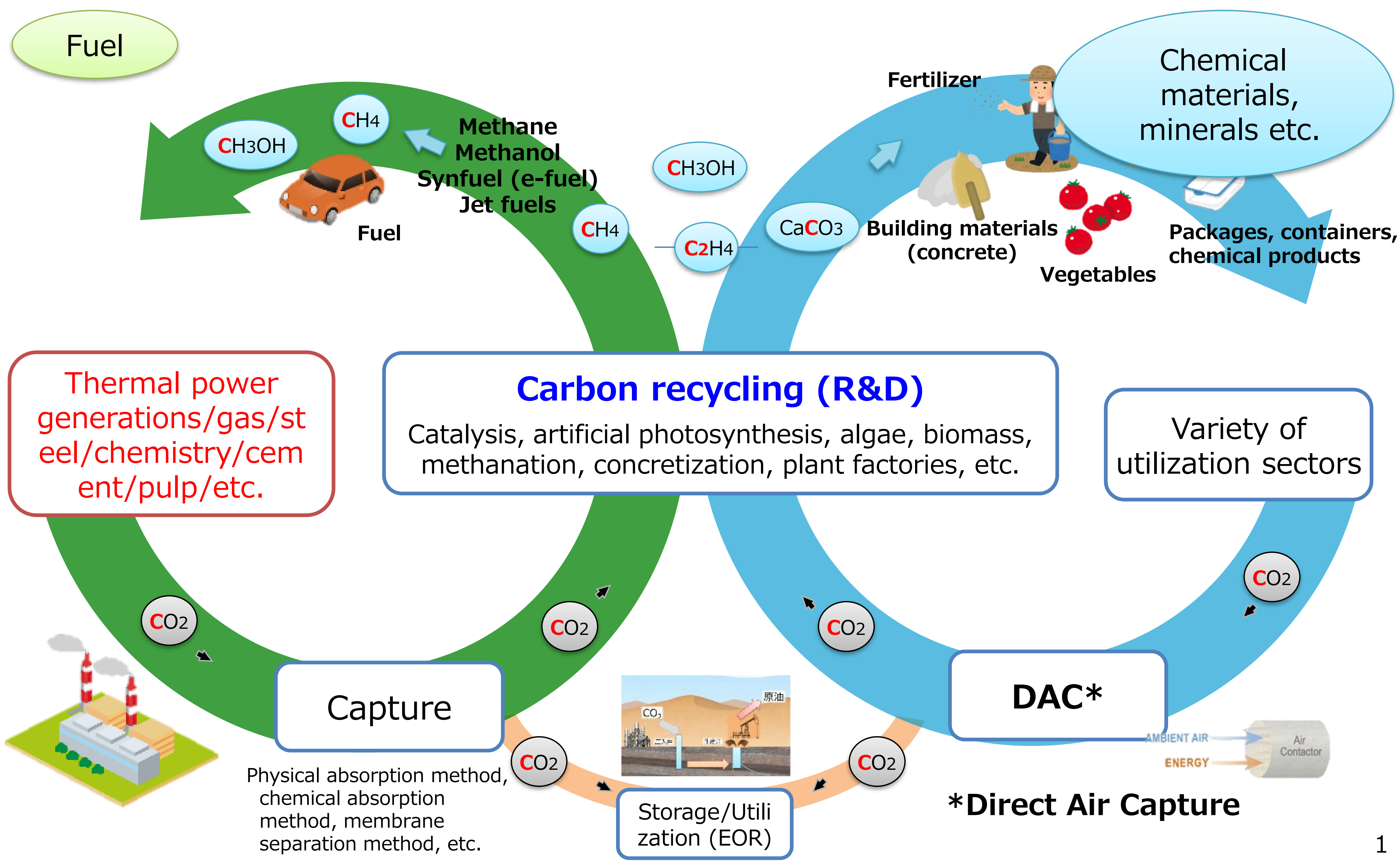
経済産業省

Carbon Recycling Policy

October 2021

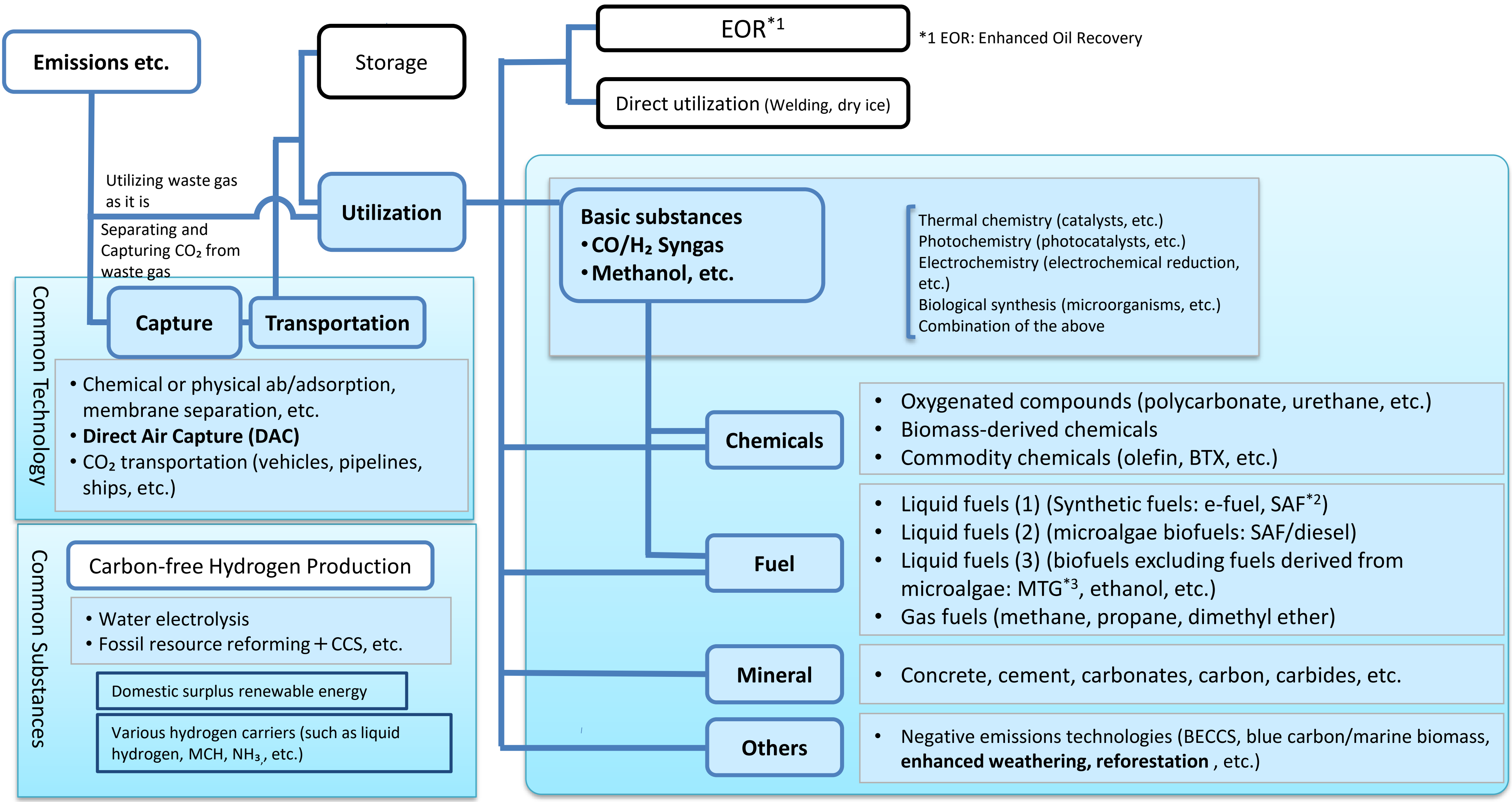
Ministry of Economy, Trade and Industry

Concept of Carbon Recycling
～Strongly promote R&D for public implementation～



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

Carbon recycling to realize overall carbon neutrality

- **To meet the goals of the Paris Agreement**, the government pursues **effective reductions in the emission of** greenhouse gases and overall carbon neutrality.
- In contrast, there are **industries/regions in which fossil fuel has to be used for improvement of people's lives, development of the economy, or energy security,** depending on the stage of development.
- **Carbon recycling is effective in achieving zero emissions from fossil fuel, as it uses CO_2 as a resource.**

