# RITE Today

Research Institute of Innovative Technology for the Earth

2005
vol. 01

Annual Report
Trial Version

Ohga-lotus bloomed in RITE

◇◆ CONTENTS ◆◇



**Research Institute of Innovative Technology for the Earth**

# Expectations for Cloning Technologies

Masaharu Higuchi, Senior Managing Director
Research Institute of Innovative Technology for the Earth (RITE)

Near the end of July 2005, about 24,000 eucalyptus seedlings produced using advanced cloning technologies were planted on the outskirts of Collie, a small city located about 200 km south of Perth in Western Australia.

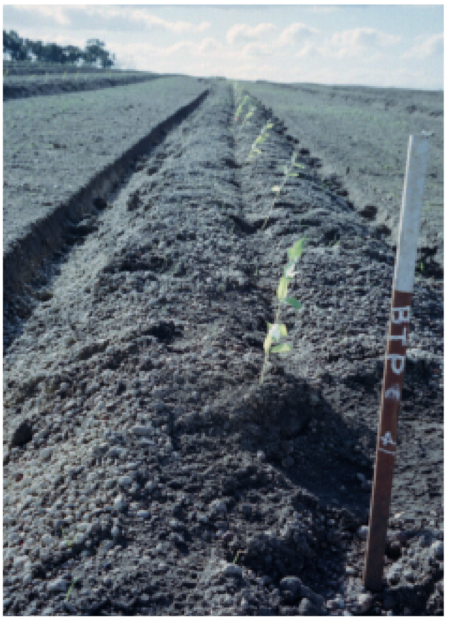
The Research Institute of Innovative Technology for the Earth (RITE) has undertaken these plantation activities for a test that comprises a part of a "Large-scale $CO_2$ Fixation Afforestation Technology Development Project" in arid regions, which has been implemented through a grant from the Japanese Ministry of Economy, Trade, and Industry. The goal of the test, which is being conducted with the full cooperation of the Nippon Paper Group Inc., is to plant 24,000 seedlings – raised from "elite" Eucalyptus globulus trees sampled from the Collie area – in a 30-hectare arid region with an annual rainfall of 600mm, and to verify the resistance of the trees to aridity and salt damage.

In ten years, the planted seedlings will grow into huge trees measuring 23-26 meters in height, with a breast height diameter of 23-25 cm (a timber volume of 1.5 times that of normal eucalyptus trees). Through this process, the trees will enable the fixation of huge volumes of $CO_2$, and at the same time will provide raw materials for paper pulp.

We were impressed by the rather reserved comments made by Mr. T, the on-site representative from Nippon Paper, who said: "There are many researchers in this field, but amid the shift to research in high-tech fields (gene manipulation), which are always a topic of lively discussions, we have finally achieved these significant results through slow and steady research using 'low-tech'. (cutting and grafting)"

In order to conduct research targeting genetically-modified plants in an outdoor environment, it is necessary to first complete various procedures stipulated by the Cartagena Protocol on Biosafety, which governs the protection of biodiversity by regulating the use of genetically-modified plants. It takes a considerable amount of time to gather the necessary data on the plants being raised and to apply for the necessary authorizations. As a result, some people working on-site have been heard to say that "it is extremely difficult to apply the most recent research results quickly at the site, and to find ways of making improvements based on actual observations at the site."

# Foreword



There are great expectations for reforestation through planting in arid regions as a means of preventing global warming, and the development of seedlings that can grow in inhospitable environments is considered an urgent issue. In a field such as afforestation research, where it is essential to use a steady and empirical approach over the course of many years, it is thus extremely important to find a way to overcome these types of time limitations.

Given the above situation, we expect that research methods based on cloning technologies (cutting and grafting technologies), which we have been using for many years and which can be used safely on the site, will contribute dramatically to the resolution of these issues, particularly given the ability to put these methods into practice quickly (i.e., their applicability in afforestation regions).

Regrettably, very few people are aware that these cloning technologies are already being put to use in the recovery of valuable old Japanese cherry trees (sakura).

There is only one "Uwamizu Sakura" remaining on the grounds of the Hono Ikazuchi Shrine in Katsuragi, a historic shrine that appears in "Ceremonies of the Engi Era," written in the early 10th Century. During the Great Thanksgiving Festival that was held after the enthronement of a new Emperor, this Sakura tree was used in a ceremony for deciding which field would grow the crops that would be presented to the Emperor's family.

As this irreplaceable tree grew older and its deteriorating health became quite noticeable, the head priest at the Hono Ikazuchi Shrine began looking for a way to ensure that this tree would remain for future generations. The latest cloning technologies have been put to use in fulfilling this request, and as a result, eight young seedlings that have been nurtured since the spring of this year are now anxiously awaiting transplantation.

The grandson of that priest, who only just recently took over responsibility for this historic shrine, appeared relaxed and hopeful as he said, "My role is to pass on this great tree, and the other trees surrounding the Hono Ikazuchi Shrine, to future generations."


The era of unlimited trust and expectation in science and technology has passed, and has been replaced by a more coolheaded view of the positive and negative aspects involved. This view has brought about a growing demand for steady and accurate clarification of phenomena that do not offer second chances. These tree cloning technologies, which have been recognized as being somewhat "low-tech" in comparison to gene manipulation, but at the same time have already achieved a high degree of familiarity, will play an important role in afforestation efforts, particularly in terms of allowing the results of the latest technological advances to be quickly accepted by society.

