RITE Today

Research Institute of Innovative Technology for the Earth

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Let Us Prevent Global Warming through Innovative Technologies

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In 2008, great attention was given to the issue of global warming.

At the Hokkaido Toyako Summit in July, the leaders of the Group of Eight major industrialized nations gathered and decided to work together and share the goal of achieving at least a 50% reduction of global greenhouse gas emissions by 2050.

However, since it is anticipated that the world's population will continue to increase in the future, it will be hard to realize the vision of halving global greenhouse gas emissions. With thoroughgoing energy-savings, it is sought to expand the use of not only nuclear energy, but also natural energy, including photovoltaic power and wind power, and renewable energy like biomass, where drastic technology innovations are required to realize a low-carbon society. Last year, the Ministry of Economy, Trade and Industry announced twenty-one technologies as "Cool Earth Energy Innovative Technologies." In the field of electric power generation, the amount of carbon dioxide emissions from which is the largest, CCS (Carbon dioxide Capture and Storage) is expected as well as nuclear power and photovoltaic power. Under existing circumstances in which approximately 80 percent of the world's energy consumption is dependent on fossil fuels, great expectations are placed in CCS as a bridge to the realization of a low-carbon society. Also, in the transport sector, the amount of emissions from which is the second largest to that from the power sector, alternative fuels production for transportation is expected from biomass in addition to fuel-cell-powered vehicles, plug-in hybrid vehicles, and electric vehicles. Biofuels started a worldwide boom last year, when a steep rise occurred in oil prices, while people point out problems such as influence on grain prices and effect on the ecosystem. There is a demand for development in biofuels that will not cause such problems.

Also, the realization of a reduction in the world's greenhouse gas emissions by half requires challenges by developing countries that account for about half of the current global emissions to reduce their emissions. "The sectoral approach" proposed by Japan as a measure for reducing greenhouse gases is expected to facilitate the implementation of challenges for developing countries to reduce their emissions through transfers of energy-savings and environmental technologies by sector such as iron and steel, and electric power from industrialized countries.

We, the Research Institute of Innovative Technology for the Earth (RITE), have been working on research and development in technologies for preventing global warming in "Kansai Science City," while receiving support and cooperation from the government, industrial community, and universities since its foundation in 1990. In the CCS field, we have developed the technology for efficient separation and capture of carbon dioxide from gas emissions from power plants and steel plants, and also succeeded in experimentation of underground storage of 10,000 tons of carbon dioxide. In the biotechnological field, we have also developed epoch-making technologies to efficiently produce ethanol from nonfood plants (rice straw, used paper, cornstalks, etc.) by using special bacteria, which is attracting attention from domestic and foreign companies. Furthermore, in the field of policy analysis, we have carried out research on "the sectoral approach" to assist the Japanese government in framework negotiations to combat global warming.

While countermeasures against global warming are positioned as one of the most important issues for humanity, RITE wishes to play an active role in the innovative technologies development field. We would like to ask for your support.

Systems Analysis Group

Technological perspectives toward "Cool Earth 50" and analysis for mid-term targets

1. Introduction

The issue of climate change was discussed as a main theme at the G8 summit held in Toyako, Hokkaido, in July, 2008. The summit leaders have declared that "We seek to share with all Parties to the UNFCCC the vision of, and together with them to consider and adopt in the UNFCCC negotiations, the goal of achieving at least 50% reduction of global emissions by 2050."

Meanwhile, the discussion has been held in the context of scientific insights into the global warming issue and progress in the implementation of measures against global warming at various places in Japan and abroad. For instance, the IPCC forth assessment report was released in 2007, and the Kyoto Protocol entered into force in 2008. The global warming issues have been paid much attention by the public, and the related articles are frequently covered by the media.

Currently, discussions and negotiations at global level have proceeded, aiming at an achievement of agreement on a new international framework and targets with regard to global warming after 2013 at the 15th Conference of Parties (COP) to the UNFCCC to be held in Denmark, December, 2009.

The Systems Analysis Group has been conducting studies on the issue of climate change by using systematic approaches in order that the public can understand such a wide and complex issues and search for a better solution. In addition, our research activities play an important role in an international discussion on the post-Kyoto framework.

This article introduces some of our analysis on the mid-term (by the year 2020) and long-term (by the year 2050) targets for CO_2 emission reduction, on the total costs to achieve these targets, and on concrete measures for emission reduction.

2. Analysis and assessment of long-term target

A former Prime Minister, Shinzo Abe presented "Cool Earth 50" on May, 2007, which aimed to halve global GHG emissions by 2050 relative to the current level.

Moreover, a former Prime Minister, Yasuo Fukuda announced "Fukuda vision" on June, 2008, which proposed a target of halving global CO_2 emissions by 2050 relative to the current level, and Japan's goal of reducing its emissions by 60 to 80 % relative to the current level.

The attempt of sharing the long-term vision for emission reductions on a global basis is of great significance, however, it will be hard to realize the vision of halving global emissions by 2050.

Given the fact that current emissions of developing countries are the same level as those of developed countries, the vision can be interpreted that even if developed countries achieve no emissions, developing countries are required to limit their emissions to the current levels in 2050.

On the other hand, the emissions of developing countries have nearly doubled in less than the past 20 years since 1990, and it is understandable how hard it is to limit their emissions to the current levels in just over 40 years.

In fact, at COP14 held in Poznan, Poland, December, 2008, developed countries sought for sharing of the vision of halving global emissions, however, consensus from developing countries was not achieved.

On the other hand, it stands to reason that it is necessary to reduce a significant amount of global emissions in the long term. To achieve this, it is required to analyze what types of concrete measures should be taken and what kinds of R&D should be carried out.

Global CO_2 emissions are expected to continue to increase in the future, and there is a possibility that if there is no change in technologies for emission reduction and social structure compared to the current situation, the global emissions will reach more than 87Gton in 2050.

The global CO_2 emissions will reach 48 Gton even if we take all the measures such as energy conservation with high cost-effectiveness (coal-fired power generation with high energy efficiency, global diffusion of blast furnace (BF) and basic oxygen furnace (BOF) with higher energy efficiency in steel sector) and fuel conversion (further diffusion of biofuels in some regions).

Following the discussion above, Figure 1 shows an assessment of cost-effective measures for emission reduction in the case of halving global emissions by 2050 relative to the current level, which is equivalent to the case of limiting the emissions to 13 Gton. The results indicate that the power sector has the largest emission reduction potential, especially by CCS, nuclear power and solar power generation. Hydrogen-based iron making in iron and steel sector, and plug-in hybrid vehicles in transport sector are also recognized as substantial emission reduction measures.

