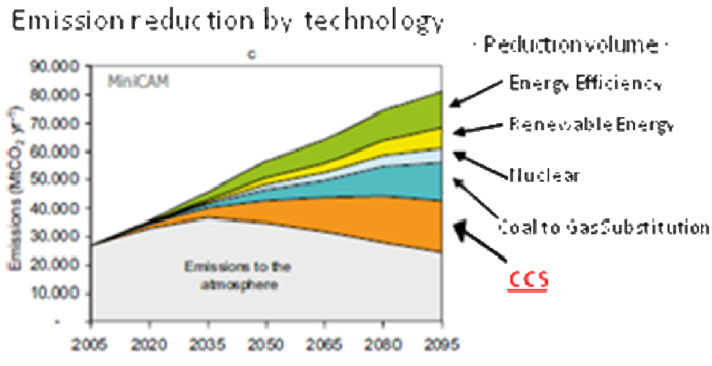
Carbon Capture and Storage Activities in Japan
(January, 2010)

Background

CCS is an important element to counter climate change. Several international organizations pointed out the importance of CCS. For example, the IPCC Special Report on CCS in 2005 shows "CCS as an option in the portfolio of mitigation actions for stabilization of atmospheric gas concentrations". Also, the IEA states in its report on CCS in 2008 that CCS will need to contribute nearly one-fifth of the emissions reductions in order to reduce global GHG emissions by 50% by 2050 at a reasonable cost. Therefore, CCS is of paramount interest as a GHG abatement option.



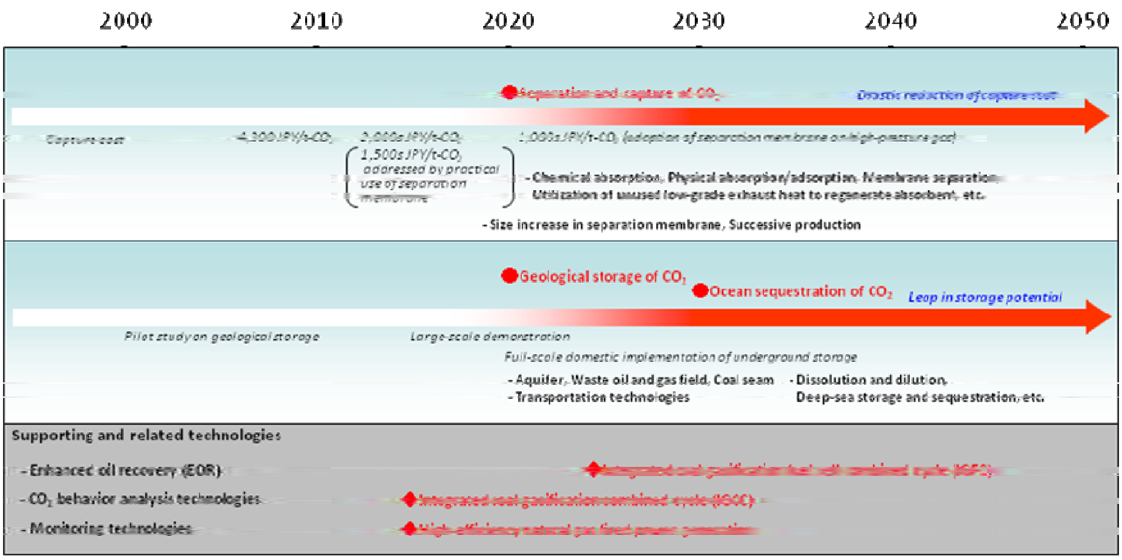
IPCC special report on CCS (2005)

Among the world leaders, G8 leaders made the following declaration at G8 Hokkaido Toyako summit:

"We strongly support the launching of 20 large-scale CCS demonstration projects globally by 2010, taking into account various national circumstances, with a view to beginning broad deployment of CCS by 2020."

Japanese government has a couple of strategies on CCS. For example, the "Action Plan for Achieving a Low-Carbon Society" and the "Cool Earth Innovation Energy Technology Program". In these strategies, we aim to launch large-scale CCS demonstration projects as soon as possible, to reduce the capture cost of CO_2 so as to commercialize CCS by 2020, and so on.

Fig. 1 Cool Earth-Innovative Energy Technology Program



Key Policy issues

The Japanese government has following three targets.

(1) Launching large scale CCS demonstration projects in Japan

(2) Commercialization of CCS through reducing the costs and risks, accomplishing the demonstrations and developing the public acceptance

(3) Developing international cooperation

For these targets, the Japanese government and industry have been implementing the following actions from 2008.

(1) Implementing body

Japanese companies willing to promote CCS established and shared an implementing body on CCS, Japan CCS Co., Ltd. (JCCS). The current shareholders of the company are 37 Japanese companies including utilities, steel and iron companies, oil companies, trading companies, and so on.

(2) Demonstration project

The Japanese government is launching a large-scale CCS demonstration project. JCCS has been planning and conducting investigations on the large-scale CCS demonstration projects. For example, JCCS has already conducted an offshore pipeline route survey and a 3D seismic survey at potential storage sites. Presently these projects are planned to store approximately 100,000 tonnes-CO_2/year for several years.

(3) R&D

The Japanese government supports the research and development of component technologies on CCS such as the advanced membrane technology, high efficiency chemical solvents, and advanced simulation and monitoring methods.

(4) Safe guideline for CCS demonstration projects

The Japanese government released a guideline "For safe operation of a CCS demonstration project" in August, 2009. The guideline shows standards in implementing a large-scale CCS demonstration projects from the safety and environmental viewpoints, and the safety rule for future CCS projects in practice will be examined separately later. The bodies who execute CCS demonstration projects are supposed to set up practical safety systems suitable for specific sites based on this guideline.

