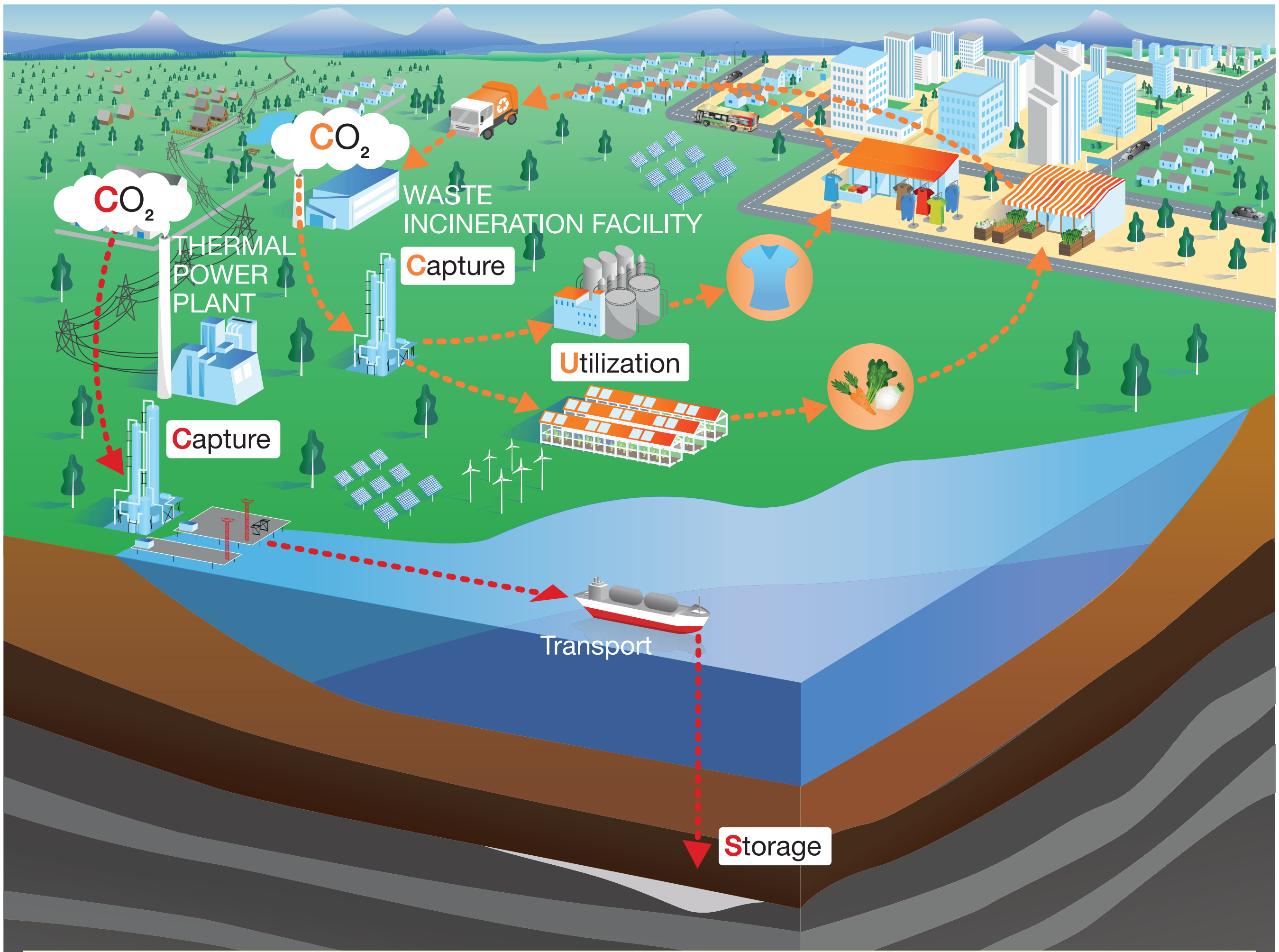
環境省
Ministry of the Environment

Toward a Carbon Neutral Society
Deployment of CCUS Technologies

In order to prevent unacceptable further global warming caused by increases in atmospheric carbon dioxide (CO_2), we need to take measures to capture CO_2 and prevent its release to the air while expanding the use of renewable energy and other low emission technologies. CCUS is a system starting from capturing CO_2 and widely recognized as an important option.



What is CCUS?

CCUS stands for carbon dioxide capture, utilization or storage and is a process that captures CO_2 released from thermal power plants, factories, etc. and either uses it in production processes for crops, chemicals, construction materials, etc. or stores it in a stable underground geological formation.