➢ Significance of carbon recycling

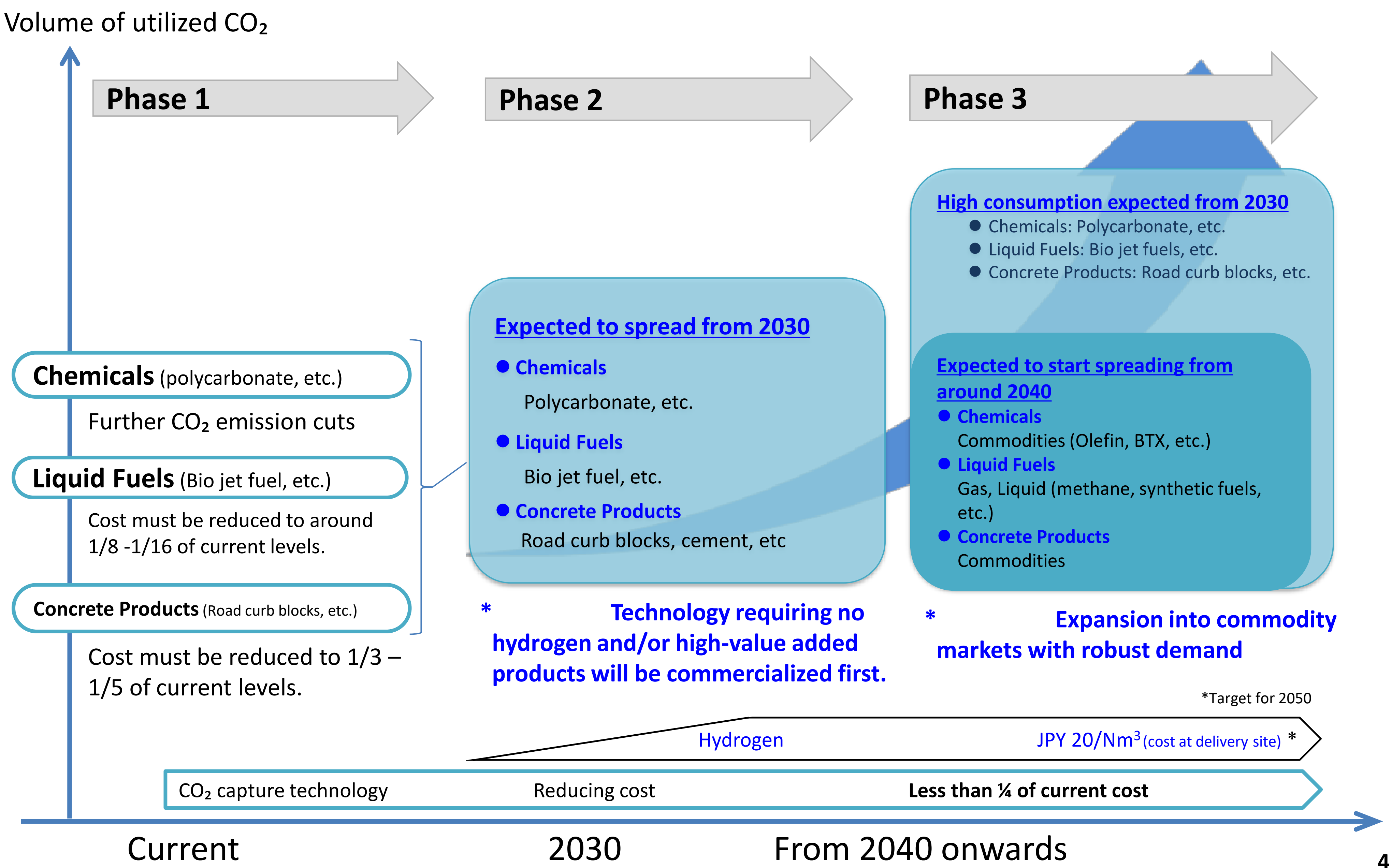
1. Carbon recycling **directly contributes to reductions in greenhouse gases.**

2. Realizing carbon recycling is **effective in achieving net zero emissions** through the use and synergistic effects of hydrogen and renewable energy.

3. Business operators in **various industrial segments** (chemistry, cement, machinery, engineering, fossil fuel, biology, etc.) can put effort into carbon recycling (like energy saving, resource saving, recycling, etc.) in **their respective business fields utilizing existing infrastructures.**
   (including methanation and synthetic fuel [e-fuel])

➢ While **utilizing fossil fuels and existing infrastructures**, Western countries also aim to achieve net zero emissions of greenhouse gases, focusing on **net zero emission technologies** (which offset CO_2 originating from fossil fuels).

Action2. Revision of Carbon Recycling Technology Roadmap



Green Growth Strategy Through Achieving Carbon Neutrality in 2050

Carbon recycling is a **key technology for realizing a carbon neutral society** with **technology that effectively utilizes CO_2 as a resource**, and Japan has a competitive edge in this field.

The carbon recycling industry is **diverse**, as shown in the Carbon Recycling Technology Roadmap, which **includes the major fields** of **minerals** (concrete products, concrete structures, carbonates, cement, etc.), **fuels** (microalgae jet fuel, microalgae diesel fuel, synthetic fuel, biofuel, gas fuel from methanation, etc.), **chemicals** (oxygenated products such as polycarbonates and urethane, biomass-derived chemicals, general-purpose substances such as olefin and paraxylene), etc.

Focusing on these major products, the government will promote **technology development and public implementation to achieve cost reduction and application development,** and aim for **global development** through the **International Conference on Carbon Recycling**.

Excerpt from *Green Growth Strategy Through Achieving Carbon Neutrality in 2050*

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.

Carbon recycling chemicals

	Current status and tasks	Future actions
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.