The guideline consists of nine technical chapters including following topics; Assessments of the storage site from geological aspects, Transportation of CO_2, Safety consideration of the surface facilities, Environmental impact assessment, Safety consideration of the wells, Safety considerations on CO_2 injection and operation, Standard of CO_2 concentration for injection, CO_2 monitoring, and Possible abnormalities and the safety measures.
(http://www.meti.go.jp/english/press/data/pdf/090807_02PDF.pdf)

(5) International cooperation

International cooperation is one of the most important aspects for promoting CCS. The Japanese government should promote international cooperation among developed and developing countries. Now we are cooperating on CCS with Australia, the U.S. and so on.

We show the details of Japanese CCS projects supported by Ministry of Economy, Trade and Industry (METI) as follows.

1. Demonstration

1-1. CCS large-scale demonstration project
1-2. Australia-Japan CO_2 Capture and Storage Demonstration Project
– Callide Oxyfuel Project -

2. Capture technology

2-1. Molecular Gate Membrane for CO_2 Capture
2-2. Development of Highly Efficient Oxygen-blown Coal Gasification Technology Combined with CO_2 Capture Process (EAGLE Project)
2-3. Cost Saving CO_2 Capture System (COCS Project)
- New Chemical Absorption System –

3. Monitoring, Simulation and so on

3-1. CO_2 Geological Storage (R&D of Monitoring, Simulation and so on)
3-2. Environmental Assessment of CO_2 Ocean Sequestration for Mitigation of Climate Change

1-1. CCS large-scale demonstration project

Outline

The Japanese government has been carrying out a program to conduct large-scale CCS demonstration projects in Japan with the object of developing and disseminating CCS technologies for reducing CO_2 emissions from industries. In this program, it is planned to demonstrate technologies to capture and inject over 100,000 tonnes-CO_2/year into offshore aquifer (below 1,000m depth) from large emissions sources such as thermal power plants. Monitoring methods, CO_2 long-term simulation methods and other related technologies are also studied to be utilized by the demonstration projects. At least one project is expected to commence injection around 2015 under the program funded by the government.

Japan CCS Co., Ltd., commissioned by the government, carried out a 3D seismic survey for site characterization and an offshore pipeline route survey over two candidate sites for a CCS demonstration project in 2009. The both sites, along with other candidate sites, are being evaluated whether the sites are suitable for large scale demonstration projects.

Several monitoring methods are also considered for the CCS demonstration project. 3D and 2D seismic survey and VSP (Vertical Seismic Profiling) are considered for monitoring of injected CO_2 distribution in the reservoir, chemical and physical marine surveys for seepage detection, and seismicity monitoring for assessing any impact to the surface and subsurface facilities of the CCS demonstration.

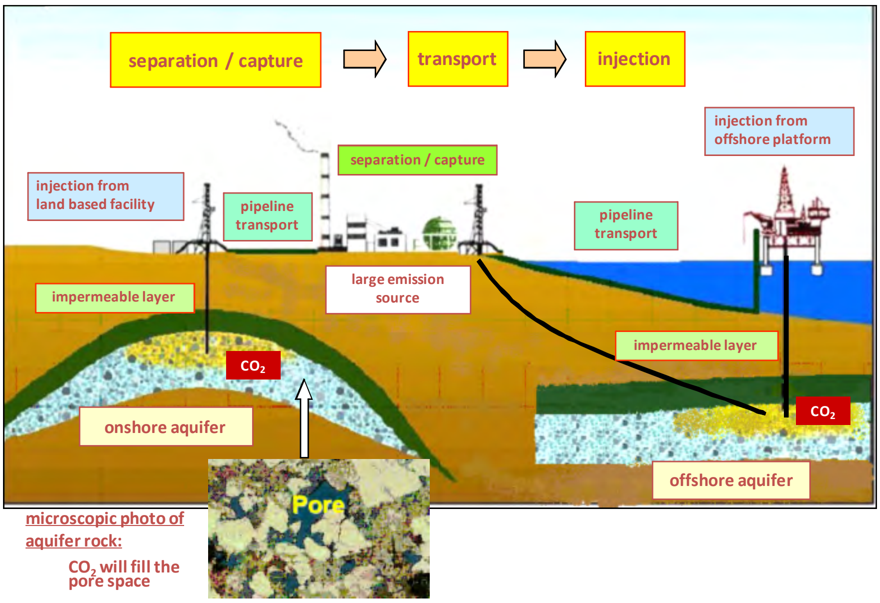


Fig.1 Scheme of CCS

1-2. Australia-Japan CO_2 Capture and Storage Demonstration Project
- Callide Oxyfuel Project -

Introduction

Oxyfuel combustion technology is one of the prospective candidates of CO_2 capture system from coal fired power plants. The fundamental elements of the technologies on this area were developed from 1990's in Japan and is now proceeded to develop through the demonstration project that is called "Callide Oxyfuel Project" located in Australia. This project has started in March, 2008, with collaboration between Australia and Japan after the feasibility study from 2004 to 2005.

Oxyfuel process with CCS (CO_2 Capture and Storage) as shown in Figure 1 has following main attractive characteristics:

- Oxyfuel process is easier to commercialize as compared with other CO_2 capture process, because of the integration of the conventional technology.
- It is theoretically possible to concentrate CO_2 in the flue gas up to 90 % and higher. This enables us to capture CO_2 from the flue gas with high efficiency and low energy consumption.
- NO_x emission from the oxyfuel boiler is drastically reduced comparing with conventional process, due to the recirculation system of the flue gas into the furnace.

