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

September 26, 2022

Ministry of Economy, Trade and Industry

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

◆ Carbon Neutrality by 2050

- In October 2020, the Japanese government declared that it aims to achieve "Carbon Neutrality by 2050". 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. Open the R&D and demonstration base for Carbon Recycling

- The Opening Ceremony for the R&D and demonstration base for Carbon Recycling was held on September 14, 2022. It consists of 3 areas (total area 14,300m^2) : the Demonstration Research Area, the Basic Research Area and the Algae Research Area. It was developed as Japan's first facility capable of supplying CO_2 separated and captured by the adjacent Osaki CoolGen Project. More than 10 projects from industry, universities, etc. will be implemented. We will promote collaboration with overseas researchers using this center as a "showcase" for realization of carbon neutrality.

Action 2. Promoting Public offering and adoption of the Green Innovation Fund

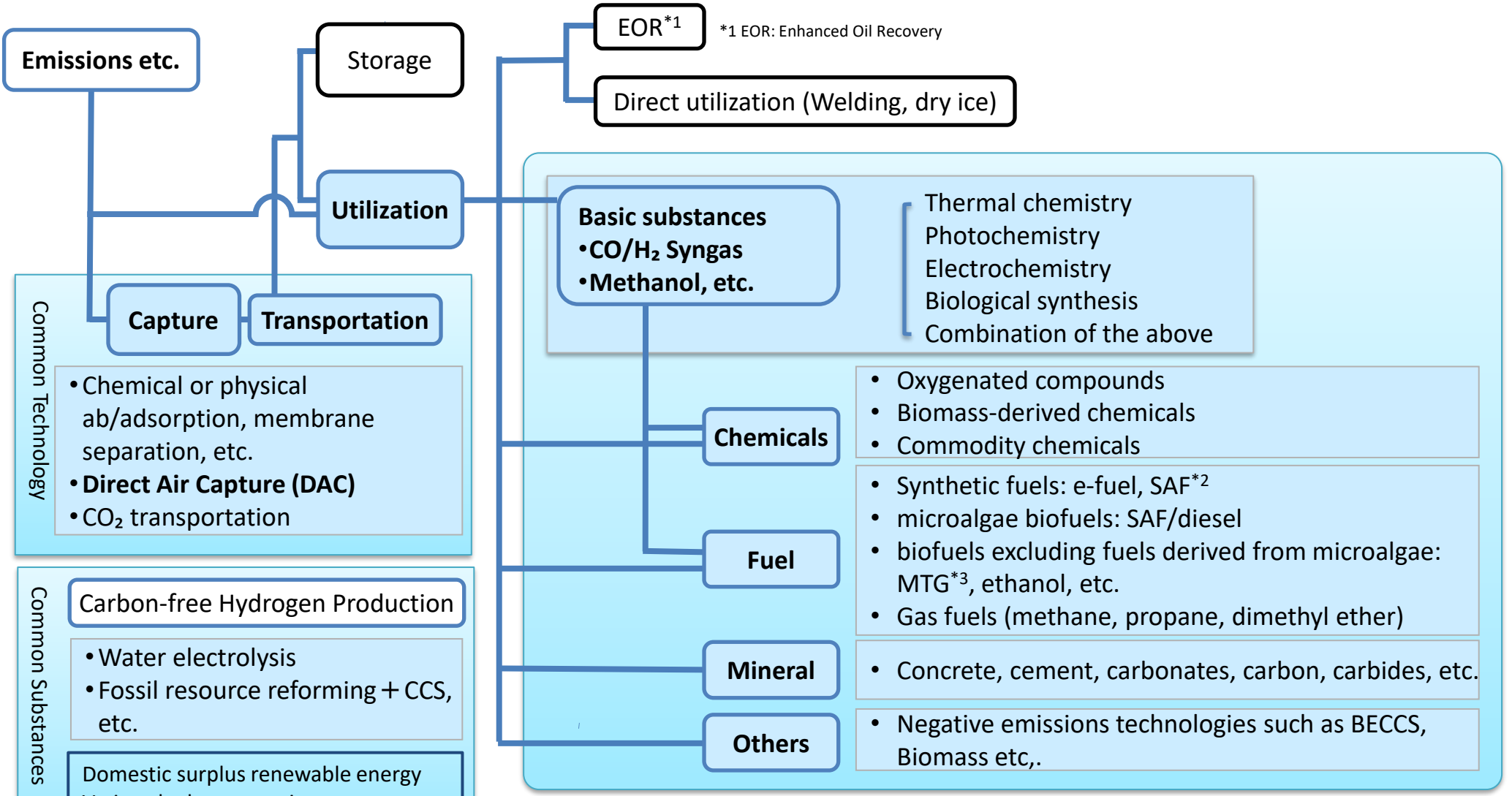
- METI accelerates R&D and demonstration for social implementation by using **the Green Innovation Fund** at the level of 2 trillion yen this year. New Energy and Industrial Technology Development Organization (NEDO) supports 4 projects such as **producing plastic feedstock**, **fuel**, **concrete** and **CO_2 capture** through utilizing Green Innovation Fund. The scale of budget is 336.5 billion yen. Furthermore, we are considering projects related to **Bio manufacturing**.