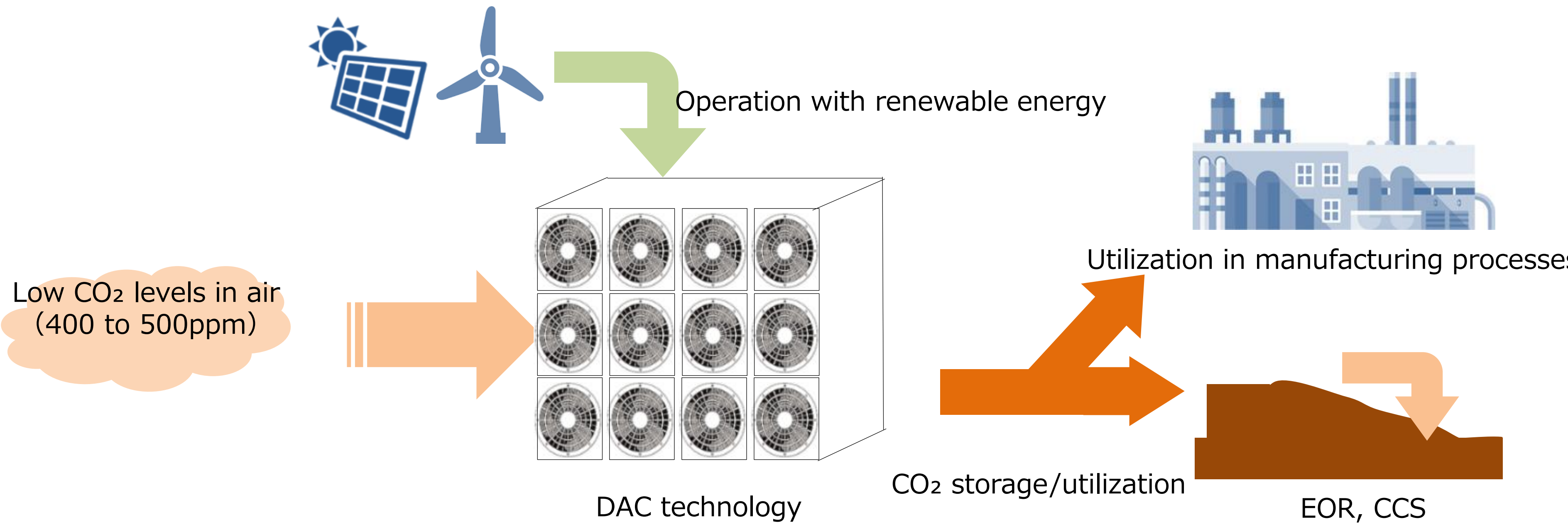
Future actions

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

(Innovative technology under development 1) DAC technology

- **DAC (Direct Air Capture)** is a technology for direct separation and recovery of CO_2 in the atmosphere. It is broadly divided into the following three methods. Technological development has progressed primarily for chemical absorption/adsorption.
  - **Chemical absorption/adsorption** (Absorption/separation of CO_2 in the air using amine absorbing solutions/adsorbents, following the recovery of CO_2 from the absorbing solution/adsorbents through heating or decompression)
  - **Membrane separation** (Separation/recovery of CO_2 from the air using an ion exchange membrane)
  - **Deep cooling** (Separation of CO_2 by cooling air to a temperature equal to or below the boiling point of CO_2 (-79℃) to turn CO_2 into dry ice)
- **Reduction in energy costs required for separation/recovery** is a common issue.