On the other hand, it is estimated that marginal abatement costs will be over 300 US$/ton CO_2 to

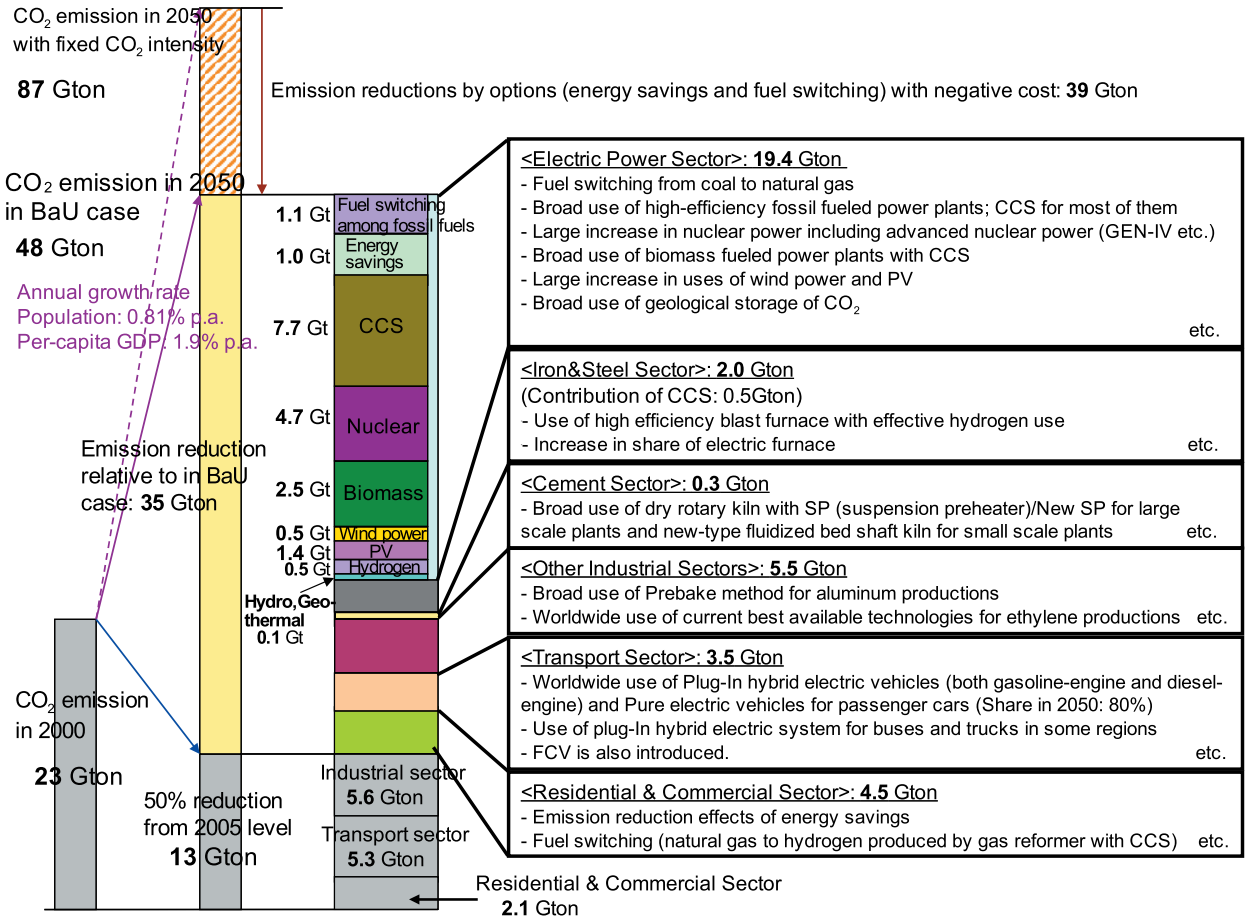


Figure.1 Technology portfolios and CO_2 emission reduction by sector to halve global CO_2 emissions by 2050

achieve the goal of halving global emissions by 2050. It will be difficult to pay such a high cost under global cooperation. Furthermore, it will be considerably hard to realize this goal unless new and currently unimaginable technology emerges. Therefore, it is important to take the burden of abatement costs into consideration, and to search for more realistic target for emission reduction which can be achievable for the entire world.

3. Analysis and assessment of mid-term targets

The greatest global concern in the context of climate change lies in how to establish a mid-term target for 2020 in the discussion on framework and target for post-Kyoto climate policy. EU leaders announced its mid-term target of reducing its emissions by 20 % (up to by 30% provided a global cooperation is achieved) relative to the 1990 levels. The Obama administration established its target of cutting U.S. emissions to 1990 levels by 2020. Moreover, the declared mid-term target is 20% emission reduction compared to 2006 for Canada, and 5% reduction compared to 2000 for Australia. The Japanese government has examined its mid-term national reduction target by employing a sectoral and bottom-up approach. The examination led by a governmental body called “Mid-term target examination committee” has been progressing since November, 2008.

What is considered most important in an international discussion can be to establish a framework and target that lead to an effective reduction by all the major emitters, and to set up emission reduction levels for developed countries that reflect a regional effort required.

The sectoral approach has been widely acknowledged as one of the effective measures for emission reduction. For the realization of sectoral approach, our group has been contributing to a development of international discussion by doing related analysis and assessment with a high level of ability to conduct model analysis.

Figure 2 shows estimated marginal abatement costs of CO_2 by country when each country reduces its CO_2 emissions of the year 2020 in the range of 5% to 40% relative to 2005.

The results of our evaluation are estimated with a comprehensive emission reduction assessment model having high resolutions in region, sector and technology.

For instance, to reduce national emissions by 20% relative to 2005, a marginal abatement cost for Japan is estimated to be 200 US$/tCO$_2$, which is the highest among other nations. The marginal abatement cost for EU is estimated to be around 50 US$ and that of US is around 30 US$. The results imply that the costs to be borne by Japan will be extremely high to carry out further measures as Japan has already achieved high energy efficiency.

On the other hand, EU, especially East Europe has a large potential for emission reduction. Likewise, it is estimated that U.S. also has a large potential for emission reduction due to many low- efficiency technologies and high dependency on coal.

Figure 3 shows results of our estimation on emission reduction potentials of 2020 (emission reduction potentials compared to the case where the level of energy technology is assumed to be unchanged from a current level) for major countries including developing countries by marginal abatement costs.

It can be found that on a global scale, there is a large amount of emission reduction potential at relatively lower marginal abatement costs, such as those amounting to less than zero US$ (negative net costs) or to less than 25 US$/tCO$_2$. Especially, China and U.S. have large emission reduction potentials at relatively lower costs.

The results of our evaluation indicate that it is important to achieve cooperation between developed countries and developing countries, and to reduce emissions by addressing potentials for emission reductions at lower costs that are largely found in developing countries.

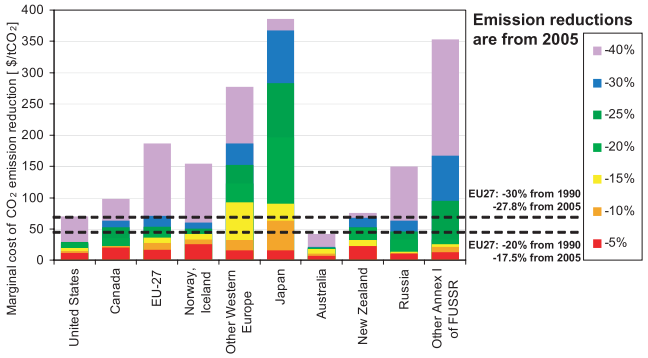


Figure.2 Marginal abatement costs of CO_2 for Annex I countries in 2020 by the rate of emission reduction relative to 2005

Note: CO_2 from fuel combustion only. GHGs reduction of -20% from 1990 corresponds to -14% from 2005.