Action 3. Start the demonstration test for IGFC in Osaki Cool Gen Project

- The demonstration test for **IGFC (Integrated Coal Gasification Fuel Cell Combined Cycle)** with CO_2 separation and capture facilities started on April, 2022.

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

Action 1. R&D and Demonstration Base for Carbon Recycling at Osaki-kamijima, Hiroshima

- Accelerating the Implement technological R&D of Carbon Recycling by **conducting underlying technology development and demonstration in a concentrated and extensive manner** with CO_2 separated and collected in Osaki Cool Gen Project at **Osaki-Kamijima, Hiroshima**.
- Its opening event was held on September 14, 2022.

Coal gasification facility

Facility for CO_2 separation and capture

Opening Event

Algae Research Area　Demonstration Research Area　Basic Research Area

R&D and demonstration base

Algae Research Area

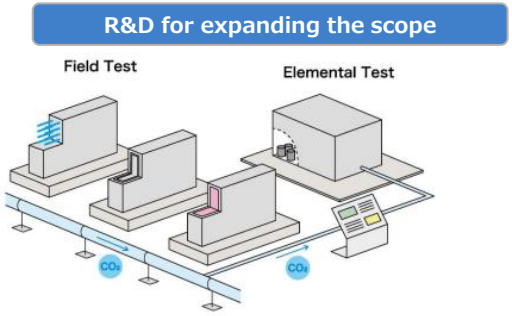
Demonstration Research Area

Basic Research Area

(Ref.) Sample of R&D and demonstration for Carbon Recycling at Osaki-Kamijima, Hiroshima

Efficient CO_2-use Concrete

- Development of technology to **expand the scope of application of concrete for related to concrete manufacturing technology and rust prevention performance at construction sites**.
- Confirmation of the performance of concrete manufactured with the above technology(CO_2 absorption volume, Strength, Corrosion status, etc).



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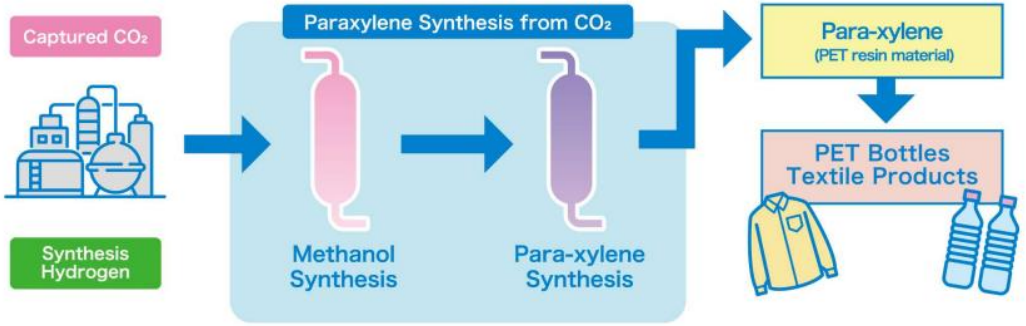
Chemical Products Synthesis from CO_2