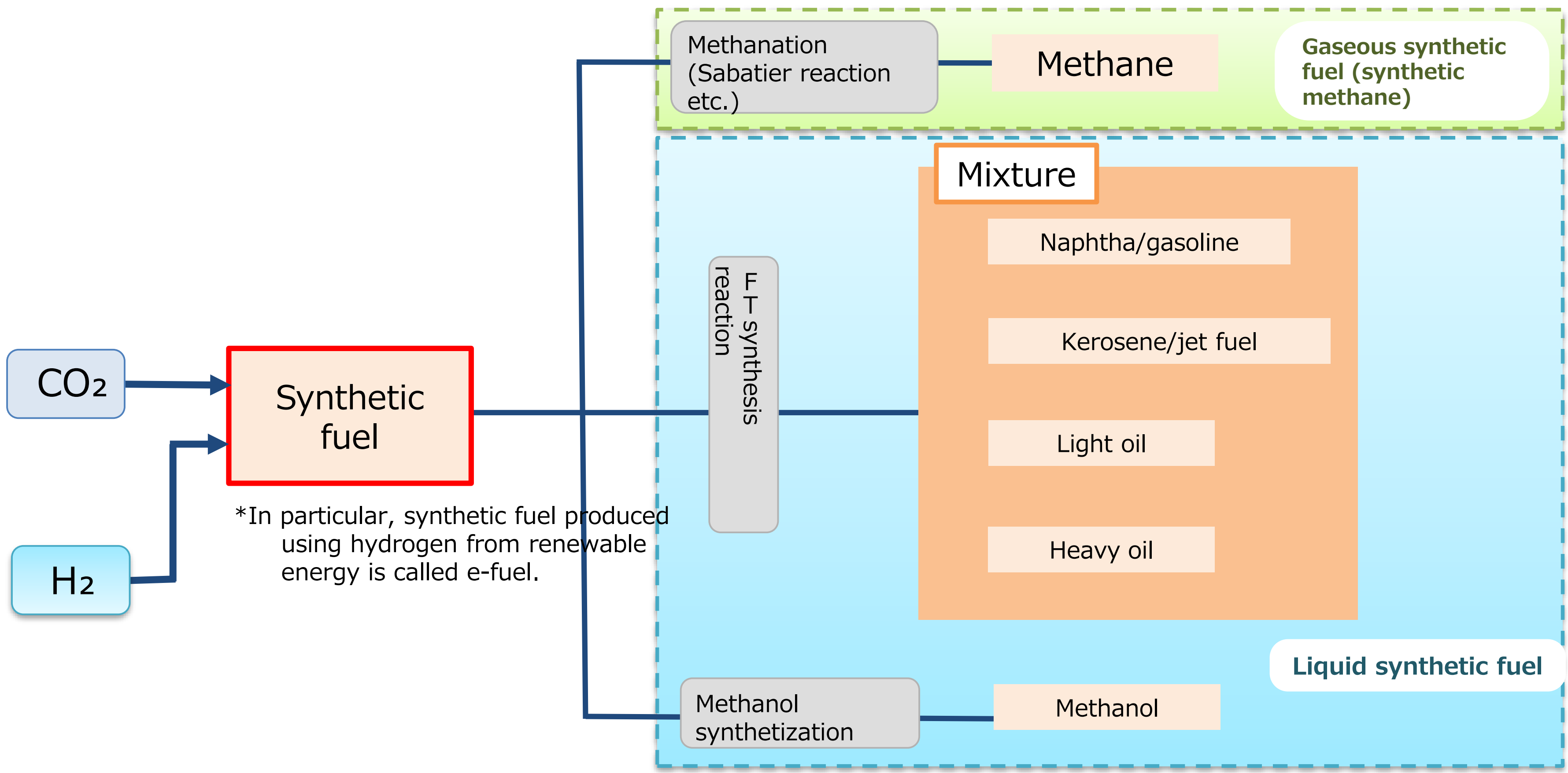
→ **Development of innovative separation membranes, chemical absorbents and system development** is necessary.



Source: Progressive Environmental Innovation Strategy

(Innovative technology under development 2) Synthetic fuel

- Synthetic fuel is a fuel produced by synthesizing CO_2 and H_2. It is regarded as **carbon-neutral fuel because it is produced by reusing emitted CO_2. Existing fuel infrastructures can be utilized, and the cost of introduction can be kept lower than that of other new fuels.**
- An integrated manufacturing process for commercialization has yet to be established, and R&D and demonstrations are necessary for establishing a manufacturing process.



International trends in carbon recycling technologies (1)

- **CO_2 separation/recovery**: **Superior** in **international competitiveness** of technologies
  Chemical absorption (amine solutions): **Commercialized**. **Higher efficiency/larger scale** depending on the source of emission is an issue.
  DAC technology: High cost resulting from large amounts of input energy is an issue. Is in the stage of **elemental technology development for reducing cost.**
- **Chemicals**: **Some chemicals, such as polymers, commercialized. R&D and demonstrations are in full swing.**
  Research and the demonstration of various products/technologies **have been boosted worldwide. R&D, led by chemicals manufacturers,** is advancing.

CO_2 separation/recovery

Country	Company/organization	Product	Stage of development
JPN	**Mitsubishi Heavy Industries Engineering**	**Chemical absorption (amine solution)**	**Commercialization**
JPN	**Nippon Steel Engineering**	Chemical absorption (amine solution)	Commercialization (NEDO)
DE	**BASF** (chemical manufacturer)	Chemical absorption (amine solution)	Demonstration to commercialization
Neth.	**Shell** (petroleum chemistry)	Chemical absorption (amine solution)	Commercialization
USA	**UOP** (chemical manufacturer)	Membrane separation (organic membrane)	Demonstration to commercialization
JPN	**Sumitomo Chemical, RITE**	Membrane separation (organic membrane)	Demonstration (NEDO)
JPN	**Kanazawa University, RITE**	DAC (chemical absorption [solid])	Basic (NEDO)
Switz.	**Climeworks**	DAC (using amine solid absorbents etc.)	Commercialization *High cost