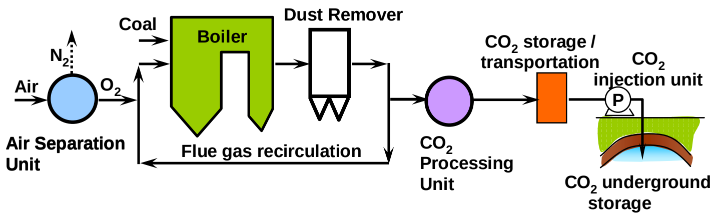


Fig.1 Oxyfuel process with CCS

Callide Oxyfuel Project

Table 1 shows the project schedule. Our project is divided into 3 kinds of main stage. FEED of stage 1 was conducted during the feasibility study stage, and retrofit work at site has now started. We expect to start the oxyfuel demonstration operation at middle of 2011. Detailed site selection study of stage 2 is now conducted. CO_2 from oxyfuel power plant will be injected from the end of 2011 in our plan. The project will be summarized in 2016.

Table.1 Project Schedule

Items	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16
Stage 1 Boiler retrofit & CO_2 capture	FEED		Retrofit work & commissioning			Demonstration operation					
Stage 2 CO_2 storage		Site selection / Trial drilling			Construction & commissioning	CO_2 injection & monitoring					
Stage 3 Summary											

Objectives of Callide Oxyfuel Project are to demonstrate the CCS integrated process using oxyfuel combustion technology with the application to the existing coal fired power generation system that is Callide-A power station No.4 unit owned by CS Energy in Queensland, Australia and to evaluate the performance for the large-scale coal fired power plant with CCS towards the commercialization.

In Callide-A No.4 unit that is capacity of 30MWe, air separation units (330 tonnes/hour, 2units)

will be installed, boiler system will be modified into oxyfuel process and CO_2 compression and purification unit that is capacity of 75 tonnes-CO_2/day will also be installed with temporary CO_2 storage tank.
Our project has a plan to store CO_2 at the location in the approximately 300km west of Callide-A power station.

Notes
The project partners are J-POWER, IHI, Mitsui, JCOAL, CS Energy, Xstrata Coal, Schlumberger, and Australian Coal Association, and funded by Japanese Government (METI), Australian Government and Queensland Government.

2-1. Molecular Gate Membrane for CO_2 Capture

CSLF Recognition Project "CO_2 Separation from Pressurized Gas Stream"

Outline

Reduction of CO_2 capture cost is urgent requirement for implementation of CO_2 capture and storage (CCS). RITE is currently developing a CO_2 molecular gate membrane with the goal of producing a new, high-performance CO_2 capture technology. The membrane will be preferably applicable to CO_2 capture from pressurized gas streams, such as IGCC with CCS.

The purpose of this project is to develop a molecular gate membrane module that can greatly reduce the energy requirements and costs of CO_2 capture. For this purpose, the major objectives of this project are as follows:

1. Development of materials that have molecular gate function, which show excellent selectivity and permeability

2. Development of the composite membrane and its module

3. Testing of the module.

This project is being conducted from FY2006 to FY2010. Figure 1 shows the basic outline of the CO_2 molecular gate function. The separation membrane (separation function layer) has a pathway through which gas molecules pass. In RITE's CO_2 molecular gate membrane, the pathway for gas molecules is occupied solely by CO_2, which acts as a gate to block the passage of other gases. Consequently, the amount of the other gas leaking to the other side of the membrane is greatly limited and high concentrations of CO_2 can be obtained.

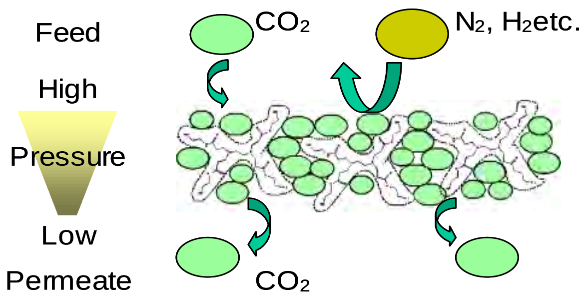


Fig.1 Concept of CO_2 molecular gate membrane

International collaboration is the key to the development and implementation of CCS technologies. In developing this CO_2 molecular gate membrane, RITE conducted joint research with the US DOE/NETL and the University of Texas at Austin (UTA). RITE also involves four major membrane companies, Daicel Chemical Industries, Ltd, Kuraray Co., Ltd., Nitto Denko Corporation, Toray Industries, Inc., and Nippon Steel Engineering Co., Ltd.

RITE has developed novel dendrimer hybrid membranes with polymeric matrix (Fig. 2). The dendrimer hybrid membranes show the world largest CO_2 selectivity over H_2 of more than 30 at an elevated pressure, which encourages effective CO_2 capture from IGCC process gases.

Membrane modules of the dendrimer hybrid membranes are now under trial production by four major membrane companies (Fig. 3)

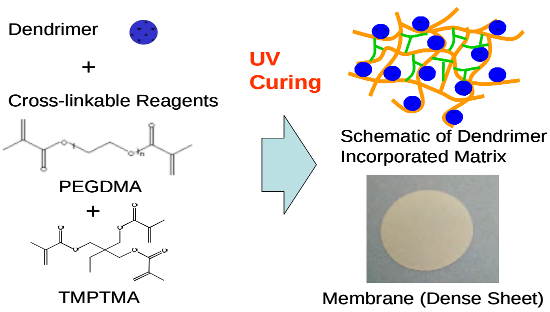


Fig.2 Dendrimer incorporated membrane

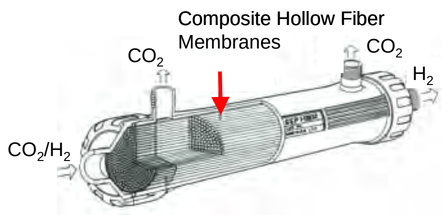


Fig.3 Conceptual drawing of dendrimer membrane module (Hollow fiber type)