# System Analysis Group

## Analysis of International Emissions Reduction Regimes beyond the Kyoto Protocol

Even though the Kyoto Protocol is an historical first step toward the reduction of GHG emissions, its effectiveness is doubtful for the following reasons: no obligations on developing countries whose emissions are anticipated to rapidly and drastically increase; the withdrawal of the US, currently the world's largest emitter; and the existence of "hot air", which is a situation where a granted emission permit quota is larger than actual emissions, for Russia, Ukraine, etc. Since Japan ratified the Protocol, she must obey it and contribute to the reduction of the world's emissions. But it is also important to explore international emission reduction regimes beyond the Kyoto Protocol because some regimes might more effectively reduce world emissions and hold lower barriers for many countries to participate in. Thus, using a world energy model, we performed consistent and quantitative analyses and evaluations to provide useful data and information for such regime examination and exploration. This paper introduces our research activities and achievements.

### 1. Research objectives and overview

The objectives of this research are to obtain minimum cost emission reduction measures and their reduction costs/marginal reduction costs that correspond to various reduction targets for such countries of interest as Japan, the US, EU, China, India, etc. Goals also include computing and evaluating emission trades, the monetary flows accompanying the emission trades, and the evaluation of various reduction regimes using integrated indexes of reduction costs/marginal costs, per capita and per GDP emission amounts, and other indicators.

To achieve these objectives, we constructed a world energy system model, DNE21+, which has high regional resolution, and used it to obtain the minimum costs and the minimum cost reduction measures for reduction targets imposed on each country based on various views. After defining such indexes as "sovereignty," "burden," "their equities," and "capability of burden sharing," we compared and evaluated the reduction regimes using these indexes.

### 2. World energy model DNE21+

The DNE21+ model explores the world's minimum cost energy systems (energy flows, capacities of energy conversion facilities, etc.) for given final energy demands and given costs of conversion technologies for a reference case having no emission reduction constraints. It also explores minimum cost systems that satisfy the final energy demands that decrease depending on energy price hikes for emission constraint cases. The model's capability includes: 1) long-term analysis to the year 2050; 2) analysis of regional differences based on the world disaggregated into 77 regions; and 3) analysis of concrete technological measures of emission reduction.

### 3. Cost effective measures for $CO_2$ concentration stabilization at 550 ppm

A case study was conducted of the minimization of the world's total cost under a constraint of 550 ppm stabilization, which is an idealistic case.

(1) Analysis Outline

The DNE21+ model analyzed the cost to Japan and the world to achieve $CO_2$ concentration stabilization at 550 ppm and derived corresponding appropriate measures.

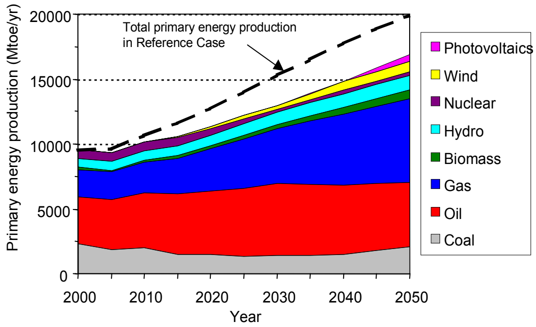
(2) Assumptions

Assumptions of future population, GDP, and final energy demands were determined based on the IPCC B2 scenario. The S550 IPCC WG1 emission scenario was adopted as an emission constraint scenario. The entire world was set to achieve targets in such a way that marginal $CO_2$ reduction cost is the same for all the regions, which is identical to the minimization of the world's total costs.

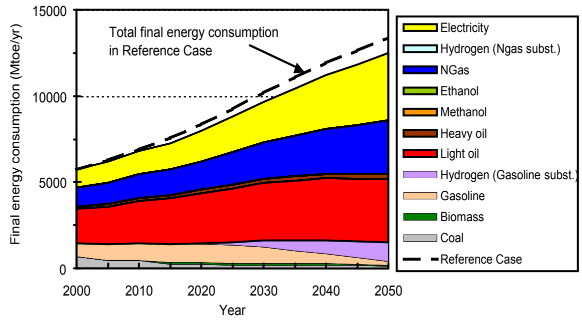
(3) Results

Figure 1 shows the optimum primary energy production and final energy consumption for the S550 achievement. Increases of wind and hydro power, photovoltaic introduction, energy savings in both primary and final energies and hydrogen usage for FCV in 2020 and thereafter were observed. The marginal cost of $CO_2$ emission reduction was computed to be 55 and 123 $/tC by 2020 and 2050, respectively. It was 135 $/tC by 2050 where FCV is unavailable, and

182 \$/tC where CCS technology is unavailable. This indicates that these technologies play an important role for 550 ppm stabilization.




(a) Primary energy production




(b)Final energy consumption

*Fig. 1 Global primary energy production and final energy consumption for S550*

## 4. Comparison and evaluation of various reduction regimes

(1) Outline

For each reduction regime, reduction cost, emission amount, and their per capita and per GDP values etc. are computed for each region using the model run results; the indexes introduced in (3) were quantitatively evaluated.

(2) Simulation cases

Six cases of reduction regimes were studied. In all the cases, S550 was assumed to be a constraint on the entire world.

(a) The marginal reduction cost is the same for all the regions, as treated in Section 3.

(b) Reduction targets are based on per capita emissions.

i. Per capita emissions of all the regions converge by 2050.

ii. Per capita emissions of all the regions decrease at the same rate.