Chemicals

Country	Company/organization	Product	Stage of development
JPN	**Asahi Kasei**	Polycarbonate	Commercialization
USA	**Newlight Technologies** (start-up)	Polymer (utilizing biocatalysts)	Commercialization
JPN	**Nippon Steel Chiyoda**	Para-xylene	Basic (NEDO)
JPN	**Tokyo Institute of Technology**	Acrylic acid	Basic (JST)
JPN	**TOSOH/AIST**	Urethane raw materials	Basic (NEDO)
DE	**BASF** (chemical manufacturer)	Acrylic acid	Basic
JPN	**Mitsubishi Chemical, The University of Tokyo, etc.** (artificial photosynthesis project)	Methanol/olefin	Basic (NEDO)

International trends in carbon recycling technologies (2)

- **Fuels and minerals** (cement/concrete):

  Some fuels/minerals are being commercialized. R&D and demonstrations have started and are in full gear.

  (Development and demonstrations in various products/technologies have been **activated. Reductions in cost and expansion of applications** are issues.)

  In Japan, companies in various fields, such as chemistry, cement, energy, and engineering, are involved.

  In **Europe and the US**, development and demonstrations have been activated through **national projects or start-ups.**

Fuels

Country	Company/organization	Product	Stage of development
USA	**Lanza Tech** (start-up)	Ethanol	Demonstration
USA	**Opus12** (start-up)	Methane, ethane, ethanol	Demonstration
JPN	**INPEX** **Hitachi Zosen**	Methane	Demonstration (NEDO)
JPN	**Euglena**	Jet fuel (microfuel)	Demonstration
DE	**Audi** (automaker)	Methane, synthetic fuel (e-fuel)	Demonstration
JPN	**IHI**	Jet fuel (microalgae)	Basic (NEDO)
JPN	**ENEOS**	Synthetic fuel (e-fuel)	Basic

Minerals

Country	Company/organization	Product	Stage of development
JPN	**Chugoku Electric Power Company, Kajima Corporation, etc.**	CO_2 absorption type concrete	Commercialization
UK	**O.C.O Technology** (start-up)	Light-weight aggregate	Commercialization
USA	**Solidia Technology** (start-up)	CO_2 absorption concrete	Commercialization
USA	**Blue Planet** (start-up)	Light-weight aggregate	Commercialization
CA	**Carbon Cure** (start-up)	Cement raw material	Commercialization
JPN	**Ube Industries, JGC, Idemitsu, Tohoku University**	Cement raw material	Demonstration (NEDO)
JPN	**Taiheiyo Cement, The University of Tokyo, Waseda University**	Cement raw material	Basic to demonstration (NEDO)
FR	**LafargeHolcim etc.** (cement manufacturer)	Cement raw material	Basic to demonstration (FastCarb PJ)

Additions made to a figure prepared by Technology Strategy Center, NEDO (2021)

Action3. Utilization of Green Innovation Fund

- Implement **technological development, demonstration, and base development** of carbon recycling technology (concrete/cement, fuel, chemical CO_2 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 CO_2 separation and capturing technology and carbon recycling technology for effective use of CO_2.

＜Business 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
- Technology development of artificial photosynthesis to manufacture chemicals from 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.

Energy

- 1.Offshore wind power, PV, Geothermal (Next generation RE)
- 2. Hydrogen, fuel ammonia
- 3. Next generation heat energy
- 4. Nuclear power

Transport/manufacturing

- 5. Mobility, batteries
- 6. Semiconductors, ICT
- 7. shipping
- 8. Logistics, People flow and infrastructure
- 9. Foods, agriculture, forestry and fisheries
- 10. Aviation
- 11. Carbon recycling and material

Home/office

- 12 Housing and building, Next generation electricity management
- 13 Resource circulation
- 14 lifestyle related industries

(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)

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)

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)

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)

