyo Institute of Technology	Development of CO_2 electrolysis reversible solid oxide cell	Basic (NEDO)
AIST, Doshisha University	CO_2 reduction and decomposition using high temperature soluble salt electrolysis	Basic (NEDO)
Toshiba Energy Systems & Solutions, Kyushu University	CO_2/H_2O co-electrolysis	Basic (NEDO)
Tokai National Higher Education and Research System, Sawafuji Electric, Kawada Industries	CO_2 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, CO_2 mineralization	Basic (NEDO)
MHPS, Central Research institute of Electric Power Industry, Toyo Construction, JCOAL	CO_2 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 CO_2	Basic (NEDO)