(c) Reduction targets are based on per GDP emissions.

i. Per GDP emissions of all the regions converge by 2050.

ii. Per GDP emissions of all regions decrease at the same rate.

(d) Kyoto Protocol + UK proposed target

In 2003, the UK proposed the following target for Annex I countries to achieve 550 ppm stabilization: reduction of emissions by about 60% by 2050. Considering this proposal, the following emission reduction targets by region were assumed:

<2010> Except for the US, Annex I countries obey the Kyoto Protocol; the US achieves her own target of 18% reduction in GDP intensity in 10 years. An EU bubble or joint fulfillment of 15 countries is allowed.

<2015 and thereafter> Annex I countries achieve the target proposed by the UK (61% reduction by 2050 relative to 1990). The 27 EU countries are allowed to joint fulfillment. Non-Annex I countries must constrain their emissions so that the world's total emission does not exceed S550. Emission allotment among non-Annex I countries is proportional to their historical emissions in 1990.

(3) Results

Evaluations used the following indexes: "sovereignty," which consists of $CO_2$emission amounts and its ratio to the values of the year 2000; "equity in sovereignty," which consists of per capita and per GDP "sovereignty;" "burden," which consists of $CO_2$ reduction amount, reduction costs etc.; and "capability of burden sharing," which consists of per GDP "burden" and "equity in burden," which consists of per capita " burden." It was found that the (c) i case in Section 4. (2) is advantageous for Japan and the (b) ii case is advantageous for the US, and that the (b) i case of per capita emission convergence has the highest equity when it is assumed that the smaller the variations in the above indexes among countries are, the higher equity the regime can claim.

## 5. Future study

Such reduction regimes as participation timing of emission reduction varies depending on the countries, and a "bottom-up approach" is implemented to improve $CO_2$ intensity by sector, unlike a "top-down approach" of ceilings on emission amounts, are topics for future study.

# Chemical Research Gruop

## Chemical Group Activity

Extensive usage of fossil fuels is causing $CO_2$ emission increase and rapidly increasing the atmospheric $CO_2$ concentration which causes the global warming. The atmospheric $CO_2$ concentration should be stabilized at a low level to mitigate the global warming.

There are two measures for the atmospheric $CO_2$ stabilization. One is to reduce $CO_2$ emissions and the other is to sequestrate emitted $CO_2$ into the land or ocean (Carbon Capture and Storage, CCS).

A scenario of the $CO_2$ stabilization determines scales and schedules of the implementation of measures. A stabilization level of 550ppm at 2100 which is two times higher than the $CO_2$ concentration before the industrial revolution is generally considered.

It is difficult to stabilize at 550ppm only by the implementation of technologies of energy efficiency improvement and of fuel switching to renewable energy sources.

Therefore, as additional stabilization options CCS technologies which have high potential for the stabilization should be developed for a practical use. Reduction of the energy consumption and also cost of CCS system is essential for its practical use.

For that purpose, basic technologies ranging to three fields of material, process and system are necessary for innovative technology elements.

Our chemical group has worked for establishing and accumulating those technologies and also is advancing them.

At present, we are focusing our research activity to establishment of a CCS system in ten years using our technology elements.

Our R&D work on them relates to not only CCS, but also new energy systems enabling the construction of sustainable carbon cycle society.

## Chemical Absorption Process

A new $CO_2$ capture project by chemical absorption process has been started with collaboration of three Japanese companies since fiscal year 2004 as a five-year project.

The project aims at reducing a $CO_2$ capture cost to half and includes two main research objectives: One is to develop higher-performance chemical absorbents and the other is to utilize low-grade waste heat in integrated steel works in order to provide $CO_2$ capture process with low-cost energy.

RITE has especially worked on developing the new absorbents. Both experimental and theoretical studies on the reaction characteristics of amine compounds with $CO_2$ are carried out and clarifying chemical structure of hopeful absorbents is done. The newly-developed absorbent will be graded as the highest-performance one.

## Practical development of membrane /absorption hybrid separation technique

Membrane/absorption hybrid method has been studied as a new $CO_2$ separation technology. (The work was supported by NEDO and guided by Prof. Teramoto, Kyoto Inst. of Technology, in 2001-2003 fiscal year.) In this method, $CO_2$ is absorbed in the absorbent liquid in one side of the porous membrane and emitted in the other side with the liquid permeation under the reduced pressure. This method is characterized by drastically little energy consumption compared to the current separation method and highly concentrated $CO_2$ obtained. At present, cooperation with the companies is promoted for applying this method to the separation of $CO_2$ from flue gas, chemical process, bio-process, etc.

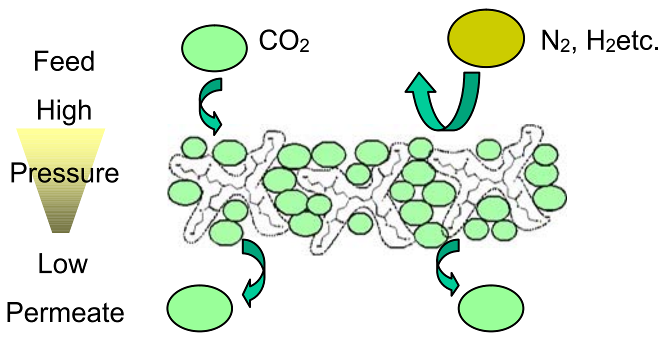
## Polymeric membrane

One promising means of lowering the cost of $CO_2$ separation is the development of new, high-performance $CO_2$ separation membranes that allow $CO_2$ recovery via membrane separation. RITE is now involved in developing just such polymeric separation membranes.