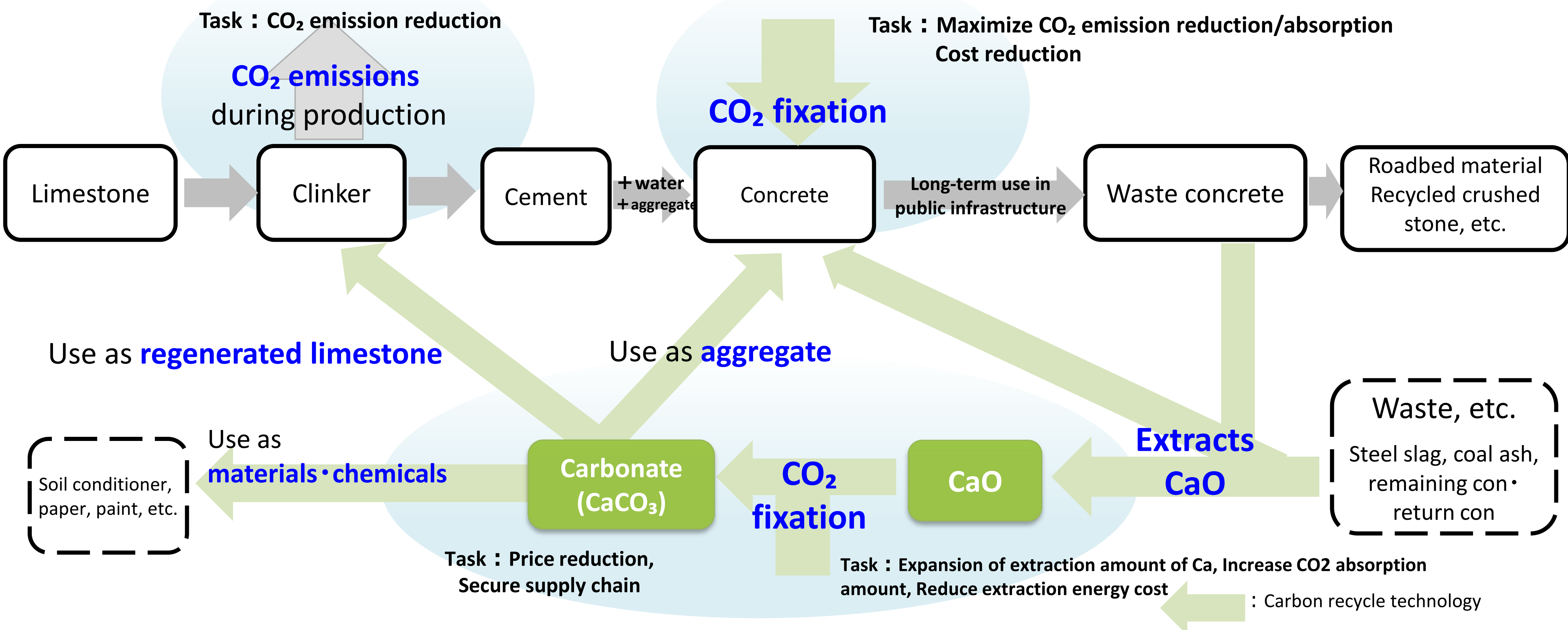
DAC (Direct Air Capture)	Commodity/Product	Development stage
Kanazawa University, RITE	DAC Chemical absorption (solid)	Basic (NEDO)
Nagoya University, TOHO GAS CO., Ltd.	DAC （Chemical absorption・Cryogenic energy utilization)	Basic (NEDO)
Tokyo University, Osaka University, Ube Industries, Ltd., Shimizu 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)

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 CO_2 into concrete and cement products.**
- **It is necessary to maximize CO_2 emission reduction/absorption, reduce costs, and establish a sustainable resource recycling system** by combining various technologies.

Overview of concrete and cement



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**.

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**

International Cooperation; "International Conference on Carbon Recycling"

- **The conference confirmed that the members will commit to develop and demonstrate technologies toward public implementation while enhancing international collaboration concerning Carbon Recycling, which is a key technology for realizing a carbon neutral society,**

- **Japan presented its goal; that it will take the lead in technological development and demonstration for achieving a decarbonized society on a global scale by discussing areas of cooperation based on Memoranda of Cooperation (MOC) and communicating the progress of the Green Innovation Fund project and the establishment of R&D and demonstration base on Osaki Kamijima Island in Hiroshima Prefecture.**

1．Outline

- Date and time : October 4 (Mon.), 2021; from 3:30 PM to 6:30 PM
- Venue : Online
- Number of participating people, countries and regions : **About 2,800（32）**
- Program
    - Ministerial speeches, Keynote speech and Panel discussions
        - Progress of Minerals (Concrete and Cement) utilizing CO_2 by Carbon recycling
        - Progress of Fuels and Chemicals utilizing CO_2 from Carbon Recycling
        - Technologies for the Future, Expectation by Investment

2．Major participants

- Mr. HOSAKA Shin, Commissioner, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (METI)
- Dr. Fatih BIROL, Executive Director, International Energy Agency (IEA)
- HRH, Prince Abdulaziz bin Salman Al-Saud, Minister of Energy, Kingdom of Saudi Arabia
- H.E Arifin TASRIF, Minister of Energy and Mineral Resources, Republic of Indonesia
- Dr. Jennifer WILCOX, Principal Deputy Assistant Secretary for the Office of Fossil Energy and Carbon Management, Department of Energy (DOE), United States of America
- Mr. YUZAKI Hidehiko, Governor of Hiroshima Prefecture, Japan
- Dr. KOBAYASHI Yoshimitsu, Chairperson, Carbon Recycling Fund Institute (CRF), Japan, etc.