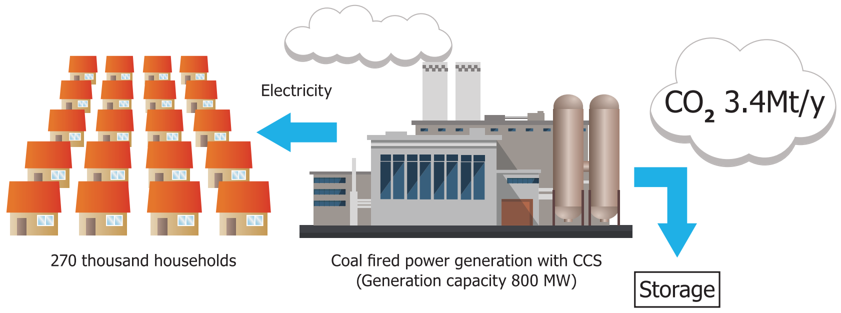
Significance of the CCUS technology

The Paris Agreement, which was concluded to prevent the most harmful global warming, aims to hold the increase in global average temperature below 2°C, and preferably below 1.5°C, compared to the times before industrialization. Japan aims to realize a "decarbonized society" at the earliest possible time in the latter half of this century and is taking various steps to achieve a long-term goal of reducing greenhouse gases including CO_2 and other gases by 80% by 2050.

Compiled on based on "Japan's Long-term Strategy under the Paris Agreement"

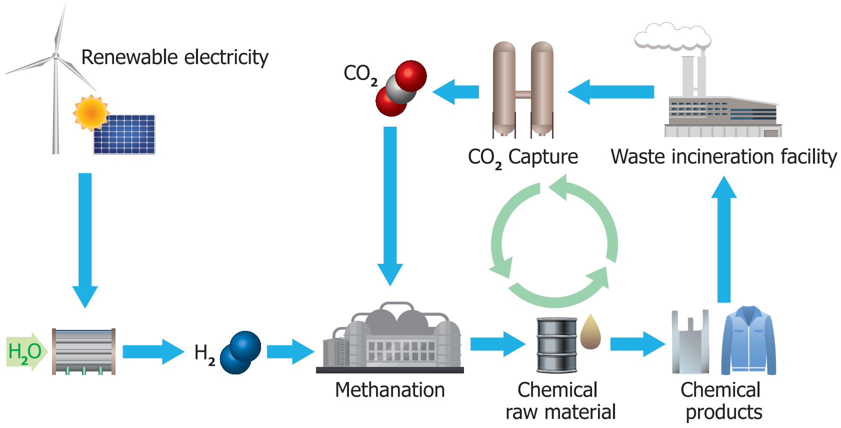
Substantial reduction of CO_2 is possible

CCS can significantly reduce CO_2 that is released to the atmosphere. Introduction of CCS to a coal-fired power plant with an output of 800 MW, that can supply power to about 270 thousand households, will prevent about 3.4 million tons of annual CO_2 emissions to the atmosphere. In addition to thermal power generation, CCS can be used in all fields that emit large amounts of CO_2, such as steelmaking, cement production and waste incineration.



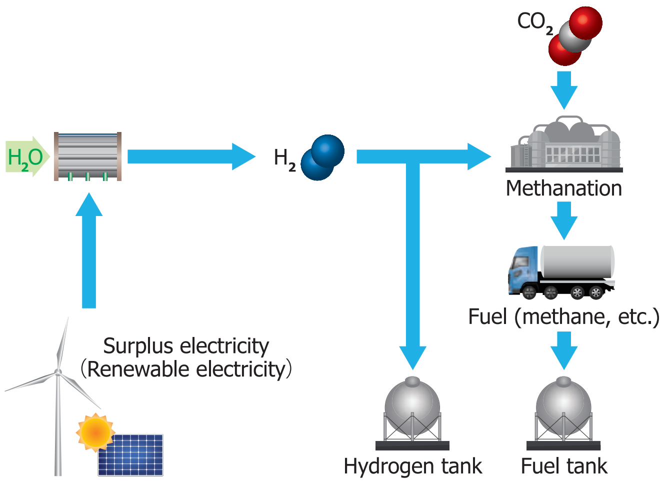
Recycling of carbon is possible

In a carbon neutral society, it is necessary to produce various products without depending on various fossil fuels (oil, coal, natural gas, etc.). Then, CCU becomes an important option. For example, we can produce chemical raw materials such as methane by reacting CO_2 with hydrogen produced using renewable energy. Combination of garbage incineration with CCU allows carbon to be recycled.