Cardo polyimide having fluorene moiety was modified in the chemical structure for good $CO_2$ separation properties. The asymmetric hollow fiber membrane of the cardo polyimide shows the largest $CO_2$ permeance among existing asymmetric membranes and the top level of $CO_2$ selectivity in various polymeric membranes. A module of the membrane can recover $CO_2$ from an exhausted gas of 25 % $CO_2$ concentration at a comparable expense to amine solution by a system involving $CO_2$ liquefaction. For a higher $CO_2$ concentration flux, the membrane separation will have an advantage over amine solution in the system.

RITE is currently developing a $CO_2$ molecular gate membrane with the goal of producing a new, high-performance separation membrane. Figure shows the basic outline of the $CO_2$ molecular gate function. 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 $N_2$ or $H_2$ leaking to the other side of the membrane is greatly limited and high concentrations of $CO_2$ can be obtained. The membrane of RITE dendrimer shows excellent $CO_2$ selectivity of more than 1000, which would have a potential to replace amine solution.

$CO_2$ Molecular Gate Membrane:




In developing this $CO_2$ molecular gate membrane, RITE conducted joint research with the US Department of Energy's National Energy Technology Laboratory (NETL) and the University of Texas at Austin (UTA).

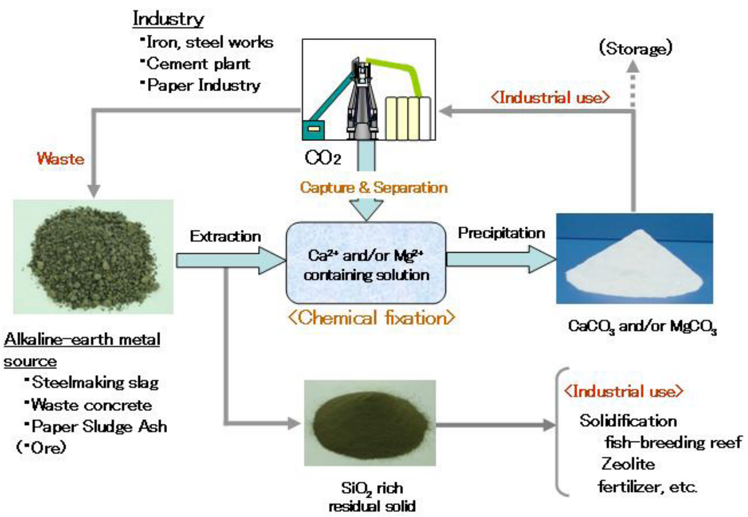
Partially carbonized membrane is a fresh subject under a founding from Global Climate and Energy Project (GCEP) in Stanford University.

## Inorganic membrane

Since zeolites and mesoporous silicas possess well defined micro/meso-pores, considerable attention has been focused on the production of membranes that are capable of separating gases with high selectivities. Polymer membrane shows good affinity for $CO_2$, however, thermal expansion/mobility of polymer at high temperature causes degradation of $CO_2$ selectivity. Since mesoporous slicas have uniform and large pores as well as high surface area, a large number of active sites or adsorption sites can be introduced uniformly on inorganic rigid pore wall by chemical grafting of surface OH group with organosilane molecules. We have studied surface functionalization of the pore wall of various mesoporous silicas that are specialized for $CO_2$ capture and separation; already reporting that the $CO_2$ adsorption capacities of aminosilane modified SBA-15 mesoporous silicas. Based on this study, we have started fabrication of organic-inorganic hybrid type membranes using zeolite or mesoporous solids. If such a material is prepared in the thin film, a molecular movement of the functional group connected with a rigid inorganic pore wall is restricted, and it seems that the decrease in the $CO_2$ selectivity because of an increase in a free volume by thermal expansion/movement of polymeric material in the high temperature region can be controlled. This research proposal was awarded by GCEP(Global Climate & Energy Project) of Stanford University, and the project research will start in September, 2005.

# $CO_2$ fixation as carbonates

Fixation of carbon dioxide as carbonate by the reaction with calcium and magnesium sources containing waste materials, such as iron- and steelmaking slag, waste concrete and minerals has recently been paid attention as one of the $CO_2$ sequestration method. The major advantages of this process are, long term stabilized and environmentally safe $CaCO_3$ and/or $MgCO_3$ production. Additionally, the overall carbonation process is exothermic and hence, has the potential to become economically feasible. However, the development of a new system with simple process, short reaction time, and lower energy consumption is necessary for practical use. We have proposed and investigating a new process of $CO_2$ fixation via carbonation of calcium contents in waste concrete or slag by using a solution of $NH_4Cl$. Studies for the new process have been carrying out to verify the possibility of the system.




## Development of an Innovative After Treatment System for Diesel Vehicles: A Non-Thermal Plasma System

### (A NEDO project from FY2004, joint study with Daihatsu Motor Co. Ltd.)

RITE had developed a plasma technology for natural gas (methane) conversion to acetylene and hydrogen using a high-frequency pulsed plasma in a R & D project of environmental friendly catalysis technology supported by funds from NEDO (FY1991-2000). In 2001, RITE started a three-year plasma particulate matter (PM) removal study financially supported by the Ministry of Education, Culture, Sports, Science and Technology, in which the pulsed plasma technology was used to establish a plasma PM removal system. This plasma PM removal system included a plasma reactor and a pulse power supply.