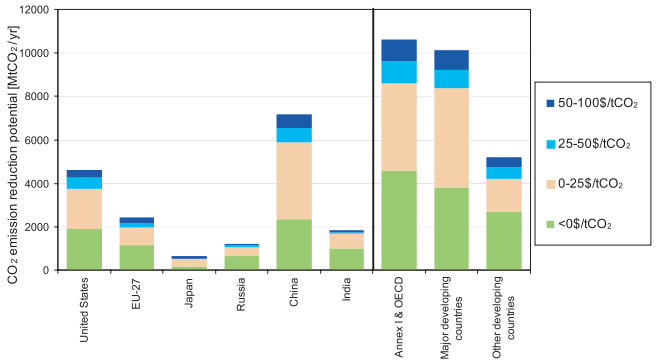


Figure.3 CO_2 emission reduction potential for major countries compared to Technology Frozen Case by marginal abatement cost of CO_2

Note: emission reduction potentials of CCS excluded.

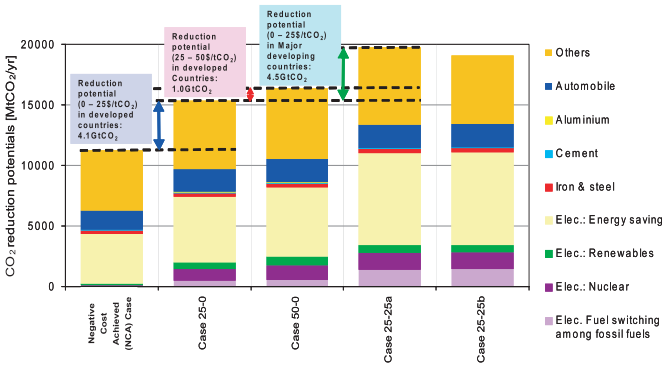


Figure.4 CO_2 emission reduction in the world by marginal abatement costs of CO_2 and by sector(compared to Technology Frozen Case)

Note: emission reduction potentials of CCS excluded.

Baseline: the case in which measures at a marginal cost of less than 0$/tCO$_2$ are taken by all countries in the world, Case 25-0: the case in which measures at a marginal cost of less than 25$/tCO$_2$ are taken by only developed countries, Case 50-0: the case in which measures at a marginal cost of less than 50$/tCO$_2$ are taken by only developed countries, Case 25-25a: the case in which developed countries take measures at a marginal cost of less than 25$/tCO$_2$, and major developing countries take measures at a marginal cost of less than 25$/tCO$_2$ as an intensity target, Case 25-25b: the case in which developed countries take measures at a marginal cost of less than 25$/tCO$_2$, and major developing countries take measures at a marginal cost of 25$/tCO$_2$ in major sectors as an intensity target.

Figure 4 provides our estimation on the emission reduction potential in the world by marginal abatement costs of CO_2 and by sector.

The analysis by RITE enables us to propose measures specifically not only by marginal abatement cost but also by sector and by technology as well as to estimate emission reduction potentials by country and by sector. Our analysis, therefore, has contributed to discussion on a numerical target with supportive evidence.

4. Conclusion

Global warming is a serious issue, extending over a long period of time and over the world. However, it is important for us to address climate change in a calm and determined manner, not being fueled by the risk. Furthermore, it is crucial to work on this issue globally and continuously.

Measures to tackle climate change should entail effectiveness and targets which can be shared by all over the world. The analysis and assessment based on data, which the Systems Analysis Group has been working on, is indispensable to a realization of the measures.

We will continue to send our research findings to industry, government and academia by conducting an analysis and assessment on measures for climate change in order that people can find a solution to address such a challenging issue of global warming.

Molecular Microbiology and Biotechnology Group

1. Introduction: The Current Status of Biofuels and Molecular Microbiology and Biotechnology Group

With crude oil prices topping $145 a barrel in June, 2008, worldwide prices of grains used in biofuel production also soared. At the 34th Group of Eight Summit held in Toyako, Hokkaido in July, 2008, the soaring of food prices was a big issue. By the second half of the year, attention had shifted to the chaos in global financial markets occasioned by failures of major financial institutions originating from the collapse of sub-prime housing loans in the United States. Though 2009 started with such an unprecedented and rapid downswing, the incoming US President brings renewed focus to an energy policy that supports production increases of biofuels such as bioethanol. Based on the US National Biofuels Action Plan (NBAP) announced in October, 2008 in partnership between United States Departments of Agriculture (USDA) and Energy (DOE), a progressive approach toward the commercial application of second-generation biofuels such as cellulosic ethanol from non-food based biomass is emphasized. The plan prospectively will contribute to the creation of employment and by supporting farmers producing biomass feedstocks for biofuels while at the same time addressing the environmental concerns of reduction of greenhouse gases. In the United States, to improve energy security and meet increasing demand for transportation fuel, former President Bush's "Twenty in Ten Initiative", aiming to reduce gasoline consumption by 20% in ten years, and the Energy and Independence Security Act (EISA) Renewable Fuels Standard goal of expanded use of 36 billion gallons of renewable fuel by 2022 were set forth. Accordingly, President Obama has emphasized acceleration of commercialization and use of biofuels.

In our group, we undertake joint research and development of bioethanol production technologies established under the "RITE-Honda Process" based on a novel and growth-arrested bioprocess. The goal of this project is to produce ethanol from soft biomass such as rice straw on a commercial basis. At the 75th Session of the Council of Science and Technology Policy held on May 19, 2008, the bioprocess was featured under the theme Current Science and Technology Trends: Contribution of Genetically Modified Micro-organisms to the Realization of Post-Oil Society. The characteristics of the bioprocess as a production system for bioethanol and commodity chemicals using recombinant coryneform bacteria were hailed as an innovative means to a low-carbon society of the future. Subsequently, the Cabinet Office and the Ministry of Foreign Affairs sanctioned a display of the bioprocess during the 2008 G8 Summit. The then Prime Minister of Japan Yasuo Fukuda emphasized biofuels in his discussions with the other G8 leaders. The advancements of the RITE-Honda Process were afforded special mention in his session with Germany Chancellor Angela Merkel (www.mofa.go.jp). Regarding biofuels, G8 leaders' statement included sustainable production of biofuels to be compatible with food supply and acceleration of effort toward research and development of second-generation biofuels from non-food based biomass. In October, 2008, RITE-Honda Research Team (Head; Hideaki Yukawa) won the 18th Nikkei Global Environment Technology Award's Grand Prize for efficient bioethanol production from rice straw. The RITE-Honda Process, which enables efficient production of bioethanol from non-food based biomass such as rice straw as an alternative fuel to gasoline, shows great potential for industrialization. It should enable us to meet increased energy demand without affecting food supply, consequently contributing to stabilizing food-supply while eschewing harmful traits that lead to global warming. Please refer to RITE Topics for a pictorial view of these achievements.