Can accelerate the spread of renewable energy (surplus electricity can be stored)

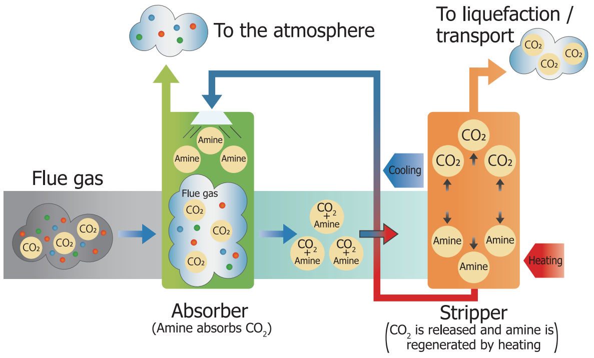
As the output of solar power or wind power generation tends to fluctuate, a mechanism for storing surplus and unusable electricity is required for wider use of these renewable energy technologies. One of the mechanisms is to produce and store hydrogen. The development of infrastructure for hydrogen production and storage is in progress but still insufficient. On the other hand, since methane is a fuel that can be used in the existing city gas infrastructure, if methane is made from hydrogen and CO_2, surplus electricity can be stored and used effectively without waiting for the development of hydrogen infrastructure, accelerating widespread use of renewable energy.



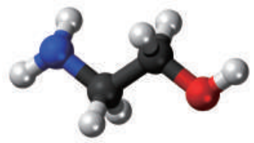
Technologies for CCUS

Capture

A chemical substance called amine is usually used to capture a large amount of highly pure CO_2 from the flue gas of thermal power plants or other facilities. By allowing the flue gas to contact an amine solution, the amine absorbs CO_2. By heating this solution containing CO_2 to about 120°C, amine and CO_2 are separated from each other and the CO_2 can be captured.



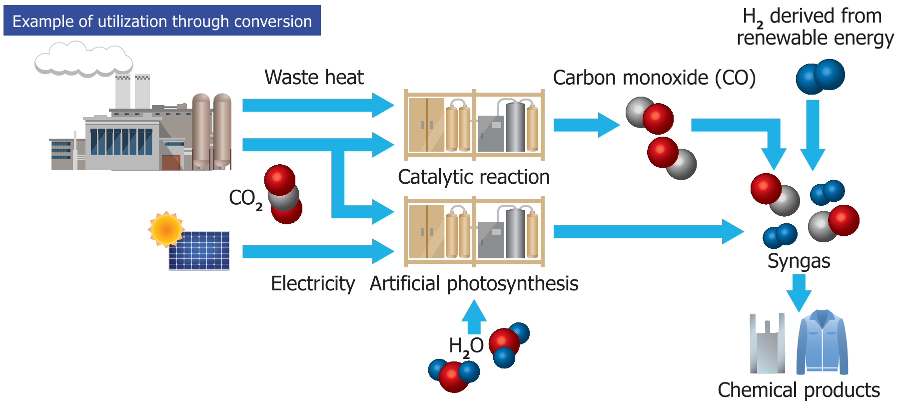
Principle of amine based CO_2 capture



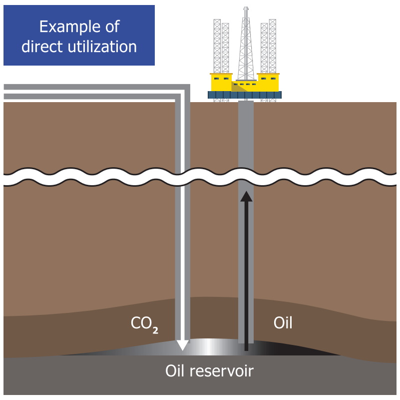
Molecule of monoethanolamine (MEA), an amine that is used for CO_2 capture.
It is also used to produce various products such as cosmetics and soap products. The uses of other various chemicals are also studied to capture CO_2 more effectively.

Utilization

One way to use CO_2 effectively as a resource is to convert CO_2 into fuel, plastics, etc. Another way is to use CO_2 directly as it is. Since CO_2 conversion into other substances requires energy, research is underway into methods that do not use fossil fuels to the extent possible, through utilization of renewable energy for instance. Examples of direct CO_2 use include enhanced oil recovery (EOR) which involves injecting CO_2 into existing oil fields to facilitate crude oil recovery, and CO_2 utilization for dry ice production.



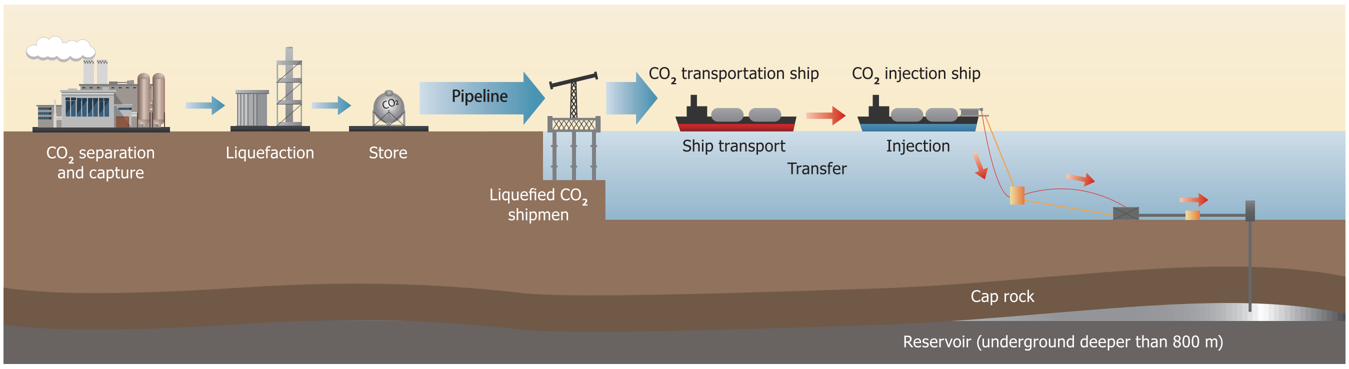
Production of syngas (CO + H_2) as a raw material for chemical products and fuels