Recently, the emission control is becoming extremely severe for diesel vehicles, although no satisfied PM removal technologies have been found yet. The plasma PM removal technology has potential as an innovative technology for the after treatment of the exhausts from diesel vehicles. We then began a new project supported by NEDO (project of comprehensive technological development of innovative, next-generation, low-pollution vehicles, R&D of innovative after treatment systems) to continue the plasma PM removal study from 2004. This new project is a joint study with Daihatsu Motor. RITE is to develop a small plasma reactor and pulse power supply that can be loaded on a small diesel car.

# $CO_2$ Sequestration Research Group

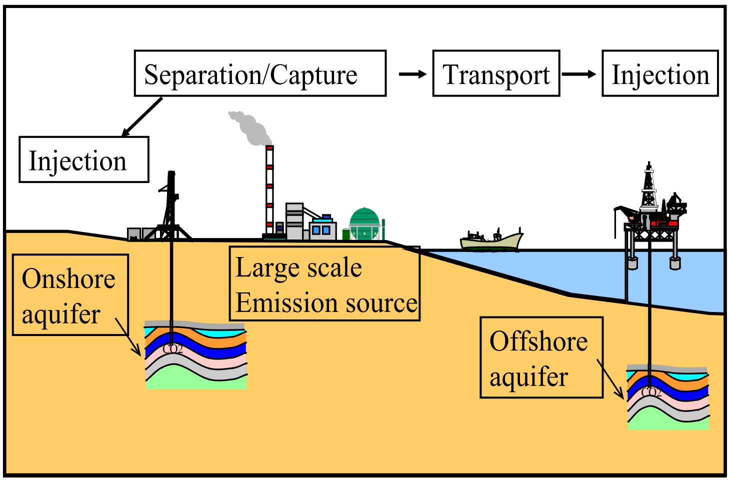
## The Outline of $CO_2$ Geological Storage Project

### 1. What is the $CO_2$ Geological Storage Technology?

The $CO_2$ Geological Storage Technology is to inject $CO_2$ to the underground safely without releasing $CO_2$ which is a greenhouse gas to the atmosphere. There are EOR which enhances oil recovery using $CO_2$ and sequestration to running out gas field, enhancing $CO_2$ to coal seams for recovering methane and also injection t aquifer which is porous sand stone layer containing ground water as methodologies.

In them, RITE has been developing the geological storage technology which is possible for long term stable reserving by sealed layer.

Also $CO_2$ geological storage is thought to be one of the most effective and practical technology because knowledge and experience of underground natural gas storage and these of enhanced oil recovery are applicable.




$CO_2$ Geological Sequestration Aquifer

### 2. Approach to the project.

"$CO_2$ Geological Storage technology R&D" launched in October 2000 far-sightedness in recognizing the importance of GHG mitigation efficiency. During 2000 to 2004, verification of geological storage to existing aquifer in Japan was done. Especially the injection testing in Nagaoka city of Niigata prefecture had been operated 10,400 t-$CO_2$ injection since July '04 until January '05. The measurements consisting of crosswell seismic tomography, well logging, the reservoir formation pressure and temperature measurements, and micro-seismicity monitoring developed $CO_2$ action simulator. There is no any $CO_2$ leakage from the reservoir, even a huge earthquake (M6.8) hit the Mid-Niigata area on October 23, 2004. Distance between the earthquake epicenter and the $CO_2$ injection site is about 20 kms. It has been monitoring underground injected $CO_2$ for improving forecasting performance.

Nagaoka site

### 3. R&D subjects of project.

It clears scientific possibility of geological storage in Japan by current approach. On the contrary, in the world, the geological storage technology R&D has been progressed with recognition as mitigation technology. So the step to technology verification should be needed. Then, to clarify the efficiency and to supply the road map towards application and to establish safety analysis methodology using $CO_2$ activity model, the following approaches has been practicing.

a. Total analysis

(a) Research on validity

Storage system will be classified in terms of source types, capture methods, transporting methods, reservoir types and injection methods. Storage potentials, costs, consumed energy and mitigating effects will be analyzed for each type. A basic scenario plan which will quantitatively explain the validity of geological storage in Japan will be made.

(b) Presentation of a technology and application road map

Technological issues of actual application will be summarized, and a first draft of research and development road map which clears milestones of solutions of subjects will be made.

(c) Investigation on assumed model areas

Assumed model areas will be chosen and issues of actual applications will be extracted by conducting engineering study including safety and environmental assessment on emission sources, transportation methods, reservoir conditions and storage potentials. Solutions for the issues will be proposed.

(d) Storage potential survey in Japan

The aquifer storage potential in Japan will be re-estimated based on the existing data. Locations and types of emission sources will be considered. Issues of the estimation method will be summarized and a new storage model will be proposed.

(e) Investigation of world trend and other relating matters

Overseas investigations on political and technical trends will be carried out and a function of public outreach will be prepared. Investigation and analyses of actual application will be carried out in terms of operating regimes, law and regulations, overseas business potentials and public outreach.

(f) Investigation about safety

Safety studies and assessment trials will be performed and a first draft guideline will be presented. A consistency will be being kept with overseas standards.

b. Establishment of safety analysis methodology

(a) Monitoring at Iwanohara

$CO_2$ injected at Nagaoka site has been monitoring for confirming the safety storage.The behavior of injected $CO_2$ in the aquifer will be monitored at the Iwanohara site and a reservoir simulation study will be conducted in order to contribute to the prediction model improvements.