- Technology development for **producing Para-xylene** by using the methanol being synthesized from CO_2 and H_2. (raw material of PET bottles and Textile products)
- Technology Development of **higher-performance catalysts for synthesizing methanol from CO_2 and H_2 as well as catalysts with an improved ratio of para-xylene, the useful product among the xylenes.**



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Carbon Recycling by Microalgae-derived SAF

- **Production technology for microalgae-derived SAF** and establishment of basic technology and standardization for the **efficient photosynthesis** by blowing CO_2 into the **microalgae**.
- ① Establishment of Microalgae Research **Testbed**
- ② **Standardization of Measurement/Analysis Methods** and Condition Settings

※ SAF: Sustainable Aviation Fuel

Environmental regulation will enable production and cultivation tests of diverse microalgae species in environments that simulate various climates, as well as trials of multiple drying and extraction processes.

Promote research and systematization of results through standardization of methods and conditions of measurement/analysis and of cultivation.

IMAT 日本微細藻類技術協会

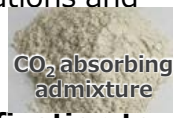
Action 2. Carbon Recycling R&D (Green Innovation Fund)

- NEDO supports 4 projects such as **producing plastic feedstock, fuel, concrete and CO_2 capture** through utilizing Green Innovation Fund (**336.5 billion yen**).
- Furthermore, NEDO is considering projects related to **Bio manufacturing**.

1. Concrete/Cement※

Concrete production technology ※

- The challenges are maximizing CO_2 reduction, expanding applications and reducing costs.



⇒**Development of concrete that maximizes CO_2 fixation to reduce CO_2 emissions.**

Cement production ※

- CO_2 is inevitably generated in the process of manufacturing cement from the raw materials limestone.

⇒**Developed a cement manufacturing process** capable of recovering almost all of the CO_2 derived from limestone.

2. Carbon Recycling fuel※

SAF (Sustainable Aviation Fuel)

- SAF Utilization in the field of international air transport is essential.

⇒Develop SAF producing technology and achieve **the production cost of 100yen level per litter**.

Synthetic fuel

- Key for decarbonization of mobility which is difficult to electrify is social implementation by synthetic fuels.

⇒**Further improve efficiency** of the entire manufacturing process.

Synthetic methane

- Decarbonization of gas body energy is an issue.

⇒Develop **highly efficient methane synthesis** by integrally performing water electrolysis reaction and methane synthesis reaction.

Green LPG

- Establishment of LP gas synthesis technology derived from non-fossil fuels is essential.

⇒Develop **catalysts and synthetic methods** that are the basic technology for producing green LPG.

3. Chemical※

・About half of the CO_2 emitted by the chemical industry is due to processes like cracking naphtha to produce basic chemicals such as ethylene and propylene.

⇒Develop for chemicals manufacturing technology (**artificial photosynthesis**) from green hydrogen and CO_2, and naphtha decomposition furnace technology by making the **carbon-free heat source**.

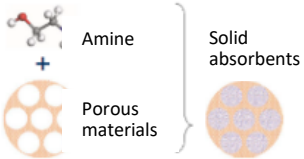
4. Bio manufacturing

・Integration of digital and genome modification technology promote bio-based products.

⇒Considering on the promotion of joint development between **microbial design platform operators and deferent field operators toward the production of bioplastics** using **hydrogen bacteria** that directly utilize CO_2 as a raw material.

5. CO_2 capture technology※

- The challenge is to **reduce the energy cost** to capture CO_2.
- Working on **innovation of separation materials** and reduce costs and strengthen international competitiveness.