2. Current Trends in Biorefinery

Biorefinery production of fuels and commodity chemicals from biomass is based on advanced biotechnology, completely different from petrochemical technology. The products from biorefinery are made in a new production system based on C_3-C_6 building blocks, which is different from the conventional petrochemical system based on C_2 building blocks. There are two recognizable trends; one is, as discussed previously, commercialization of second generation biofuels, starting from cellulosic ethanol, and the other is green chemical industry, of which implementation is at hand. In green chemical industry, the starting material is the same as that of petrochemical products, except that it is made from biomass. Ethylene can be made from bioethanol, and propylene from biopropanol. The Petrochemical industry is turned into the green chemical industry, with "petro" removed (Fig.1).

Realization of the green chemical industry is presumed to be approaching reality in a few years, as the raw material, mixed C_6, C_5 sugars, can be produced cost-effectively. This is because large-scale production of bioethanol from soft biomass is in the final countdown stage. When realized, it should enable

production of "green" ethylene from bioethanol. Also "green" propylene can be produced from biopropanol by using the mixed sugars. Furthermore, there should be no concerns about product quantity as the amount of biomass needed for green chemical industry is much less than that needed for biofuels. Technology to produce bioethanol applied for ethylene is basically the same as for fuels, except for the effect on catalysis in ethylene production. The green chemical industry is at its very early stages.

3. Approach to Research

We have established the base technology for a growth-arrested bioprocess, christened the "RITE bioprocess" based on a novel concept (Fig. 2). The key to its enhanced efficiency is that, unlike conventional bioprocesses in which productivity is dependent on microbial growth, actual production under the RITE bioprocess utilizes bacterial cells under growth arrested conditions in the same manner as inorganic catalysts are used to produce chemicals. Because productivity occurs in lieu of growth, the RITE bioprocess is not hampered by the major limitations (STY: Space Time Yield) of growth-dependent conventional bioprocesses. Yields under the RITE bioprocess therefore are close to those of chemical processes. We have pioneered complete and simultaneous utilization of both C_6 and C_5 sugars under RITE bioprocess.

4. Future Development

In the joint R&D on bioethanol production by the RITE-HONDA Process, we aim to develop an industrial process to produce ethanol from non-food biomass resources. Further, we seek collaboration with an oil company and a trading company to fast-track the practical application of the bioprocess. We believe that technologies resulting from our R&D will contribute to global warming solutions. To produce useful commodity chemicals from biomass, work on the project, "Research and Development of Biorefinery Technologies", was commissioned in 2006 and funded by NEDO. As spelt out in a progress report prepared last year, our interim goal of a technology to enable production of 3 classes of chemicals, namely, organic acids, amino acids and sugar alcohols at 10g/L/h was achieved on schedule. We are committed to further research toward the final goal. In the meantime, other ongoing projects such as development of effective utilization of woody biomass, ethanol production from syngas gasified from biomass and development of utilization technology of water-soluble polysaccharides (produced by sea algae) as well as the next generation fuel (hydrogen, butanol) production from biomass feedstock under the themes, "Programmed Methods CO_2 Fixation and Effective Utilization Technology Development" are supported by METI. In preparation for a potential expansion of biomass demands, development of effective utilization technology is underway.

5. Conclusion

Biorefinery technologies have the potential to lead to an industrial paradigm shift in the 21 century, just as the blooming of petrochemistry in the 20 century drastically changed modern society. Our approach to collaborative research and development with the private sector should enable future application of the RITE bioprocess in the production of a broader range of chemicals and biofuels.

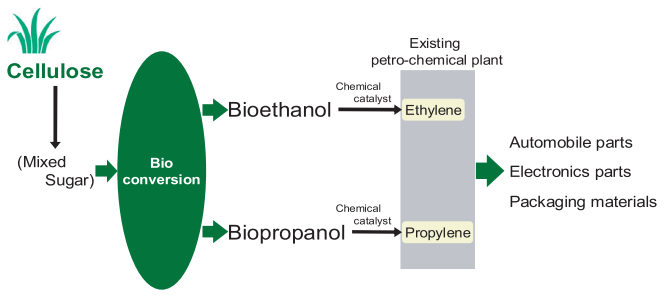


Fig.1 Green chemical industry

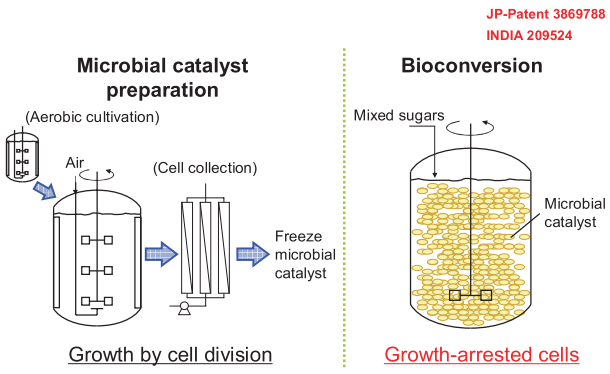


Fig.2 Highly efficient bioprocess –RITE bioprocess– (growth-arrested bioprocess)

Chemical Research Group

Looking ahead to future CO_2 separation technologies and our challenges

Discussions about a new global framework to reduce CO_2 emission is progressing, the number of people recognizing the importance of countermeasures against global warming are increasing. Generally speaking, many people believe that a countermeasure in increasing order of small economical burden will be sequentially undertaken.

A CO_2 concentration of 550 ppm is twice the concentration that was present during the Industrial Revolution. If we set a target CO_2 concentration of 550 ppm for 2100, it has been predicted that not only energy saving, fuel switching, renewable energy sources (solar cells, wind power and biomass) and nuclear energy, but also CO_2 capture and underground storage will be necessary to achieve this goal. As the cost of CO_2 capture from CO_2 sources is estimated to be 70 % of the total cost of CO_2 capture and underground storage, it is important for the commercialization of this technology that the CO_2 capture cost for CO_2 capture and storage (CCS) is reduced.

Conversion technologies of fossil energy are going to progress, and we consider the power generation system of a boiler steam turbine evolving into a combined cycle with a gas turbine for power generation and a combined cycle with a fuel cell. Various CO_2 capture technologies such as chemical absorption, physical absorption, membrane separation, and the oxy-fuel method have been developed.

Progress in these technologies will result from development of the best combination between fuel conversion processes and CO_2 capture processes, so that CO_2 capture technologies that will consistently increase the economic benefits of technical visions, as shown in Figure 1, are developed.