EOR (Enhanced oil recovery)

Storage

CO_2 is stored in a "reservoir" that is composed of porous rock such as certain kinds of sandstone, deeper than 800 meters below the ground. The reservoir needs to be covered by a "cap rock" that is made of mudstone, etc., to prevent CO_2 leakage. In Japan, many candidate CO_2 storage sites are located offshore, beneath the seabed. Additionally, many large-scale CO_2 emission sources, including thermal power plants and other facilities, are in coastal areas. Therefore, CO_2 storage below the seabed is considered suitable and we must have a technology to transport CO_2 offshore from coastal areas, for example, transport by ship.



Subsea storage of CO_2

MOE's initiative for CO_2 capture and utilization (CCU)

Recognizing the importance of CCU in building a carbon-neutral society, the Ministry of the Environment carries out various programs related to CCU technologies, including CO_2 recycling and artificial photosynthesis.

Topic Speech by Prime Minister Abe at the World Economic Forum Annual Meeting (Davos)
23 January 2019

I would very much like to highlight what innovation does and how much innovation counts in tackling climate change, because, and this is an important "because," we NEED disruptions....We must invite more and still more disruptive innovations before it's too late. CO_2, ladies and gentlemen, could well be the best and most affordable resource for multiple uses. There is artificial photosynthesis....An old technology of methanation is getting attention anew to remove CO_2. It's time now to think about CCU, Carbon Capture AND Utilization.

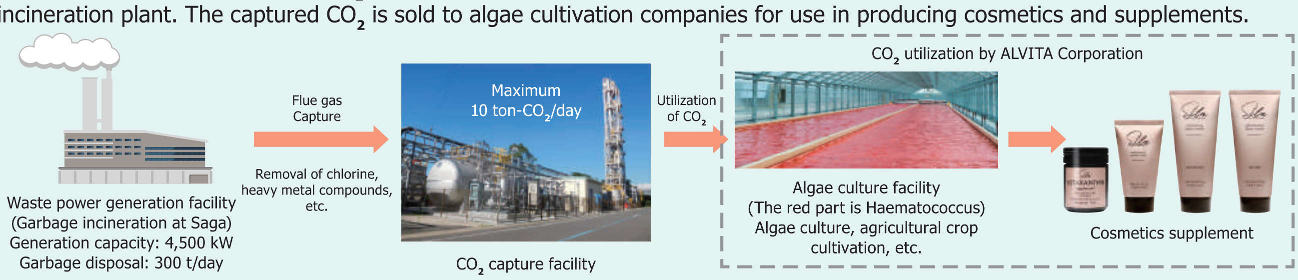
Text/Photo: Official Website of the Prime Minister of Japan and His Cabinet (https://www.kantei.go.jp/jp/98_abe/actions/201901/23wef.html)

Predecessor of current CCU projects

Incineration power generation with CCU in Saga City

Implementing Entity Saga City

For the first time in Japan, a CO_2 separation and capture facility has been installed at a waste-to-energy facility at an incineration plant. The captured CO_2 is sold to algae cultivation companies for use in producing cosmetics and supplements.

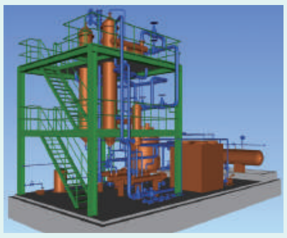


Recycling-oriented society models with CCU technologies

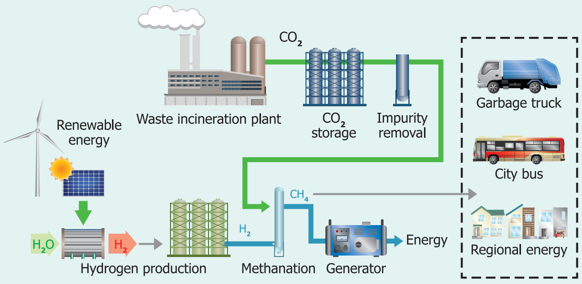
Methane production from CO_2 in incineration plant

Implementing Entity Hitachi Zosen Corporation

React the CO_2 emitted by an incineration plant with hydrogen produced from renewable energy to produce methane as a natural gas alternative.