Required energy is reduced to about 1/3

New amine absorbent (example)

※Participating organizations/companies were selected and publicly disclosed respectively on January 28 (1), April 19 (2), February 18 (3), and May 13 (5).

(Ref.) Green Innovation Fund (overview)

- Implement **technological R&D and demonstration base development** of Carbon Recycling through NEDO.
- In addition, **by utilizing the Green Innovation Fund, technological development and demonstration** for public implementation toward 2050 carbon neutrality **is accelerating**.

Carbon Recycling-related Budget (NEDO PROJECT) Budget amount for FY 2022, 53.9 billion yen

Development and demonstration of highly efficient CO_2 separation and capturing technology, and carbon recycling technology.

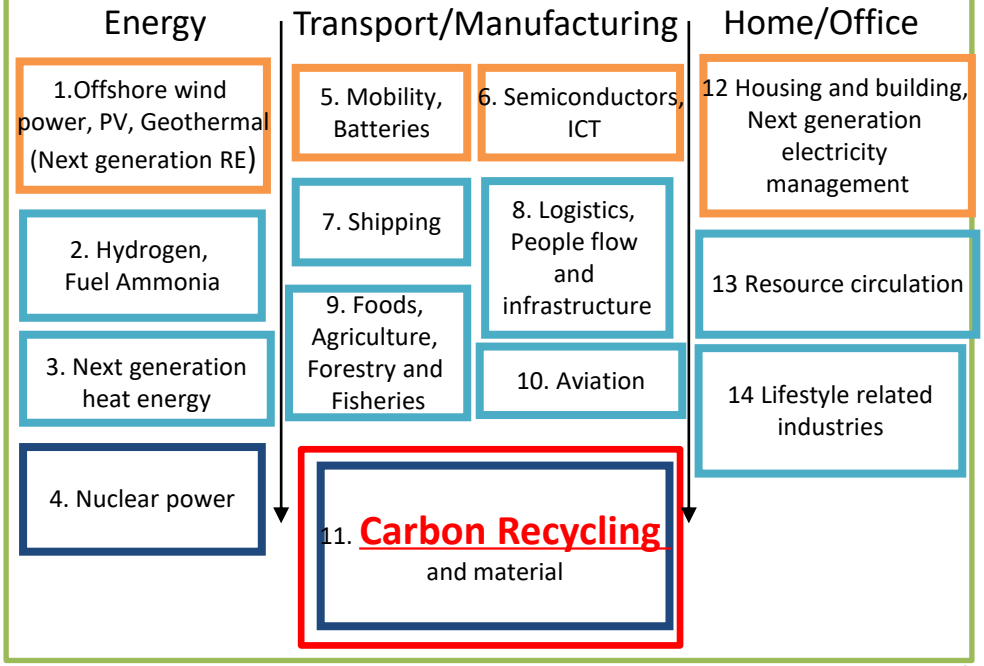
<Examples>

- Technological development of concrete that absorbs CO_2.
- Development of bio-jet fuel made from microalgae mass-produced by intensively injecting CO_2.
- Development of synthetic fuel (e-fuel) manufacturing technology using CO_2.
- Development of highly efficient CO_2 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