2-2. **Development of Highly Efficient Oxygen-blown Coal Gasification Technology Combined with CO_2 Capture Process (EAGLE Project)**

Outline

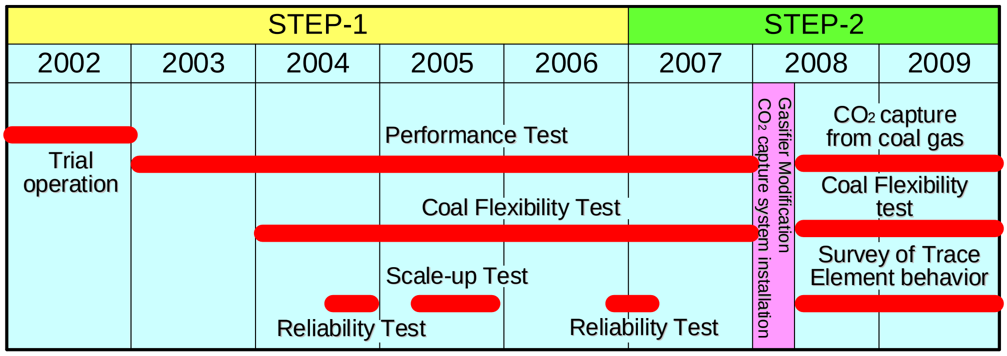
Coal possesses such features as abundant distribution of reserves in all parts of the world and is positioned to be an important energy resource well into the future. However, reducing the output of carbon dioxide (CO_2) is a pressing task driven by the need for global warming prevention on a worldwide scale; and the combination of a high-efficiency generation technology with CO_2 separation and recovery technology is currently regarded as an effective measure.

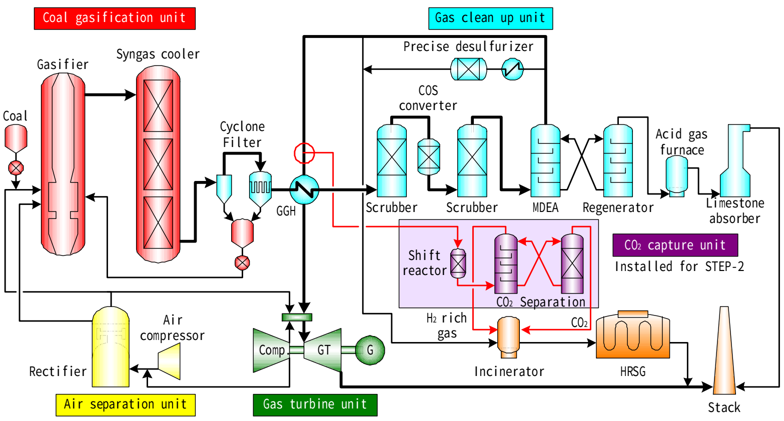
The EAGLE (Coal Energy Application for Gas, Liquid & Electricity) project is aimed at raising the efficiency of power generation from coal so as to reduce the amount of CO_2 emitted per unit power generated. Using coal gasification and a combination of methods for generating electrical power, much higher efficiency is achieved than the conventional pulverized coal-fired thermal power generation system. Moreover, if we can efficiently capture CO_2 in the coal gas and store it, we will be much closer to our ultimate goal of a zero-emission power plant.

Figure 1 gives the development schedule for the EAGLE project. In the STEP-1, which continued until FY2006, J-POWER carried out research on the development of an oxygen-blown coal gasifier and the establishment of gas clean-up technology, and succeeded in attaining our first development goal. J-POWER began STEP-2 in FY2007 as an approach to achieving zero emission. In this phase, J-POWER's R&D goals include a technology for the separation and recovery of CO_2 from coal gas.

Figure 2 illustrates the EAGLE pilot plant's system flow and equipment specifications.

Fig.1 Schedule of EAGLE project





Equipments	Specifications
Coal Gasifier	oxygen-blown, one chamber two stage, spiral flow, entrained flow
Coal feed	150t/day
Gasification pressure	2.5MPa
Gas Clean-up	MDEA (methyl di ethanol amine)
Precise desulfurizer	Zinc oxide
Air separation	Pressurized cryogenic
Purity of Oxygen	95%
GT generator output	8,000kW
CO_2 Capture (Installed for STEP-2)	Inlet gas volume : 1,000m^3N/hr (10% of syngas flow) Shift reactor : Fe/Cu catalyst CO_2 absorber : MDEA Captured CO_2 amount : 1t/hr (max)

Fig.2 System flow of EAGLE pilot plant

Results

J-POWER verified basic performance and long-term reliability, and acquired test data necessary for designing a larger plant. As basic performance measures, the pilot plant has achieved carbon conversion ratio of above 99% (indicating the extent to which carbon in coal is converted to gas) and cold gas efficiency of 82% (a measure of how much of the energy in coal is converted to energy in the generated gas). As for equipment reliability, J-POWER have achieved continuous operation of 1,015hours, with rated load maintained over nearly the entire period, which confirmed the overall reliability of the plant. For the elements that will need to be modified when scaling up the design to that of a demonstration plant, J-POWER has acquired the necessary data by conducting simulations in the pilot plant.

Current tasks

With basic performance and reliability confirmed, J-POWER is verifying the following items toward practical gasifier implementation.

1. Demonstration of CO_2 capture technology

   CO_2 separation and recovery facilities were newly set up. It branches 10% of the coal gas after the gas clean-up facilities, converts the carbon monoxide (CO) in the coal gas to carbon dioxide (CO_2) and hydrogen (H_2) by shift reaction, increases the CO_2 concentration, and then accomplishes separation and recovery of CO_2 by the chemical absorption method. J-POWER is verifying basic performance of this facility.