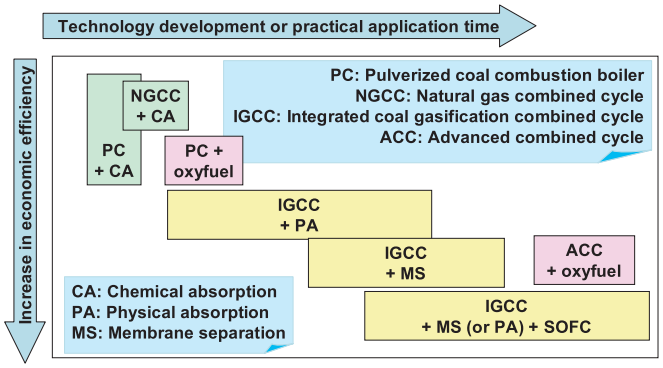


Fig.1 Vision of power plant and CO_2 capture

Our chemical research group studies various CO_2 capture technologies, with a special focus on chemical absorption and membrane separation methods. We can use chemical absorption to reduce the CO_2 capture cost for flue gas in an ironworks factory to 3000 JPY/ton-CO_2. We are developing a chemical absorbent to reduce this CO_2 capture cost to 2000 JPY / ton-CO_2. Moreover, we have discovered an excellent, world-class membrane material for the separation of CO_2 from H_2-containing gas. We are engaged in the development of the structure of a new membrane composed of this material and are developing the membrane module in order to demonstrate with real coal gasification gas. We are developing not only practical and acceptable technologies for the industries but also innovative technologies for foundation for next generation and also evaluate the various new technologies not to fail projects.

Development on CO_2 capture technology by chemical absorption system

CO_2 capture by chemical absorption has the potential to be used in practical applications for large stationary point sources of CO_2 in the near future, and a five-year project to this end was started in 2004 in collaboration with four Japanese companies.

The objective of this project is to reduce the CO_2 capture cost to half that of the existing technology for the flue gas (blast furnace gas) stream in an integrated steel works. The main objectives, shown in Figure 2, are the development of new absorbents to enable the capture of CO_2 with less energy use, and the development of a heat utilization technology to use waste heat at steel works to supply low cost steam for regenerating CO_2.

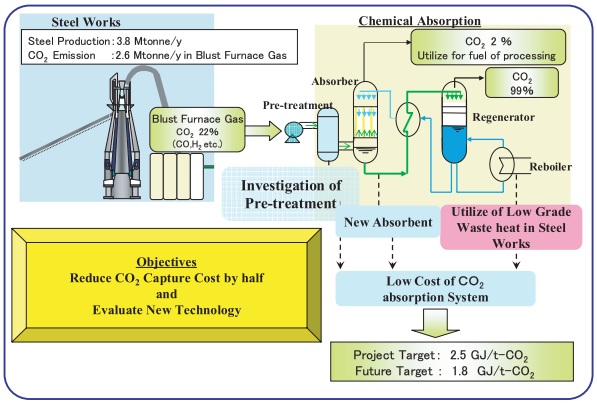


Fig.2 The outline of cost saving CO_2 capture system (COCS project)

RITE mainly develops new absorbents. The most desirable characteristics for new absorbents are: a lower heat of reaction with CO_2, fast CO_2 absorbance, and easy separation from CO_2. If this is achieved, CO_2 can be captured from a gas stream with a lower energy input. Among the solvents tested for CO_2 capture, amine

solutions have shown the best performance.

As a first step for the screening and development of new absorbents, the reaction characteristics, such as the reaction rate of CO_2, the amounts of CO_2 absorbed and the heat of reaction with CO_2, of almost 100's samples of commercial amine solvents selected were analyzed using laboratory apparatus. Furthermore, compound amine solutions, that can compensate for deficiencies in the amines, were prepared and their performance was investigated.

From these investigations, several type of high performance absorbents (RITE-3,4 series), that showed different characteristics, were developed. In succession, new absorbents (RITE-5,6 series) has been developed through the basis of our experimental database and theoretical design of molecular structure of new amine compounds using the quantum analysis approach(Figure 3). The energy for CO_2 capture of the best of these absorbents is estimated to be 2.5 [GJ/tonne-CO_2]. This value is very low compared to the 4.0 [GJ/tonne-CO_2] for a standard MEA (mono-ethanol amine) solution, so we have a prospect to accomplish the project target (Figure 4).

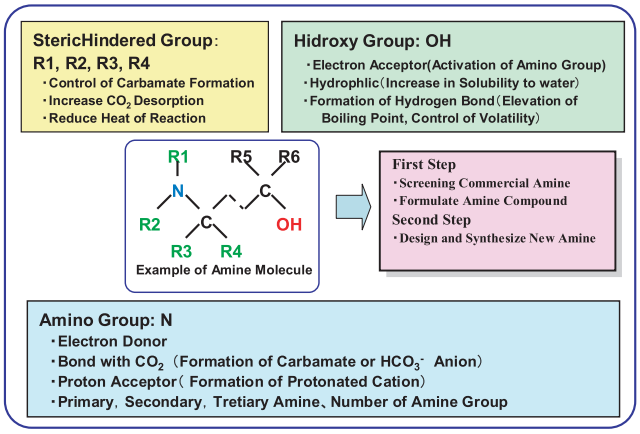


Fig.3 Development of new absorbents

The fruits of this project has succeeded to a new project of "COURSE 50" aiming at a drastic reduction of CO_2 emission in an integrated steel works. A development of new absorbents with a higher performance and application study by pilot-scale plant is scheduled hereafter.

Furthermore, based on the current knowledge on CO_2 absorbents, a development on new absorbents suitable for high pressure gas stream has also been carried out since 2007. In general, amine solvents can easily react with CO_2 under atmospheric pressure condition independent of reaction temperature. But we have confirmed that some amine solvents , nevertheless they do not react under atmospheric pressure, react with CO_2 depending on reaction temperature under high pressure condition. (Figure 4) We have proposed a new CO_2 capture system in pressurized point sources of CO_2 with these sorbents.

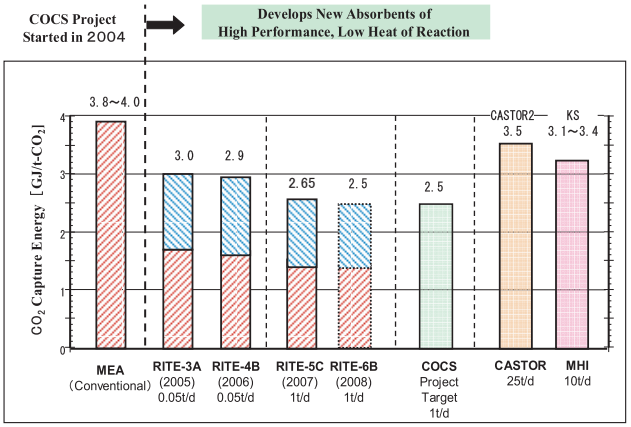


Fig.4 Reduction of CO_2 capture energy by new absorbents

The second step of the project has also been carried out, in which new types of amine compounds, designed and prepared based on the current knowledge, are evaluated by a similar method. Furthermore, research on the optimum conditions for the chemical absorption system has been carried out, so that the best performance can be obtained from the new absorbents. Currently, the aim of the project is to reduce the CO_2 capture energy down to the target value.