3．Outcomes

- Industry, academia, and government leaders in the field of carbon recycling (concrete/cement, fuel/chemicals, and R&D/investment) participated from Japan and abroad, and through panel discussions, announced their future directions toward implementing carbon recycling throughout society.

- METI presented Japan's efforts toward public implementation of carbon recycling over the last year in the form of a report summarizing the progress made, including the formulation of the Green Growth Strategy Carbon Recycling Action Plan and the revision of the Roadmap for Carbon Recycling Technologies. The participants confirmed that they will speed up open innovation while strengthening international cooperation.

Japan-U.S. Climate Partnership (April 16, 2021)

- **Japan and the United States, at their summit meeting on April 16, stated their** commitment to enhancing cooperation on climate ambitions, decarbonization, and clean energy and will take the lead on climate action in the international community.
- **Enhancing bilateral cooperation in Carbon Recycling** and other priority areas.

Japan-U.S. Climate Partnership (excerpt)

<Climate and clean energy technology and innovation>

Japan and the United States **commit to** addressing climate change and **working together towards the realization of green growth by enhancing cooperation on innovation**, including in such areas as renewable energy, energy storage (such as batteries and long-duration energy storage technologies), smart grids, energy efficiency, hydrogen, **carbon capture, utilization and storage/carbon recycling**, industrial decarbonization, and advanced nuclear power.

This cooperation will also promote the development, deployment, and utilization of a climate friendly, adaptive infrastructure through collaboration in areas that include renewable energy, grid optimization, demand response, and energy efficiency.

Carbon Recycling Fund Institute

- **To accelerate efforts for carbon recycling**, the **Carbon Recycling Fund Institute** was established in August 2019 under a private sector initiative. As of September 1, 2021, the membership consists of **85 companies, 11 individuals, and 1 local government.** A wide variety of industry segments, including chemistry, energy, construction, electronics, machinery, finance, and trading companies, are involved.
- Regarding carbon recycling, the institute performs the following activities: (1) **research sponsorship,** (2) **public relations/diffusion**, (3) **policy recommendations, fact-finding surveys.** It promotes **Open Innovation through cross-industrial cooperation.**

Chairperson: Yoshimitsu Kobayashi (Director of the Board, Mitsubishi Chemical Holdings Corporation), Vice Chairperson: Masayoshi Kitamura (Special Counselor, Electric Power Development Co., Ltd.)

[Corporate members] Listed in order of the Japanese syllabary

IHI, Aizawa Concrete Corporation, Aisan Industry, Asahi Quality & Innovations, Idemitsu Kosan, Itochu Corporation, Inpex, Ushio, Ube Industries, AGC, Ebara Corporation, NTT Data Institute of Management Consulting, Ohmori-Kensetsu, Kawasaki Heavy Industry, Kankyou-Systems, Kobe Steel, Cosmos Shoji, Kumagai Gumi, San-in Sanso Corporation, Sun Flare, JSR, JFE Shoji Corporation, Shimadzu, Shimizu Corporation, Utilization of Carbon Oxide Institute, Shin Nippon Air Technologies, Sumitomo Osaka Cement, Sumitomo Heavy Industries, Sumitomo Corporation, Seika Corporation, Japan Coal Frontier Organization, Japan Petroleum Exploration, Taisei Corporation, Dai Nippon Printing, Taihei Dengyo, Taiheiyo Cement, Daiwa Securities Group, Geothermal Energy Research and Development, Chiyoda Corporation, DIC, Denka, J-POWER, Central Research Institute of Electric Power Industry, TOA Corporation, Tokyo Eco Service, Tokyo Gas, Tokyo Sangyo, Tokyo University of Science, Toshiba Energy Systems & Solution, Dome Gold Mines Ltd, Toyo Engineering Corporation, Toray, Toda Kogyo, Toppan, JGC Holdings Corporation, Nissan Motor, Nippon Steel Engineering, NGK Insulators, Nippon Coke & Engineering, Nippon Steel, The Institute of Energy Economics, BASF Japan, Hitachi Zosen, Hitachi Power Solutions, Hulic, FKG Corporation, Social Welfare Research Corporation, Fuso, Future Estate, Furukawa Electric, Marubeni, Mizuho Financial Group, Mizuho Research & Technologies, Sumitomo Mitsui Banking Corporation, Sumitomo Mitsui Trust Panasonic Finance, Mitsui & Co., Mitsubishi Gas Chemical Company, Mitsubishi Chemical Corporation, Mitsubishi Heavy Industries, Mitsubishi Corporation, Mitsubishi Materials Corporation, MUFG Bank, Euglena, and Wakachiku Construction

[Local government] Hiroshima Prefecture