2. Coal type expansion testing

   Just as coal is distributed in all parts of the world, it possesses various characteristics. Since the EAGLE gasifier is an oxygen-blown entrained bed gasifier which melts coal ash, coal with a comparatively low ash melting temperature is well suited to it. Aimed at the establishment of a gasification technology for coal with a higher melting point of ash, J-POWER is verifying the usability with a wide range of coal types.

3. Survey on behavior of trace elements

   Coal contains trace elements such as halogens and heavy metals, but not all aspects of their behavior in the coal gasification system have been clarified. Therefore, J-POWER is attempting to understand the behavior of trace elements in the entire pilot plant.

Notes

J-POWER has conducted this technical development as a joint research project with the New Energy and Industrial Technology Development Organization (NEDO).

2-3. Cost Saving CO_2 Capture System (COCS Project) - New Chemical Absorption System -

Outline

The objective of this project is to reduce the CO_2 capture cost by half to develop innovative amine solvent and new waste heat recovery system in steel works.

CCS (Carbon capture and storage) is one of promising countermeasure against CO_2 global warming issues. Since CO_2 capture in CCS constitutes more than 70% of all the CCS cost, it has to be reduced drastically by near-term deployment of CCS. As for the capture technologies, a chemical absorption method is promising because it can be easily and practically made for large scale CO_2 emission sources. The reduction of capture cost by chemical absorption accelerates to utilize it as means as practical CCS in the near future. Based on these circumstances, RITE had engaged in a new CO_2 capture project by chemical absorption system with collaboration of four Japanese companies from April 2004 to March 2009.

First, we made innovative amine absorbents, which have high absorption rate and low desorption energy, about 2.5- 2.65 GJ/tonne-CO_2 with CO_2 capture on a blast furnace in a steel works.

Second, we developed heat recovery technologies for waste heat sources (sensible heat of slag, sensible heat of coke oven gas, etc.) and the production of ¥1,350 steam for reboiler at CO_2 capture system. We could estimate the cost for the CO_2 capture with the combination both the absorbent and the heat recovery system that was about ¥3,000. The cost is reduced by almost 50% less than that of MEA and new steam production using fossil fuel.

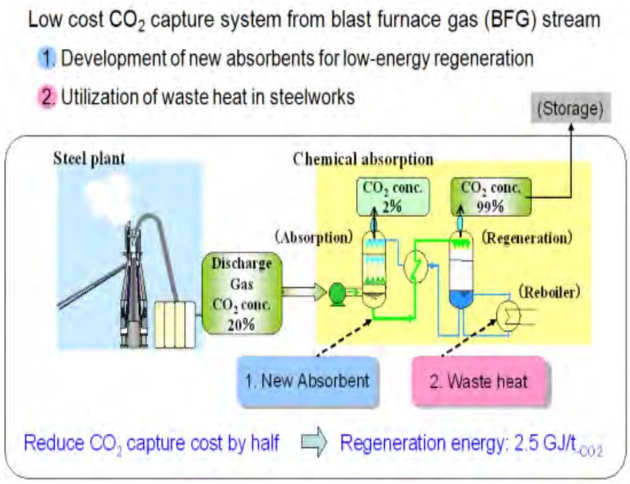


Fig.1 Object of COCS Project

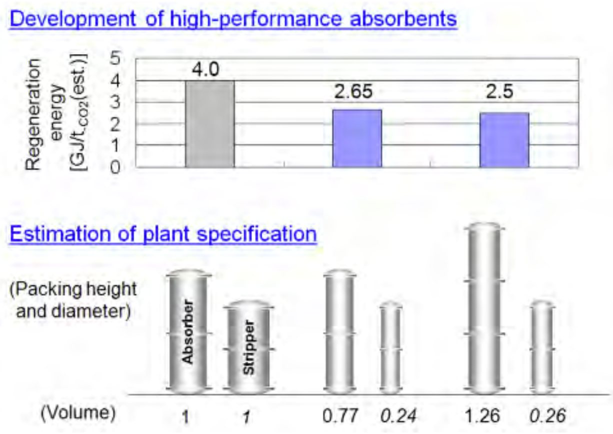


Fig.2 Results of COCS Project

Results

Case study in a standard steel works for CO_2 capture with innovative amine solvent; RITE-5 at a blast furnace

- CO_2 reboiler energy input: about 2.65 GJ/tonne-CO_2 as a 3,000 tonnes/day plant
- Amount of production steam by the heat recovery system: 2,400 TJ/year
- Steam generation cost for reboiler input: ¥1,350
- Amount of captured CO_2: 950,000 tonnes/year is equivalent to 15% CO_2 in the steel works

Future Work

30 tonnes/day of CO_2 capture test plant at Kimitsu steel works of Nippon Steel Corporation has been building and the experimental using the innovative amine solvent will be started by April 2010.

RITE is continuing to develop higher - performance absorbent than that of former developed amine absorbent.

3-1. CO_2 Geological Storage (R&D of Monitoring, Simulation and so on)

Outline

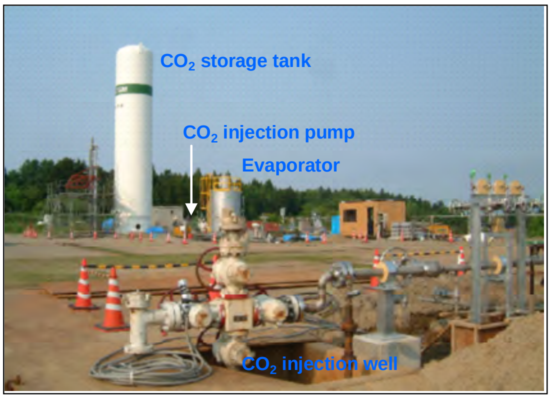
Greenhouse Gases such as carbon dioxide is the major cause of the problem on the global warming. This problem is associated with the energy policy and the economic activity for each country. All the countries of the world collaborate and work together to be settled it. Under this background, UNFCCC was took effect in March 1994. In addition the Kyoto protocol was took effect in February 2005. Japanese government issued the outline plane against the problem of global warming in March 2003 to reach the emission-reduction targets for greenhouse gas. In this statement the technology for CO_2 storage and fixation is positioned as the innovative technology that is over the current level of technique and it is demanded that this technology should be rapidly built up.