Methanation facility (Illustrative)

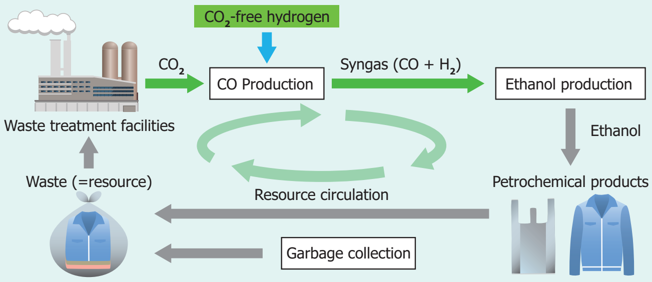


Ethanol production from CO_2 in a waste treatment facility

Implementing Entity Sekisui Chemical Co. Ltd.

Syngas is synthesized using CO_2 from a waste treatment facility and hydrogen produced from renewable energy. Ethanol is produced from syngas using a microbial catalyst.

Predecessor pilot plant



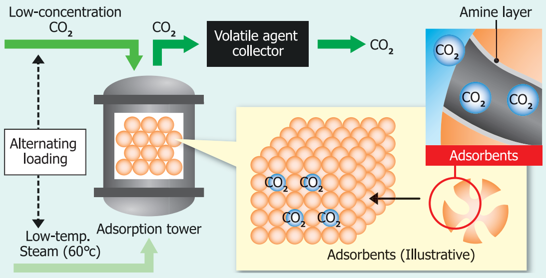
Low-concentration CO_2 capture and utilization system

Implementing Entity Kawasaki Heavy Industries, Ltd.

CO_2 in gas with a low CO_2 concentration, which has been difficult to use effectively, is captured with a special solid absorber while consuming less energy, aiming to realize Direct Air Capture.

CO_2 separation and capture facility (Illustrative)

Solid absorbent

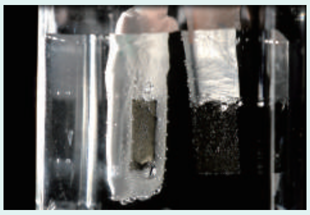


Recycling-oriented society models with artificial photosynthesis technologies

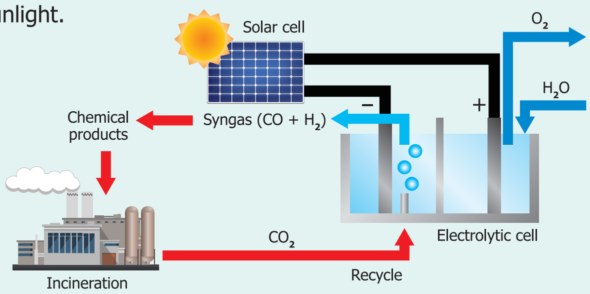
Efficient syngas production from CO_2 and water at ambient temperature and pressure

Implementing Entity Toyota Central R&D Labs, Inc.

Synthesize syngas with high efficiency from CO_2, water and sunlight.



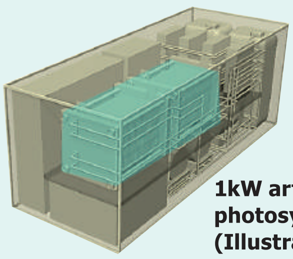
Syngas generation(laboratory scale)



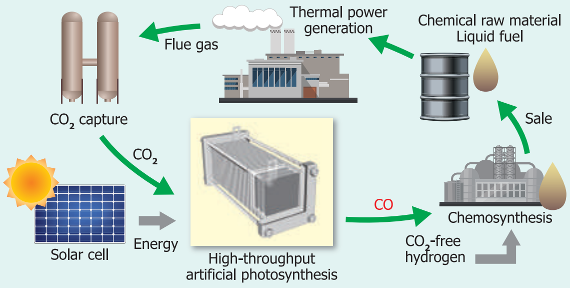
Localized CO_2 Utilization via Artificial Photosynthesis at a Large Emission Source

Implementing Entity Toshiba Corporation

Highly efficient production of carbon monoxide from CO_2 and sunlight to be used as a raw material for chemical products and fuel.



1kW artificial photosynthesis system (Illustrative)



MOE's initiative for CO_2 capture and storage (CCS)

Recognizing that carbon dioxide capture and storage (CCS) technology is indispensable to achieve the goal of long-term climate change mitigation, the Ministry of the Environment is working on various aspects of CCS which include demonstration of component technologies, investigation of potential CO_2 storage sites, research on environmental aspects and socio-economic issues.