(b) Fundamental researches

In order to contribute to the prediction model improvements the following in-house experiments will be carried out: influence of $CO_2$ dissolution water on mechanical stability of caprock, quantification of mineral dissolution rates under $CO_2$ presence, mechanisms of super critical $CO_2$ substitution for formation water in porous media, etc.

(c) Improvement of a prediction model for underground $CO_2$ behavior

Based on data and knowledge from the Iwanohara monitoring and the fundamental researches, behavior and fate of $CO_2$ in and above aquifer for a short and long period will be scientifically summarized and improved prediction methods will be presented for safety confirmation.

### 4. R&D project issues

It is scheduled that cost and potential, mitigation affects makes $CO_2$ geological storage effectiveness clear with safety analysis methodology establishment and $CO_2$ separation technology development towards practical application.

## R&D of $CO_2$ Ocean sequestration project

### 1. Overview of $CO_2$ Ocean sequestration technology

Increasing of atmospheric $CO_2$ is one of the factors of global warming. This is the result of imbalance between the dissolution of atmospheric $CO_2$ in the ocean and the emission of anthropogenic $CO_2$, mainly due to the combustion of a fossil fuel. This Imbalance is also due to the long time scale requires for the absorption of atmospheric $CO_2$ in the ocean in contrast with the rapid increase of emissions. However, there is a sufficient potentiality to dissolve anthropogenic $CO_2$ in the middle and deep layers of the ocean. Therefore, a bypass technology of direct injection of atmospheric $CO_2$, captured from high emissions, into the deep ocean was proposed. The main objection for the utilization of this technology is the resulting biological impacts when the initial concentration of injected $CO_2$ is high. From the viewpoint of suppressing environmental impact to the minimum extent, RITE is developing a dilution & injection technology to the middle and deep ocean layer using "Moving Ship" approach, as shown in Fig. 1.

### 2. Purpose of R&D

In order to implement the anthropogenic $CO_2$ sequestration into the ocean as a practical used technology, it is important a prior understanding of the environmental impacts, especially onto the biosphere, to prevent possible damages caused by the application of this new technology. Therefore $CO_2$ sequestration technology can be clearly understand with a wide social receptiveness among the international frameworks, such as Framework Convention on Climate Change (FCCC) and Convention on the Prevention and of Marine Pollution by Dumping of Wastes and other Matter (London Convention, LDC). This project is being carried out with the purpose of clarifying these subjects towards the utilization of $CO_2$ ocean sequestration. In addition, during the phase 1, carried out from FY1997 to FY2001, macroscopic $CO_2$ action grasp in the adjacent seas of Japan, including predictions and investigations of environmental effects, mainly on the biota, produced by the nozzle back discharge of $CO_2$, were conducted. Following the development of technologies, the aims of the present phase 2 in FY2002 - the FY2006.

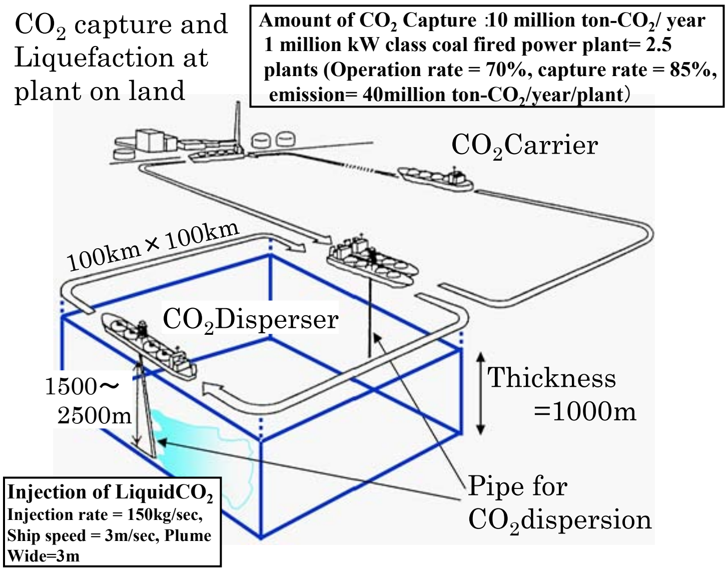



Fig.1 Image of enterprise for ocean sequestration by Moving ship

a. Technical evaluation of $CO_2$ ocean sequestration capacity
  (a)Technical evaluation of $CO_2$ sequestration capacity
  (b) Economical evaluation of the $CO_2$ sequestration effect
  (c)Investigation of positioning on International Law
b. Development of Environmental-impact-assessment technology
  (a) Investigation of marine environment
  (b) Understanding of deep-sea ecosystem
  (c) Investigation of Biological impact
  (d) Development of Biological impact model
c. Development of $CO_2$ dilution technology
  (a) Development of $CO_2$ injection equipments
  (b) Improvement of calculation model of $CO_2$ distribution

## 3. Present of a project

The phase 2 of this project started from the FY2002, and now it is the 4th year. A middle evaluation of this project by the evaluation subcommittee of Industrial Structure Council of METI was carried out in the 2004 fiscal year. From the middle evaluation, comments and indications are as follows. "Ocean sequestration technology represents a relevant method applicable on global warming. However, there is still a topic, which is to complete the evaluation of the environmental (ecosystem) impacts. Positive deployment of publicity work, international education activities, international joint research, etc. is need." By these indications, RITE has enhanced actions as investigations and PO (public outreach) activities for future cooperation with overseas. Within this context, it is necessary to conclude the so-called "Collaboration of carbon dioxide impact on marine ecosystem" program, being carried out together with NIVA (The Norwegian Institute for Water Research). For this, an experiment will be carried out in a fjord of Norway during the period from August - October of this year. In addition, it is planed a possible international joint research project together with U.S.A, Brazil, and a South Korean. Moreover, in order to promote PO actions, investigations of the PO working group were started from FY2005. The working group has started a working plan on publicity, education and production of PO materials among other actions.