From this social background, we need to build up the technology that is able to inject CO_2 safely and storage CO_2 stably. To make sure the potential of CO_2 storage in Japan and study the framework of methodology for the safety assessment and the system of the law and the regulation for the CO_2 storage, the project for the development of the geological storage was started in 2002.

Results

To obtain the scientific and technological knowledge and experiences of the CO_2 geological storage, RITE had conducted the demonstration of CO_2 injection. RITE has studied on the research for the mechanism of CO_2 geological storage, the estimation of CO_2 storage potential and the development of the method for the safety assessment of the geological CO_2 storage. We set out the development of the methodology for the safety assessment for the commercial scale CCS.

RITE investigated for the possible of CO_2 geological storage into the anomalous stratum in Japan and demonstrated CO_2 injection in Nagaoka, Niigata prefecture, Japan. 10,400 tonnes-CO_2 was successfully injected at the rate of 20-40 tonnes-CO_2/day into a saline aquifer of 1,100m depth from July 2003 to February 2005. During the injection, Niigata Chuetsu Earthquake occurred on 23rd Oct 2004. The main shock was the magnitude 6.8 at 10km depth and seismic intensity at Nagaoka site was 7. Injection was automatically stopped at the main shock. After checking the condition of the equipment, no any leakage and no damage by this earthquake was confirmed. Injection



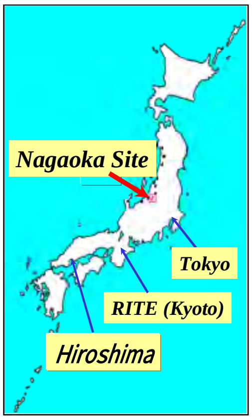


Table 1 Outline of the demonstration of CO2 injection

CO_2 injection period	Jul. 2003 to Jan. 2005
CO_2 injected amount	about 10,400 t-CO_2
CO_2 injection rate	20 to 40 t-CO_2/day
CO_2 source	purchased commercial CO_2
Monitoring	well logging, crosswell seismic tomography, microseismicity, formation water sampling, etc.

Table 2 Outline of Niigata Chuetsu Earthquake

Niigata Chuetsu Earthquake
Main shock: 23 Oct 2004
M6.8 at 10km depth
Seismic intensity: 7
→ **Injection was automatically stopped at the main shock.**

was carefully resumed in 6th Dec. 2004.
The following result from this demonstration has been obtained.

- The safety CO_2 injection was conducted.
- The stable CO_2 storage into aquifer by the micro-seismic measurement, well-logging and cross-well seismic tomography was confirmed.
- Based on these data, RITE has developed the simulator, GEM-GHG, that can predict the behavior of stored CO_2 for anomalous formation. The prediction of the CO_2 condition after 1,000 years has calculated by the historical matching using monitoring results.
- The dissolution of injected CO_2 was observed by the resistivity.

The basic knowledge of aquifer storage on Japan is obtained.

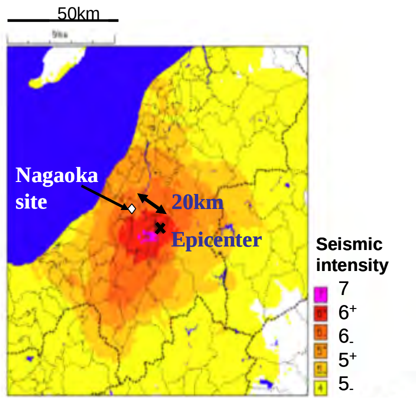


Fig.1 Location of Earthquake

Current Activity
RITE has supported the large scale demonstration of CO_2 geological storage and conducted following researches especially with the view of establishing the safety assessment methodologies and the suitable technique for CO_2 storage in Japan.

- Characterization of reservoirs
- Investigation of the mechanism of long-term CO_2 behavior in reservoirs
- Development of the technologies to survey the geological structures under sea bottom

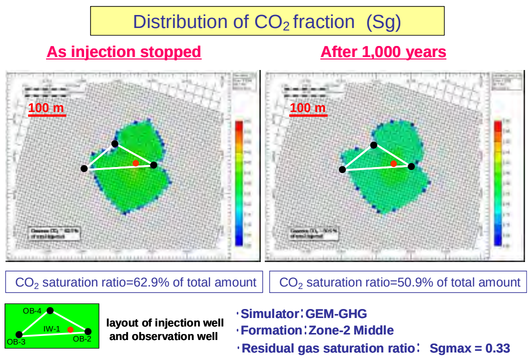


Fig.2 Comparison of CO_2 condition

Based on these knowledge and experience from these results of the demonstrated injection and several studies, the following targets are storage potential evaluation, safety assessment and large scale demonstration.