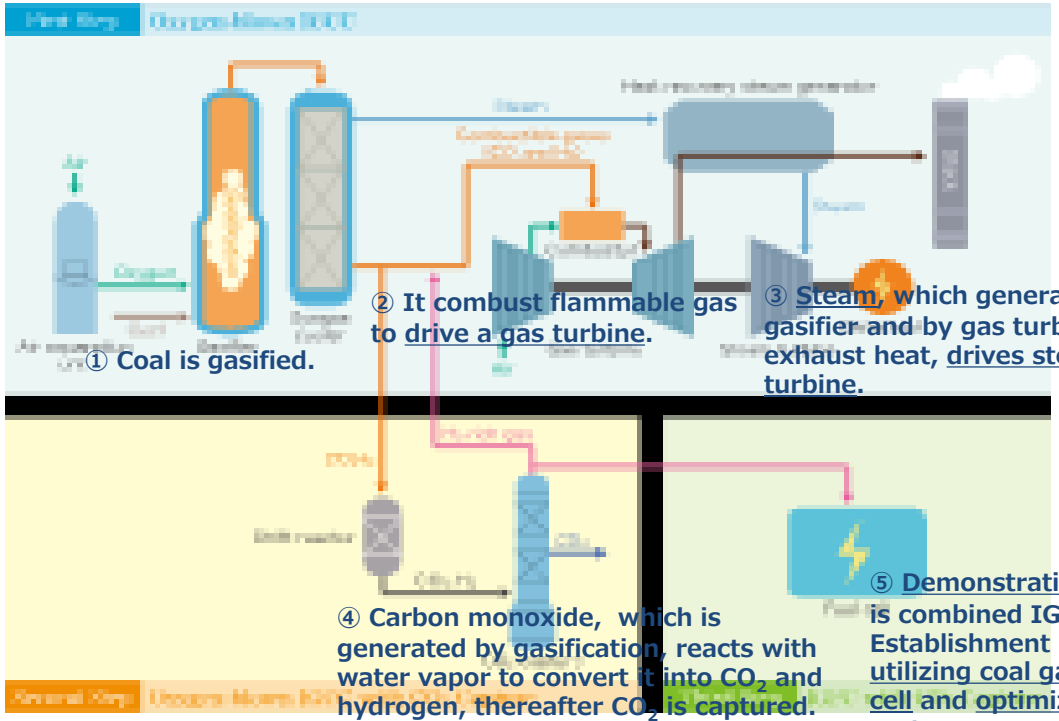
R&D/demonstration and public implementation of 14 fields, including Carbon Recycling, will be supported for 10 years.



Action 3. Osaki CoolGen Project

- **Osaki CoolGen Corporation** (share: The Chugoku Electric Power 50%, J-POWER 50%) proceed **project implementation for IGCC/IGFC** by 3 steps since 2012 at Osaki-Kamijima, Hiroshima supported by METI and NEDO.
  - -1st Step: Oxygen-blown **IGCC (Integrated Coal Gasification Combined Cycle)** 【2012-2018】
  - -2nd Step: CO_2 capture type **IGCC demonstration** 【2016-2022】
  - -3rd Step: CO_2 capture type IGCC with fuel cell **IGFC (Integrated Coal Gasification Fuel Cell Combined Cycle) demonstration** 【2018-2022】
- Since April, 2022, **the demonstration by IGFC (166MW) with CO_2 Capture started as the third step.**