## 4. Future of the Project

Development of a $CO_2$ dilution technology and environmental-impact-assessment technology is progressing using laboratory experiments, field observations and numerical simulations. For an effective utilization of the ocean sequestration technology, it is necessary to prove the developed technology using field experiments in the ocean. Finally, it is necessary to trace the $CO_2$ behavior in several 100 km scale, and to investigate the biological impact. Therefore, field experiments covering a wide range of scale from small-scale to a real scale is desired. Since the ocean is a human common property, the implementation of an ocean sequestration technology needs to build up an international consensus. Therefore, it is necessary to obtain the agreement to ocean sequestration implementation at the “London convention”.

# Plant Research Group

## Forest of RITE in Western Australia

In the plant research group, we have just started the construction of Forest of RITE in Western Australia as the first step to mitigate $CO_2$ increase in the atmosphere. Environmental factors affect the growth of plant directly because plants are not allowed to move about. The most suitable ground for plant growth is usually used for food production, agriculture. In this project, plantation of trees in the semi-dry area where is not used for agriculture, to inspect quantity of the growth and $CO_2$ absorption.

Forest of RITE occupies about 30 hectares in the neighborhood of Collie, Western Australia (figure 1). Here is the semi-dry area of precipitation around 600mm in a year. In addition, it is the area where damage from salt breeze occurs partially.

When we construct a forest in arid condition such as semi-dry grounds, an application of suitable trees that are tolerance against the environmental stresses is required. Even if we apply a eucalyptus for the construction of the Forest of RITE, normal growth could not although a eucalyptus is the tree that comparatively resists drying. An application of genetically modified trees is alternative. However, the use of genetically modified trees with an environmental stress tolerance is hard to say quick-acting technology because development of those trees are in research stage and, in addition, social acceptance is required to cultivating them in the outdoors even if the genetically modified trees reached a practical use stage. The quick-acting method we used this time is the application of a non-genetically-modified but a clone of elite trees.

Although propagation of the elite trees usually performs by the method of cutting, the application of normal cutting method to a eucalyptus, the tree we use for Forest of RITE, seems to be difficult. Thus we used an alternative method for the propagation of elite eucalyptus instead of general cutting method. The alternative method has basically been developed by Nippon Paper Industries, including a tissue culture technique to amplify eucalyptus tissue in a container, an effective rooting technique under a relatively high $CO_2$ condition. As the result, we prepared a young plant of 20,000 elite clones containing high growth rate, drought tolerance and salt stress tolerance, respectively, in a relatively short period. After acclimatization, the plantation has started in July that is local rainy season (figure 2).

We will measure growth rate and photosynthetic activity of the planted trees. We will improve the practical use of elite clone planting through evaluation of Forest of RITE in terms of $CO_2$ reduction.

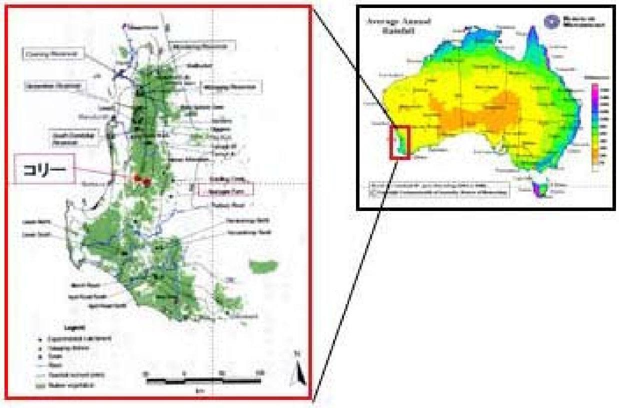



*Figure 1. Location of the Forest of RITE in Western Australia.*
Forest of RITE occupies about 30 hectares in the neighborhood of Collie, approximately 100km south of Perth.

*Figure 2. Elite clone seedlings (the left) and scenery of the planting (the right).*

# Microbiology Research Group

## Biorefinery in the post-genomic era

### Introduction

In recent years, the term biorefinery has received a lot of attention. The biorefinery concept is a new concept in which renewable resources such as biomass are converted to fuel and chemicals. This is in contrast to oil refinery technology by which chemicals and fuel are produced from fossil fuels oil refineries. In the United States, where this concept was developed, massive R&D in the fields relating to biorefineries has been the result of increased environmental awareness and rapid progress in biotechnology. The biorefinery concept is expected to develop into a key industry of the 21st century, and is envisioned to bring forth an industrial revolution of the 21st century because of the significance of its fundamental technology and effect it will have on the industrial paradigm.

### A novel bioprocess technology at RITE.

The main technical hurdle in the development of biorefineries is the efficiency of conversion of the biomass resources used as raw material. A suitable bioprocess to accompany biotechnological modification of microbial cells must be developed in order to achieve optimal efficiency. At RITE, we have developed novel bioprocess techniques based on a totally different concept from the conventional fermentation method (Figure 1).