CCS project for sustainable society

Led by a consortium consisting of 18 organizations, this project will demonstrate large scale CO_2 capture technology while paying attention to the environmental aspects and carry out various engineering and design studies on CO_2 transport and storage. The results of these technical projects will be reflected in the studies on the creation of an enabling environment for CCS in Japan.

[Consortium members]

Project leader: AKAI Makoto

Capture	Transport	Storage
TOSHIBA; MIZUHO Mizuho Information & Research Institute	UYENO; JGC JGC JAPAN CORPORATION; CHIYODA CORPORATION; TAISEI For a Lively World; THE UNIVERSITY OF TOKYO	MITSUBISHI MATERIALS; TAISEI For a Lively World; DIA CONSULTANTS; CRIEPI Central Research Institute of Electric Power Industry; Mitsubishi Corporation Exploration; KYUSHU UNIVERSITY; I²CNER; INPEX INPEX CORPORATION; JANUS JAPAN NUS CO.,LTD.; AIST; THE UNIVERSITY OF TOKYO

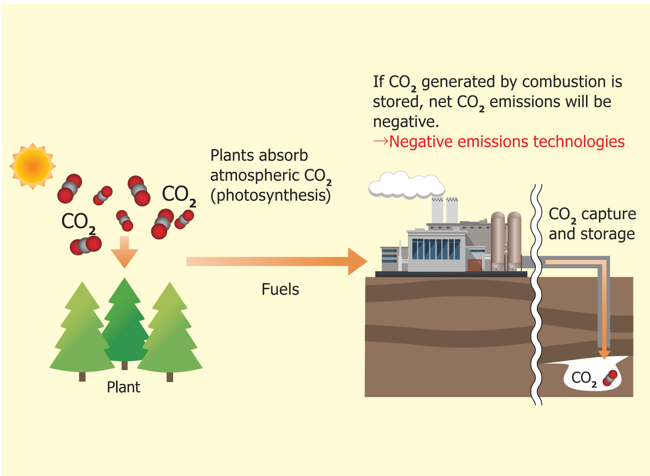
Policies and measures

QJ Science; JANUS JAPAN NUS CO.,LTD.; MIZUHO Mizuho Information & Research Institute; KYUSHU UNIVERSITY; I²CNER; TAIHEIYO CEMENT; JCOAL Japan Coal Energy Center

Verification of a large scale CO_2 capture facility integrated with a commercial thermal power plant

Construction of a large-scale demonstration facility is underway that can capture 50% of the CO_2 (>500 tons) emitted daily from SIGMA POWER Ariake Corporation's biomass power plant (Mikawa Power Plant, Omuta City, Fukuoka Prefecture, output 50MW). A series of test-runs will be aimed at verifying the performance and operability of the facility integrated with the power plant, identifying technological issues, estimating costs. In parallel with these, research on the environmental aspects of the amine-based CO_2 capture process is carried out which include examination of environmental impact assessment methodology, engineering studies to minimize the environmental burden, and verification that there will be almost no environmental impact associated with the facility.

CO_2 capture demonstration facility under construction (as of the end of January 2020)



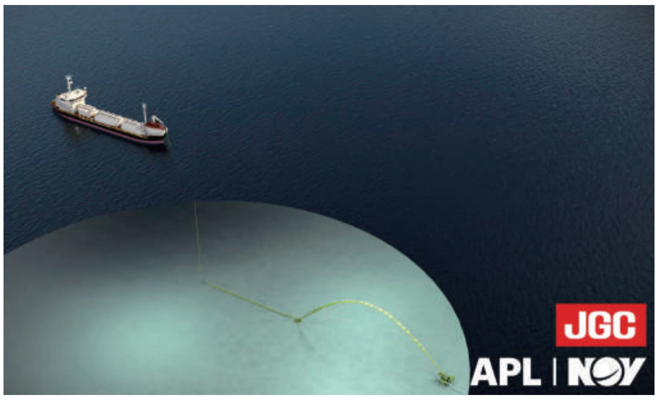
BECCS(Biomass Energy with CCS)

In biomass power generation, plants that have absorbed CO_2 from the atmosphere are burned. Therefore, if the CO_2 generated there is captured and stored underground by CCS, "negative emissions" of CO_2 to the air can be achieved, which can be considered as an equivalent process to capture and reduce CO_2 in the atmosphere. This combination is called BECCS (Biomass Energy with CCS) and is expected as a key technology for creating a carbon-neutral society in the future. With this project, the Mikawa Power Plant will become an innovative one which leads the way to BECCS.

Study of CO_2 transportation suitable for Japan

In Japan, CO_2 storage under the seabed is considered to be appropriate (see page 3). Therefore, engineering studies aiming at rapid establishment of CO_2 ship transport technology are underway. This technology has a high degree of flexibility to accommodate the variety of emission sources and storage sites and can respond to a wide range of transportation distances and water depths at storage sites.