Novel techniques for regenerating the chemical absorbent

We are developing a regeneration technique for accelerating CO_2 desorption with a pressure difference to reduce the energy consumption in a chemical absorption system. To date, the following observations have been made. Desorption can be accelerated by flashing the solution into a reduced pressure space, which can reduce electric energy consumption by more than half in comparison with the conventional method that uses high temperatures. Moreover, by using low-temperature waste heat, as shown in Figure 5, it is possible to achieve an electric energy consumption about 1/4 (0.1 kWh/kg-CO_2) of that of the conventional chemical absorption method. We will attempt to apply this method to the separation of CO_2 from flue gases, chemical processes, bioprocesses, etc., while efforts are made to further reduce energy consumption.

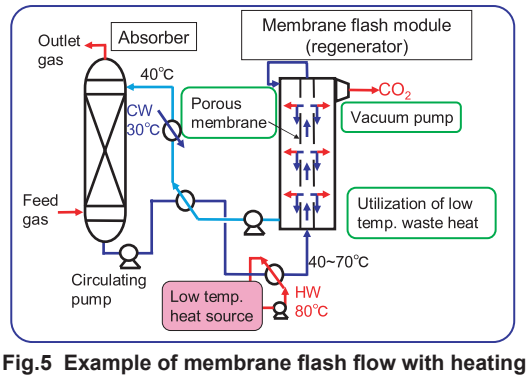


Fig.5 Example of membrane flash flow with heating

RITE and Taiyo Nippon Sanso Corp. have developed the equipment (Figure 6) which gets the high-concentration methane by removing CO_2 from biogases, and the practicability has been confirmed in continuous running for two months at the biogas generation site.

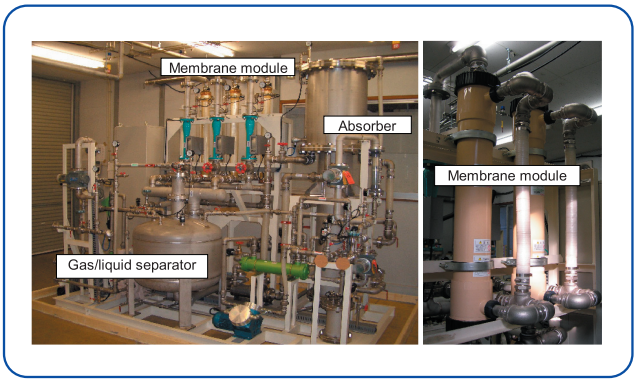


Fig.6 Biogas purification test equipment developed by RITE and Taiyo Nippon Sanso Corp.

CO_2 and H_2 separation with a polymeric membrane

Japan's government has declared the reduction of CO_2 emission to half by 2005 as "Cool Earth 50". One promising means of dimidiating CO_2 emission is the development of an integrated coal gasification combined cycle with CO_2 capture & storage (IGCC-CCS). In the process of IGCC-CCS, CO_2 separation membranes will play an important role of reducing CO_2 capture cost. The cost estimates indicate that CO_2 capture cost from the pressurized gas stream with a membrane might be 1500 JPY/t-CO_2 or less.

We are currently developing a CO_2 molecular gate membrane with the goal of producing a new, high-performance separation membrane. Figure 7 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 permeating to the other side of the membrane is greatly limited and high concentrations of CO_2 can be obtained. The RITE dendrimer having excellent CO_2/H_2 selectivity is fixed stably in a cross-linked polymer matrix to form the separation membrane. Figure 8 shows the CO_2/H_2 separation properties of the membrane along with the other membranes reported previously. Our dendrimer membrane shows the world largest CO_2/H_2 selectivity of 30 or more. The RITE is now improving the performance and developing practical membrane modules of the dendrimer membrane in cooperation with membrane companies.

In developing this CO_2 molecular gate membrane, the RITE conducted joint research with many foreign partners such as the US Department of Energy's National Energy Technology Laboratory (NETL) as a recognized project of the Carbon Sequestration Leadership Forum (CSLF), University of Texas at Austin and Norwegian University of Science and Technology.

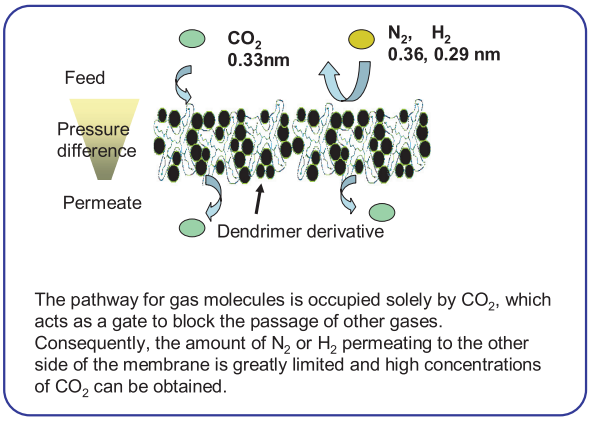


Fig.7 Conceptual diagram for the CO_2 molecular gate

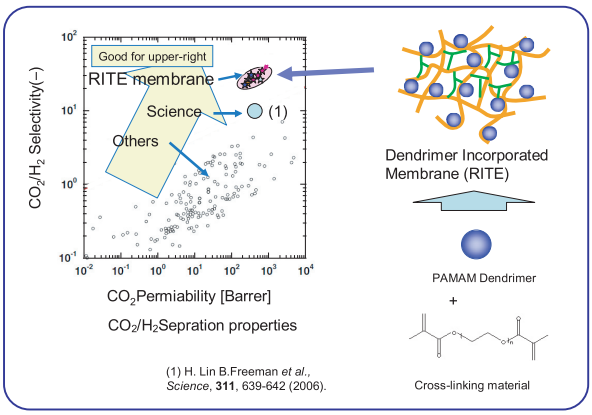


Fig.8 Dendrimer incorporated membrane and its performance

Development of an energy-saving CO_2-PSA process using hydrophobic adsorbents

The usual means of CO_2 separation, pressure swing adsorption (PSA) using polar hydrophilic adsorbent, is energy intensive: to regenerate the absorbent, the partial pressure of CO_2 must be changed by the vacuum pump. In addition, a dehumidification process which consumes approximately 30% of total energy is necessary for the conventional PSA process using hydrophilic 13X zeolite, because water vapour is adsorbed more strongly than CO_2 on 13X zeolite surface. 13X zeolite strongly adsorb both CO_2 and H_2O and had a Langmuir-type adsorption isotherm. The CO_2 adsorption capacity of hydrophilic zeolite is completely lost with the coexistence of water; therefore, hydrophobic adsorbent should be used for CO_2 separation in high moisture conditions, such as that for stack gas.