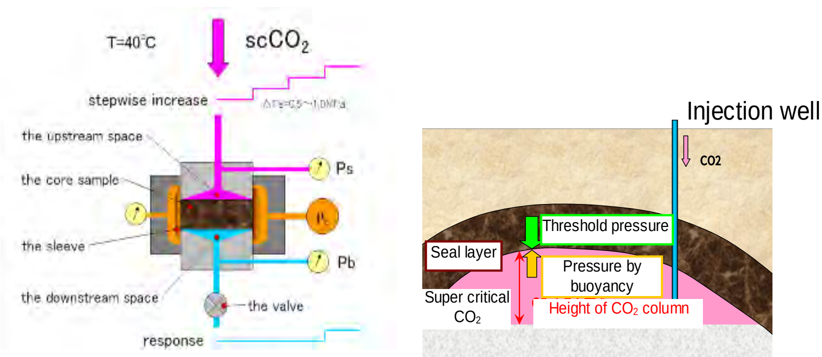


Fig.3 Concept of evaluation of shielding property of cap rock

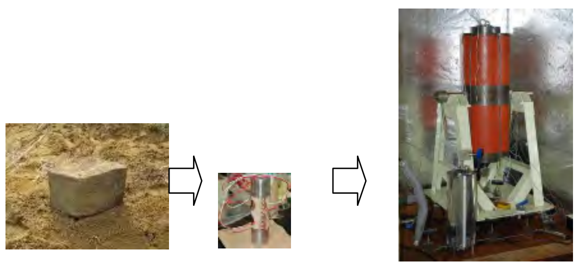


Fig.4 Concept of the testing the performance of geological structure

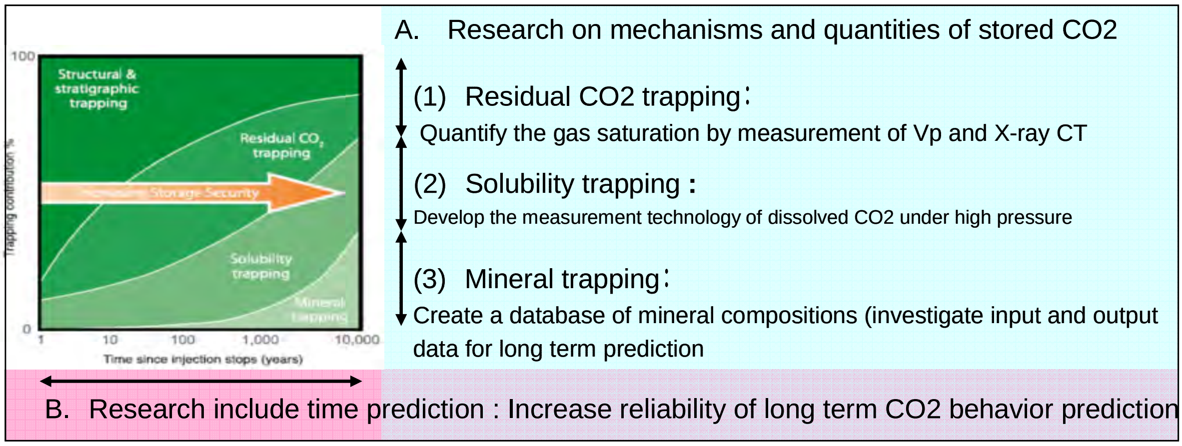


Fig.5 Concept of the study for the breakthrough the mechanism for long-term CO_2 behavior

3-2. Environmental Assessment of CO_2 Ocean Sequestration for Mitigation of Climate Change

Background:

In order to control global warming, it is necessary to decrease the discharge of CO_2 into the atmosphere. CO_2 ocean sequestration technology is a kind of enhancement technology for the natural process of ocean, which is the absorption of CO_2 in the atmosphere into the mid-depth of ocean. The CO_2 emission over several centuries causes the increase of atmospheric CO_2 concentration, and the pH of surface of the oceans decreases during taking up CO_2, and finally, the atmospheric CO_2 concentration decrease in equilibrium. If captured CO_2 is injected to mid-depth layer without contacting the sea water of surface layer, the marine organism of the surface layer is not affected by the injected CO_2. Injected CO_2 to mid-depth is dissolved into the sea water as well as the atmospheric CO_2 is naturally absorbed to the ocean (Fig.1).

Before the implementation of ocean sequestration, the validity of this technology should be evaluated. The biological impact study and the development of the monitoring technology are necessary for CO_2 ocean sequestration. And also, the feasibility study of CO_2 dilution technology should be implemented to confirm the viability of ocean sequestration.

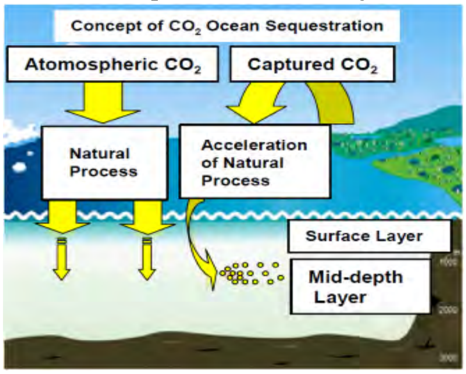


Fig.1 Concept of CO_2 Ocean Sequestration

Primary Project Goal:

Japan was developing environmental assessment technology of CO_2 ocean sequestration using Moving Ship system for the R&D aimed toward a practical system that could make a significant contribution to reducing atmospheric CO_2. The concept of Moving Ship system is shown in Fig.2.

The liquefied CO_2 injected as droplets into the mid-depths of ocean (1,500-2,500m) is diluted and dissolved in sea water. The project goals of the second phase started in 2002 were the assessment of ocean sequestration validity, the development of environmental impact assessment technology and the development of CO_2 dilution technology.