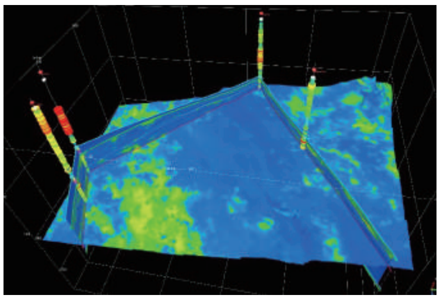
CO_2 transport ship (Illustrative)



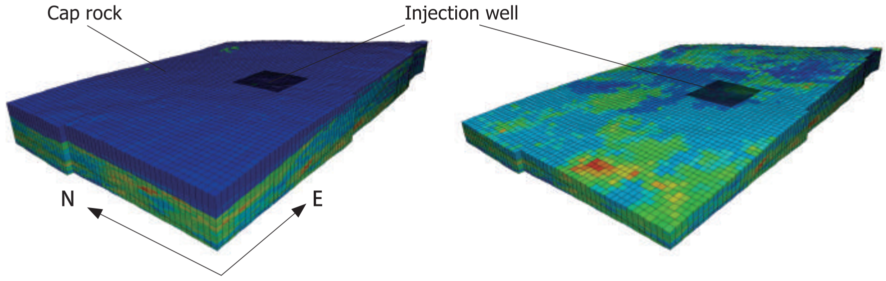
CO_2 injection into a sub-sea reservoir by ship
Illustrated by APL Norway AS and JAPAN CORPORATION

Study on management of CO_2 storage site

We are required to prevent the stored CO_2 leaking from the seabed, in order to avoid impacts on marine ecosystems as well as to ensure permanent CO_2 storage. For this reason, we are working to identify issues related to the reliability of CO_2 storage under the seabed, and to evaluate and plan measures to monitor stored CO_2, to identify unexpected leakage, and to mitigate leakage should it occur.



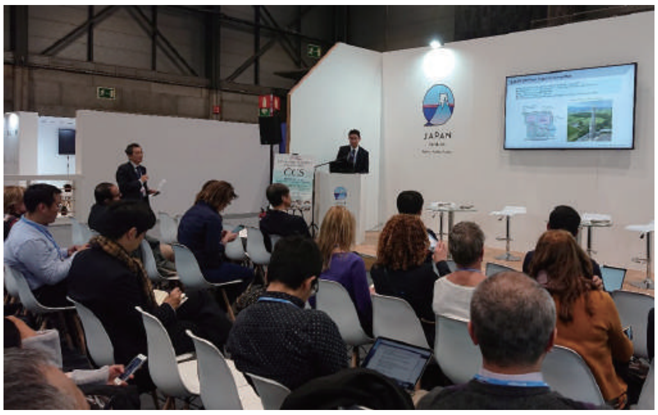
Characterization of porosity distribution within a sub-sea reservoir by using information from bore-holes and seismic surveys.
Illustrated by Mitsubishi Materials Corporation and NC Geophysical Survey Co.,Ltd.



Modeling of permeability distribution of the sub-sea reservoir (10km×8km area in this case). Numerical simulations using this model are conducted to estimate the dynamics of CO_2 under the cap rock.
Illustrated by Taisei Corporation

Modeling of permeability distribution of a sub-sea reservoir for the estimation of the dynamics of injected CO_2.

Comprehensive review of socio-political environment for CCS suitable for Japan

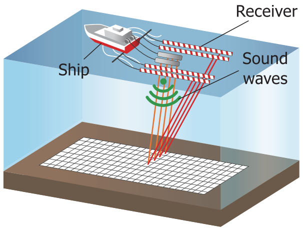


Speech on this CCS project in the UN Climate Change Conference COP 25.
Photo courtesy of Mizuho Information & Research Institute, Inc.

In this project, to complement technology development, we are conducting a comprehensive review of social and political issues to enable the smooth introduction of CCS into society as a global warming countermeasure. As part of the work, we are striving to examine the early introduction of CCS into the cement industry where it is theoretically difficult to reduce CO_2 emissions, realize energy savings in capture technology (a verification test is planned in the Integrated Test Center located in the Dry Fork Power Station, Wyoming, USA), enhance awareness of CCS, and create a platform for sharing and managing knowledge to support integration of knowledge about CCS.

Investigation of potential CO_2 storage sites (collaborative project with the Ministry of Economy, Trade and Industry)

Based on marine surveys, this project aims to select several promising storage sites around Japan, each site being expected to store more than 100 million tons of CO_2. In the survey, comprehensive evaluations of reservoirs will be performed based on the results of seismic surveys*, survey well drilling, and constructing geological models.



*Seismic surveys use reflected waves to determine the nature of sub-surface rock formations. The principle is similar to the ultrasonic examination for the human body.