In this project, newly prepared hydrophobic adsorbents have been proposed as CO_2 adsorbents for the separation of CO_2 from high pressure gas. They

can overcome such obstacles to adsorption processes. Hydrophobic adsorbents have an advantage over traditional adsorbents such as activated carbon and zeolites because they can adsorb CO_2 in the presence of water vapour, which is usually present in flue gases from fossil fuel combustion. Furthermore, vacuum pump can be eliminated for the adsorption process from high pressure gas.

CO_2 adsorption capacities of 13X zeolite and newly synthesized adsorbents were shown in figure 9. It was confirmed that the adsorbent synthesized in our study had a hydrophobic property and adsorbed considerable amounts of CO_2 under high CO_2 pressure. It was also confirmed they adsorbed CO_2 even in the presence of water vapor.

Evaluation of the process cost is now in progress.

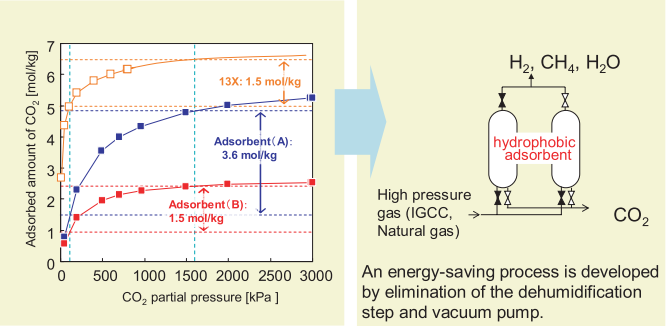


Fig.9 Energy-saving CO_2 - PSA

Development of an innovative after treatment system for diesel vehicles

Recently, the emission control for the diesel vehicles is becoming extremely severe; each diesel vehicles has to install an after-treatment system in order to satisfy the severe standards. The plasma technology has been getting great attention as an innovative technology for particulate matter (PM) removal from the exhaust gases of diesel vehicles. We carried out the study supported by NEDO (Comprehensive Technological Development of Innovative, Next-Generation, Low-Pollution Vehicles, R&D of innovative after treatment systems) to develop the plasma technology for PM removal from FY2004 to FY2008. After mechanism investigation of plasma discharge and PM oxidation/combustion, a plasma PM removal system (Fig. 10) of a pulse power supply and a plasma PM reactor has been developed for light-duty diesel vehicles. The plasma PM reactor has been evaluated by Japan Automobile Research Institute (JARI, Tsukuba). It was found that the PM emission from a light-duty diesel vehicle installed with the plasma PM reactor with 93 W discharge powers is 0.005 g/km (Fig. 11); this result suggested that if using the plasma PM removal system the PM emission satisfies the post new long-term emission standard (to be effective from 2009) for light-duty diesel vehicles.

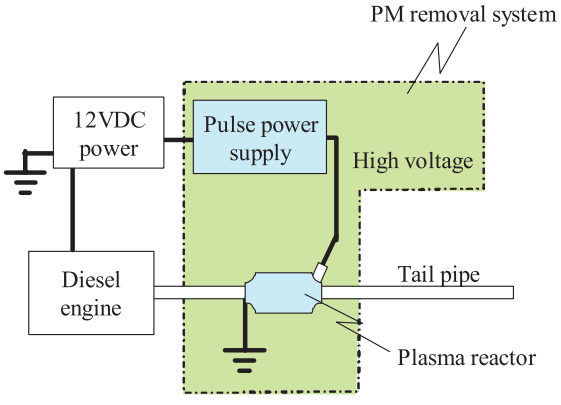


Fig.10 Non-thermal plasma PM removal system.

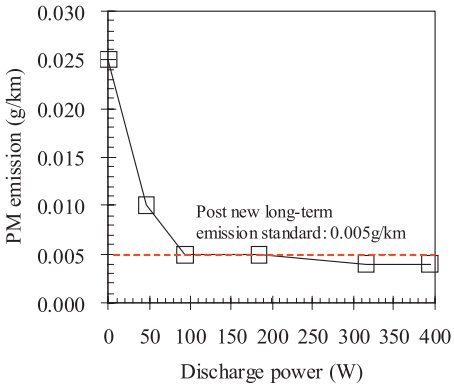


Fig.11 Relation of PM emission and discharge power under JC08 mode.

CO_2 Storage Research Group

CO_2 Storage Technology Development for Practical Application

CO_2 Geological Storage Project

The CO_2 geological storage technology is a technology for safely and securely trapping CO_2, a greenhouse gas, into subsurfaces without releasing it into the atmosphere. There are various methods for the storage, including EOR, which injects CO_2 into depleted oil fields and recovers the enhanced oil; isolation of CO_2 in depleted gas fields; ECBM, which injects CO_2 in coal seams and recovers methane; and storage of CO_2 in highly porous sandstone aquifers, containing formation water.

RITE has been working on aquifer storage, which enables stable storage of CO_2 over long periods because there is a gas- and water-impermeable sealing layer on top of the aquifer where CO_2 is stored(See Fig.1). Since technology of underground natural gas storage can be applied, this method is thought to be the most immediately effective and closest to practical use.

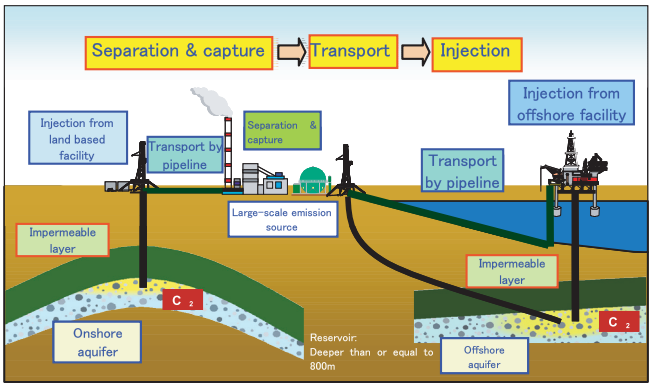


Fig.1 Concept of CO_2 geological Storage

"R&D project of CO_2 Geological Storage Technology" was launched in 2000 to scientifically verify the feasibility of CO_2 storage in subsurface aquifers in Japan, focusing on its effectiveness as a global warming countermeasure. In particular, for the CO_2 injection demonstration test conducted at the Iwanohara site in Nagaoka City, Niigata Prefecture, 10,400 tons of CO_2 were injected in the aquifer of 1,100m depth below the ground during the period from July 2003 to January 2005(See Fig.2). The underground behavior of CO_2 was observed by cross-well seismic tomography and well loggings, and a behavior prediction simulator was developed, based on the observation data. Besides, during testing, the Chuetsu Earthquake took place in Niigata Prefecture, approx. 20 km away from the Iwanohara site, but no abnormalities were found in the injected CO_2, the aquifer, and the well, confirming the safety of the storage. In 2007, the CO_2 stored underground were monitored to improve the accuracy of the prediction technique.