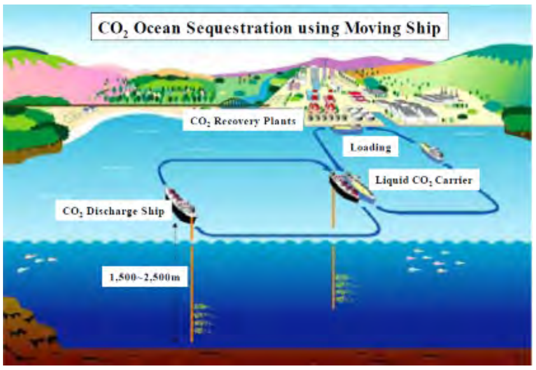


Fig. 2 The image of CO_2 Ocean Sequestration

Objectives:

The major objectives of this project were as follows:

(1) Biological Impact Assessment on CO_2 Ocean Sequestration Technology: CO_2 impact on ocean environment, especially impact on biota in mid-depth of ocean, must be elucidated before practical implementation of CO_2 ocean sequestration,

(2) Prediction of CO_2 behavior in the ocean, and technical feasibility study of CO_2 Ocean Sequestration: Development of CO_2 dilution technology is needed to reduce CO_2 impacts on ocean environment as much as possible and its results are applied to the study on the

environmental impact assessment technology.

(3) Trend survey on CO_2 Ocean Sequestration technology: The effectiveness of ocean sequestration technology must be elucidated by additional investigations using newly developed models based on the accumulated scientific knowledge.

Major Results:
Outline of R&D results in FY2002 to FY2009 are followings (Fig.3);

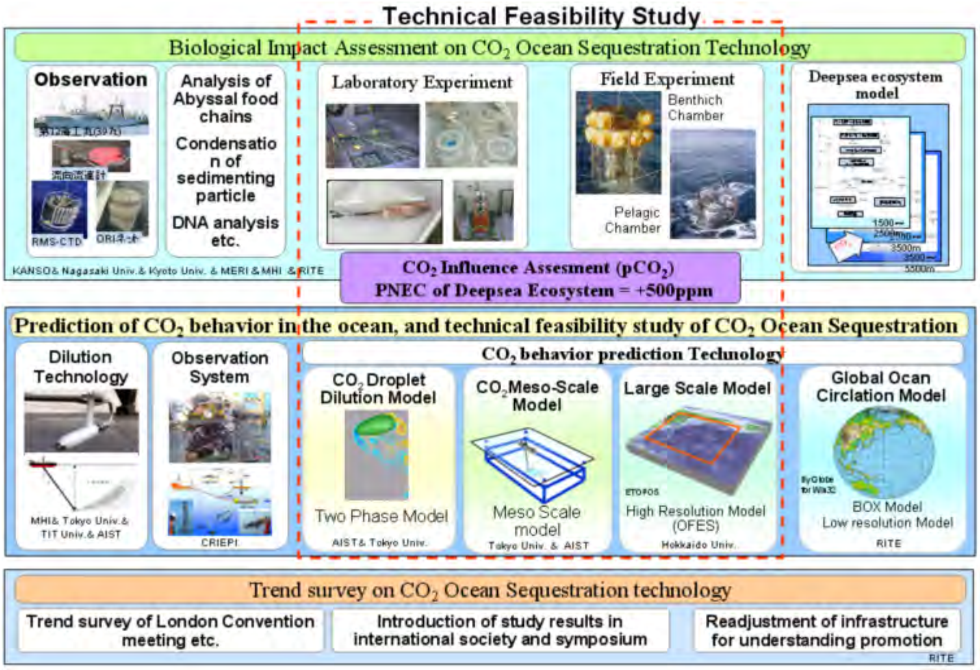


Fig.3 Technological development of Ocean Sequestration Project

(1) Biological Impact Assessment on CO_2 Ocean Sequestration Technology: In the development of biological impact assessment method, the accuracy of three-dimensional ecosystem model was improved. In the collection of the data on biological impact in the deep ocean, assembly of a Pelagic Chamber System was fundamentally completed. In the testing of its operation capabilities, preliminary field observation was conducted and oxygen consumption rate and gene analysis of micro-organism can be adapted as detection methods.

In studies of CO_2 impact on deep-sea organisms, the stable isotope ratio of settling particles in the seawaters and predator food chain of copepod were analyzed. In order to integrate the effect of increase of CO_2 concentration, the parameter fluctuation rate was detected with ecosystem model. In view of CO_2 effects on deep-sea flux, dynamic status of the ecosystem and carbonate were elucidated. Especially, technological introduction of the DGGE method to analyze genes linked to production of N_2O in relation with denitrifying activity was technologically studied. Based on gene analysis from the sample acquired by Pelagic Chamber experiment, it was scientifically confirmed that increase of CO_2 concentration affected index number of the species, but did not diversity index. As one methodology for assessment of CO_2 impact on bacterial communities, basic study for distinction method of bacteria that has physiological activity as "viable bacteria" was carried out. In the study of acute impact on the marine organisms under the high CO_2 concentration, the results of experiment show that high pressure condition did not influence deep-sea fish for the acute impact.

(2) Prediction of CO_2 behavior in the ocean, and technical feasibility study of CO_2 Ocean Sequestration: In the development of CO_2 behavior observation and prediction technology in the ocean, an observation of natural analogue site and development of meso-scale and large-scale ocean model was carried out. Also, development of prediction technology of dissolution and behavior of CO_2 droplets was propelled. In the case study of CO_2 ocean sequestration, the cost of sequestrated CO_2 quantities and the avoided cost considered additional CO_2 were calculated. Technical feasibility of a small-scale field experiment was also investigated. Furthermore, new global ocean box model was developed to evaluate the effectiveness of CO_2 ocean sequestration technology for CO_2 reduction in the atmosphere.

(3) Trend survey on CO_2 ocean sequestration technology: The trend survey of the international and domestic law and the trend surveys of international research organizations and international academic conferences were carried out for the construction of the scientific and technical international network of oceanic sequestration, and the future action plan was proposed Especially, London Convention was focused to identify the feasibility of field experiment of ocean sequestration. Project results on CO_2 biological impact study was presented at the Science Group meeting of London Convention. For the purpose of gaining public acceptance, project website was periodically updated and preparation of web forum system was promoted as base system.