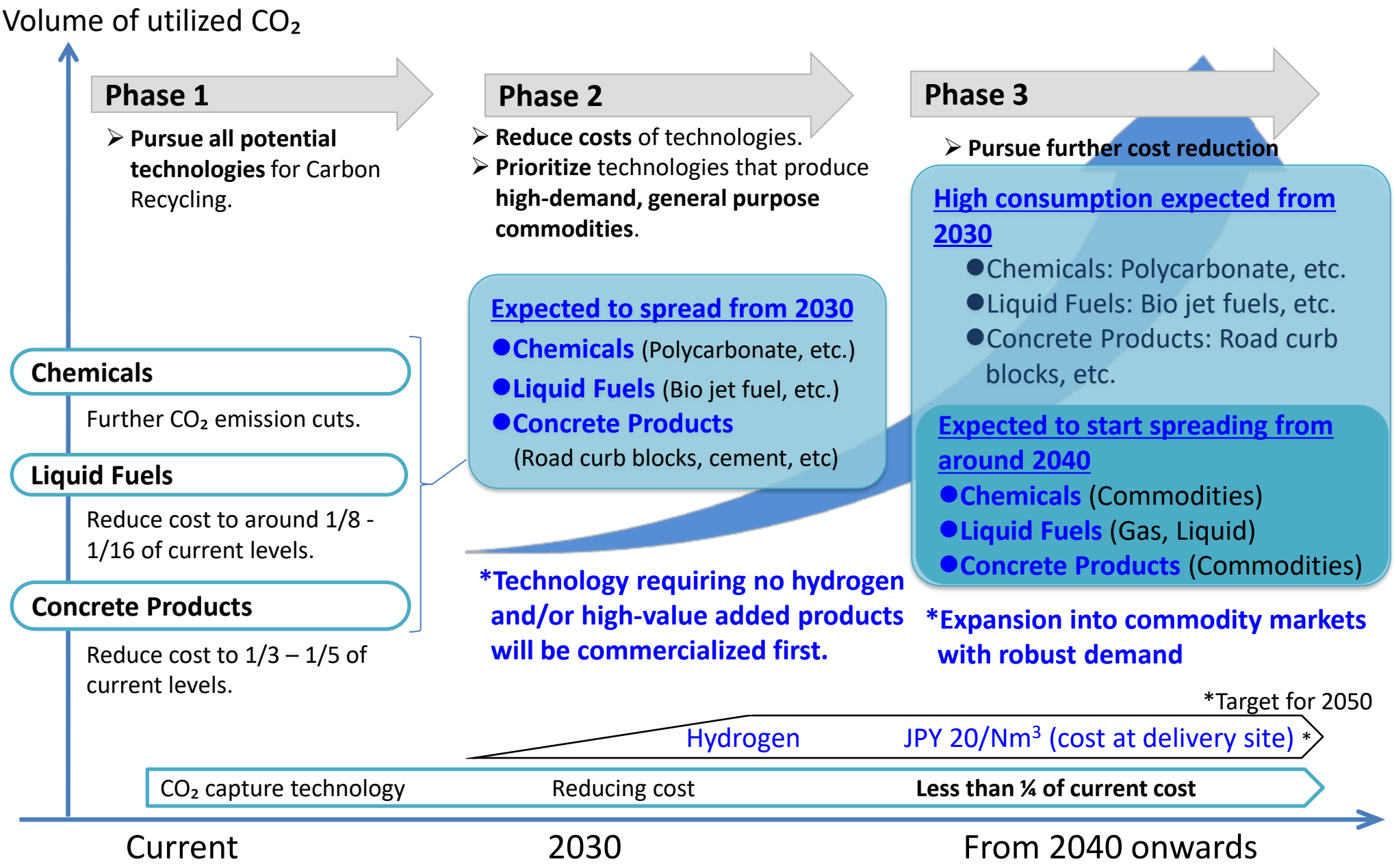
Process Overview



Project Schedule

fysical year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1st Step Oxygen-blown IGCC demonstration	Design/Produce/Install					Dmon-stration					
2nd Step CO2 captured type IGCC demonstration					Design/Droduce/Install			Demon-stration	Additional Produce	Demon-stration	
3rd Step CO2 captured type IGFC demonstration								Design/Produce/Install		Demon-stration	

(Ref.) Carbon Recycling Technology Roadmap



(1-1) R&D Projects within Carbon Recycling Budget of NEDO（FY2022)

Minerals	Commodity/Product	Development stage
Idemitsu Kosan, Ube Industries, Ltd. JGC HOLDINGS CORPORATION, Seikei University, Tohoku University	Calcium carbonate	Basic -Demonstration （NEDO）
The Chugoku Electric Power CO.INC. Hiroshima University, Chugoku Koatsu Concrete Industries	Greening infrastructure material, etc.	Basic -Demonstration （NEDO）
Kobe Steel, Ltd, Kobelco Eco-Solutions Co.Ltd.	Calcium carbonate	Basic -Demonstration （NEDO）
JFE Steel Corporation	Calcium carbonate	Basic -Demonstration （NEDO）
Mitsubishi Materials Corporation	Carbon nanomaterial	Basic -Demonstration （NEDO）