Seismic survey by ship

Topic CCS projects in the world

A total of 19 large-scale CCS facilities are already in operation as of November 2019, and other projects are in the phase of either planning, construction or ready to start operation.

Quest
1. Canada
2. 1Mt
3. CO_2 generated during the upgrading of oil sands bitumen is captured and injected into an underground aquifer.

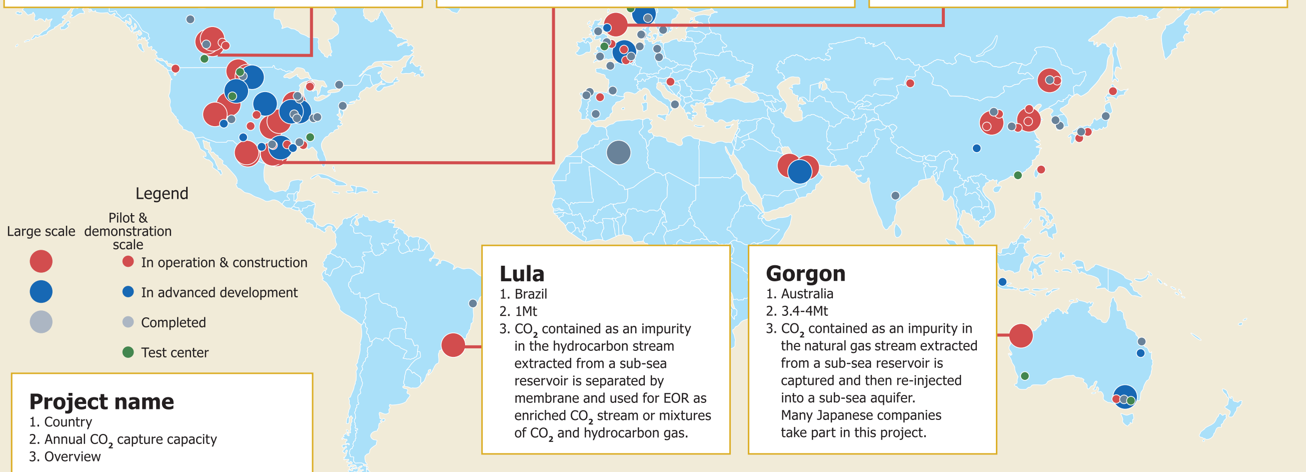
Photo courtesy of Shell

Petra Nova
1. USA
2. 1.4Mt
3. The second project in the world that has installed CCS (EOR) technology at a coal-fired power plant. Many Japanese companies take part in this project.

Photo courtesy of NRG Energy

Sleipner
1. Norway
2. 1Mt
3. The world's first commercial-scale CCS project. CO_2 contained as an impurity in the natural gas stream extracted from a sub-sea reservoir is captured and then re-injected into a sub-sea aquifer.

Photo courtesy of Harald Pettersen / © Equinor



Lula
1. Brazil
2. 1Mt
3. CO_2 contained as an impurity in the hydrocarbon stream extracted from a sub-sea reservoir is separated by membrane and used for EOR as enriched CO_2 stream or mixtures of CO_2 and hydrocarbon gas.

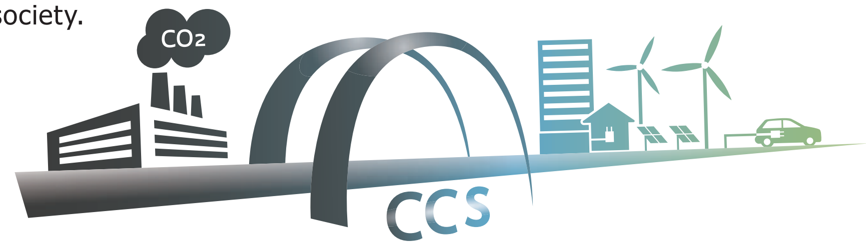
Gorgon
1. Australia
2. 3.4-4Mt
3. CO_2 contained as an impurity in the natural gas stream extracted from a sub-sea reservoir is captured and then re-injected into a sub-sea aquifer. Many Japanese companies take part in this project.

Project name
1. Country
2. Annual CO_2 capture capacity
3. Overview

Map and data: Global CCS Institute, 2019. The Global Status of CCS: 2019. Australia.

[CCS - a bridging technology for the future]

As the effects of climate change, such as recent unusual weather events and disasters becoming apparent, there is a global need to transform into a carbon-neutral society. However, for the time being, it is not expected that we can avoid CO_2 emissions from thermal power plants, factories and so on being released into the atmosphere. CCS has the potential to minimize the rapid increase of atmospheric CO_2. It is therefore called "bridging technology" to avoid the worst impacts of climate change and accelerate our steps toward a carbon-neutral society.



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