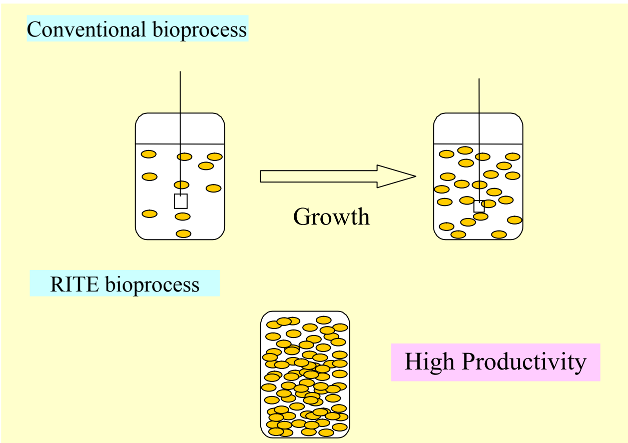



*Figure 1 Illustration of conventional bioprocess and RITE bioprocess.*

Unlike conventional bioprocesses, this novel process does not require "space" for growth (cell division). By using a compact bioreactor filled with "catalyst" (microbial cells) at high density, chemicals can be produced through continuous reaction. Microbial cells can be used in a similar manner as in chemical catalysis. Thus a highly efficient bioprocess can be established and productivity equivalent to or above conventional chemical processes can be expected.

This break-through technology enables us to overcome the shortcomings of conventional bioprocesses. By using this bioprocess as core technology, the RITE Microbiology Research Group, in collaboration with the private sector, is now advancing R&D aimed at environmental conservation. Our latest research regarding the highly efficient conversion of biomass to industrially useful chemicals is outlined below.

### Applications in chemical production

＊Succinic acid

Succinic acid is used in the manufacture of food and pharmaceutical products, surfactants and detergents, green solvents and biodegradable plastics. It is an ingredient in formulations that stimulate animal and plant growth, and an intermediate for chemical synthesis. Although known to be a fermentation by-product of anaerobic bacteria, succinic acid to date is mostly produced commercially by way of chemical processes utilizing fossil oil. However, cost effective fermentative production of succinic acid from renewable carbohydrate feedstocks for the sake of environmental conservation has recently become necessary. By adapting the RITE bioprocess to succinic acid production, we successfully synthesized succinic acid from biomass-derived sugars. The process is continuous and cost-effective, with the addition benefit of net consumption of $CO_2$ Now we are in collaboration with the chemical company, Showa Highpolymer Co., Ltd., toward industrial succinic acid production.

＊Production of ethanol

Ethanol production using bioprocess technology gained prominence in response to the oil crises of the 1970s. However R&D for ethanol production in Japan unfortunately faded away due to the stability in the international oil trade in the 1980s and 1990s. In contrast, however, basic and applied studies aimed at bio-ethanol production in the USA continued. As a result, many companies producing ethanol from biomass are now being established. The estimated amount of bio-based ethanol to be produced in the USA is this year is 10 M tons, double the amount produced in the past 5 years. Most of the produced bio-ethanol is consumed as gasoline additive.

According to the plans of the USA Department of Energy, cost reduction of bio-ethanol to less than 20 cent/L should be realized by 2015. The basis of this reduction is the creation and utilization of ethanol-producing microbes optimized for bioindustry through biotechnology. However, it is apparent that the technology pursued by the USA cannot avoid the main drawback of conventional bioprocesses – requirement for space in a reaction chamber for cell growth. We developed a new cost-effective bio-ethanol producing process utilizing the RITE bioprocess. It may lead to a new horizon in bio-ethanol production.

＊Bio-hydrogen

Biological hydrogen production occurs at ambient temperatures and pressures, thus lowering the energy requirements of the production process. In contrast, the well-established method for hydrogen production in which oil or natural gas is chemically refined occurs at high temperatures and pressures. It often produces carbon monoxide, which is an extremely harmful byproduct to fuel cells. Bio-hydrogen production has the merit of being devoid of this problem. However bio-hydrogen producing systems have the serious limitation of commercially low volumetric hydrogen productivity. Previous studies on bio-hydrogen indicate that the low volumetric productivity is attributed to low hydrogen production rate per cell and low cell density in the reactor, the latter which is a result of low growth rate under anaerobic conditions. The RITE bioprocess overcomes these limitations because microbial cells are not growing and can be used in a similar manner as in chemical catalysis. A bioreactor filled with the "catalyst" at high density. By using the RITE bioprocess, we achieved hydrogen productivity two orders of magnitude higher than that of conventional bio-hydrogen producing systems. At such productivity, a reactor the size of a coffee cup can generate enough hydrogen to supply the energy requirements of a household television set, while a 1.8-liter PET bottle-sized reactor can satisfy the electricity requirements of a typical household.

## Conclusion

The key for biorefinery development is the underlying bioprocess technology. The RITE Microbiology Research Group has developed a new, highly effective bioprocess technology. By using this, we demonstrated the production of useful chemicals using biomass as raw material. We are currently advancing the R&D toward practical application in bio-industry.

**Research Institute of Innovative Technology for the Earth**

9-2, Kizugawadai, Kizu-cho, Soraku-gun
Kyoto, 619-0292 JAPAN
TEL. +81-774-75-2300　FAX. +81-774-75-2314
**URL http://www.rite.or.jp**