Chemicals	Commodity/Product	Development stage
University of Toyama, Nippon Steel Corporation, Nippon Steel Engineering, HighChem, Chiyoda Corporation, Mitsubishi Corporation	Paraxylene	Basic -Demonstration (NEDO)
IHI Corporation	Olefin	Basic -Demonstration (NEDO)
JFE Steel Corporation, RITE	Methanol	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)

Fuels	Commodity/Product	Development stage
INPEX	Methane	Demonstration （NEDO）
JPEC、ENEOS, Idemitsu Kosan Co.Ltd Seikei University	Synthetic fuel(e-fuel)	Basic （NEDO）
IHI Corporation, Mitsubishi Power, Euglena, bits, Chitose, J-POWER	Jet fuel	Basic -Demonstration （NEDO）

R&D and Demonstration Base for Carbon Recycling at Osaki-Kamijima	Commodity/Product	Development stage
The Chugoku Electric Power CO.,INC., Kajima Corporation, Mitsubishi Corporation	Improved type carbon absorption concrete	Basic -Demonstration (NEDO)
Kawasaki Heavy Industries, Osaka University	Paraxylene	Basic -Demonstration (NEDO)
The Chugoku Electric Power CO.,INC., Hiroshima University	Cosmetics etc.	Basic -Demonstration (NEDO)
Keio University、Tokyo University of Science、JCOAL	Formic acid	Basic （NEDO）
Tokai National Higher Education and Research System、KAWADA INDUSTRIES, INC	Urea	Basic （NEDO）
NIPPON STEEL CORPORATION	Fuel for steel making	Basic （NEDO）
Tohoku University	Silicon carbide	Basic （NEDO）
ENEOS GLOBE Corporation、NIPPON STEEL CORPORATION 、University of Toyama	LPG	Basic （NEDO）
Algal Bio Co.,Ltd、Kansai Electric Power Company, INC	Bioplastic etc.	Basic （NEDO）
Institute of Microalgal Technology(IMAT)	Jet fuel	Basic -Demonstration (NEDO)

※ JCOAL and Osaki CoolGen operate the center, support research, and maintain the facilities.

Sector coupling	Commodity/Product	Development stage
Yokogawa Electric Corporation	Carbon recycling cooperation project in Chiba Goi area	Basic （NEDO）
RING, JCOAL	Carbon recycling cooperation business of petrochemical complex nationwide	Basic （NEDO）
JAPEX, Deloitte	Carbon recycling cooperation project in Tomakomai area	Basic （NEDO）

(1-2) R&D Projects within Carbon Recycling Budget of NEDO（FY2022)

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)	Base-Demonstration (NEDO)
Toray Industries, Inc	Membrane separation (inorganic membrane)	Basic - Demonstration（NEDO）
KYUSHU UNIVERSITY、Tokyo Institute of Technology、TOSOH CORPORATION	Membrane separation (organic membrane)	Basic - 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, etc.	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
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)
Mitsubishi Gas Chemical, Central Research institute of Electric Power Industry, TOYO CONSTRUCTION CO., LTD., JCOAL	Intermediate for the production of polycarbonate using CO_2	Basic (NEDO)
Tokyo Institute of Technology、Saitama University、Hokkaido University	Electrocatalyst to enable to direct reduction of CO_2 to higher hydrocarbons by gas-phase electrolysis	Basic (NEDO)
Kitasato University、University of Tokyo、Nihonkaisui CO.,LTD、Idemitsu Kosan Co., Ltd	CO_2 mineralization method using seawater and biogenic amines	Basic (NEDO)
JGC HOLDINGS CORPORATION、JGC CORPORATION、Hiroshima University	Ammonia methanation for CO_2	Basic (NEDO)
Kyushu University、The Japan Research and Development Center for Metals	Activated carbon conversion technology derived from marine biomass utilizing CO_2	Basic (NEDO)
Institute of Japan Green LP Gas Promotion、AIST、N.E. CHEMCAT CORPORATION	Synthesis for Carbon Recycling LP Gas	Basic (NEDO)
AIST、Hitachi Zosen Corporation	CCU process with dual function material (DFM)	Basic (NEDO)