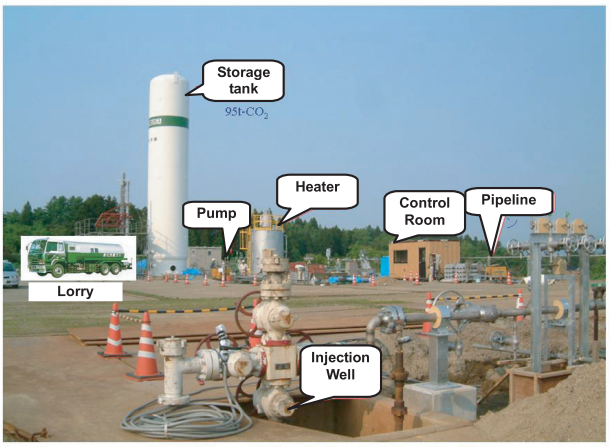


Fig.2 Nagaoka demonstration test site

The passable possibility of the implementation of geological storage in Japan was indicated by the CO_2 injection demonstration test in Nagaoka for eight years. CO_2 geological storage technology development and demonstration is steadily progressing and is closer to practical use as a CO_2 emission reduction measure around the world. Therefore, it is necessary to clarify the effectiveness of CO_2 geological storage and issues for its practical application, and develop a social system.

RITE has performed a comprehensive research & development centered around safety assessment of CO_2 geological storage: the fundamental studies on the assessment of seal performance and reservoir for CO_2 storage, the impact assessment of earthquake in the CO_2 geological storage, the advancement of technology to monitor the leakage of CO_2 under the seabed. In addition, we estimated the potential capacity of the geological storage near the emission sources and performed the trend survey of CCS and risk assessment.

We intend to develop the safety assessment methods including the formulation of criterion for safety assessment to clarify issues in promoting CCS (Carbon dioxide Capture and Storage), and conduct basic studies for the implementation of large scale demonstration project (injecting 100,000 tons of CO_2 per year) targeted by the government.

CO_2 Ocean Sequestration Project

The ocean dissolves a large quantity of CO_2. There is sufficient potentiality to dissolve CO_2 in the middle and deep layers of the ocean, which is rapidly increasing in the atmosphere. CO_2 ocean sequestration technology

captures CO_2 from large emission sources and directly injects it into deep-sea areas without passing through the ocean surface has been proposed. RITE has been developing technology for CO_2 dilution and injection to middle ocean layer using a Moving Ship method, as shown in the Fig.3. According to chapter 6 of the IPCC special report "Carbon Dioxide Capture and Storage" in 2005, ocean sequestration is evaluated as an effective technology to mitigate climate change. The challenge in preparing this technology for practical use lies in controlling the impact of CO_2, which is injected directly into the ocean, on marine species. Development of environmental impact prediction technology is our immediate challenge.

In phase 1 of this project, which was implemented from FY1997 to FY2001, we conducted a CO_2 macroscopic behavioral study, an analysis of CO_2 behavior behind the release nozzles, and predictions and investigations of biological impacts. In the following phase 2 (from FY2002 to FY2011), we are developing and assessing technology aimed at "Study of environmental impact assessment for CO_2 ocean sequestration for mitigation of climate change"

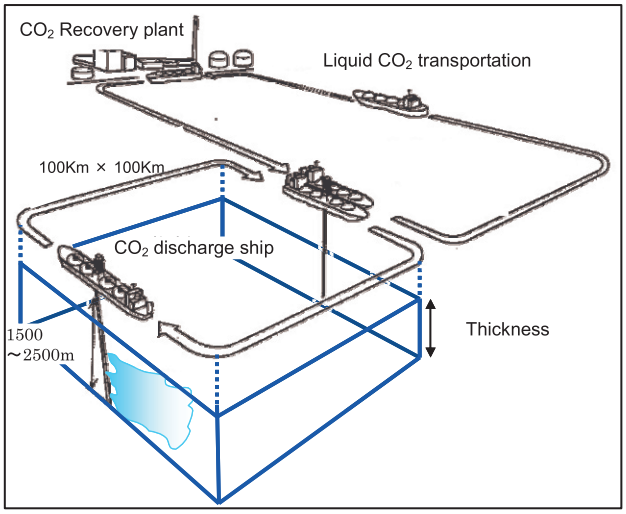


Fig.3 Image of ocean sequestration using a Moving Ship

As a result, for CO_2 discharge using a Moving Ship method, the simulation predicted that within a few hours, the CO_2 concentration is lower than the natural fluctuation range and the acute impact on marine living species is negligible. To clarify the image of ocean sequestration in practical use, the engineering study of its implementation was carried out under the case which is the ocean sequestration of about 50 million tons of CO_2 annually into the ocean near Japan, and got the result that the CO_2 concentration can be reduced to below the level of the predicted no-effect concentration. These results were reported in the special symposium of Japan Ocean Society "CO_2 ocean sequestration: what is the appropriate assessment for the environmental impact" in the autumn of 2005 and in the symposium of Advanced Marine Science and Technology Society in 2007 FY "Development of technologies for CO_2 ocean sequestration" and promoted scientists' understanding. Industrial Structure Council of METI carried out an interim assessment of ocean sequestration project in 2007 FY and evaluated this project as progressing satisfactorily in general. The reliability improvement for the model to predict the CO_2 behavior in the ocean will be promoted along with the future proposal given in this interim assessment.

We have conducted the following activities since 2007 FY: (1) Study on trends in CO_2 ocean sequestration technology (1. Preparing the base to promote understanding and 2. Establishing a global network), (2)Study on biological impact assessment for CO_2 ocean sequestration (1. Developing biological impact assessment techniques, 2. Collecting biological impact data in the actual ocean, and 3. Studying the CO_2 impact on deep-sea living species) and (3) Development of CO_2 behavior technology (1. Developing CO_2 behavior observation and prediction technology, and 2. Potential ocean sequestration assessment).

In future development, we will proceed with development of ocean sequestration technology for practical application by developing a more accurate CO_2 behavior prediction technology, as well as biological models of the middle and deep layers of the ocean and long-term impact prediction technology, by taking advantage of achievements such as environmental impact assessment technology and CO_2 dilution technology. However, to put the ocean sequestration technology into practical use in the future, it is necessary to demonstrate developed technology by conducting experiments in the actual ocean, and ultimately, to trace the CO_2 behavior in several 100 km scale, and to investigate the biological impact. In addition, since the ocean is a human common property, international consensus to implement the ocean sequestration test is essential. Therefore, we will make efforts to establish a global network not only to promote scientists' understanding of ocean sequestration but also to acquire agreement to experiment via international treaty.

IZEC (International Zero Emission Coal)Project

Fossil fuels account for approximately 80% of global energy sources and the long-term use of coal is expected in the future. Clean coal power generation in particular attracts a lot of attention. From the perspective of global warming, it is necessary to combine coal power generation technology and CCS technology that separates, recovers, and stores the emitted CO_2 in the earth in order to achieve this goal.

As such combined technologies, Post-Combustion, Oxy-Fuel and Pre-Combustion are specified (See Fig.4).

At present, many zero emission coal power generation projects such as FutureGen in U.S. are planned all over the world. Also in Japan, some plans such as "Innovative Zero Emission Coal Gasification Generation Project" supervised by NEDO have started.

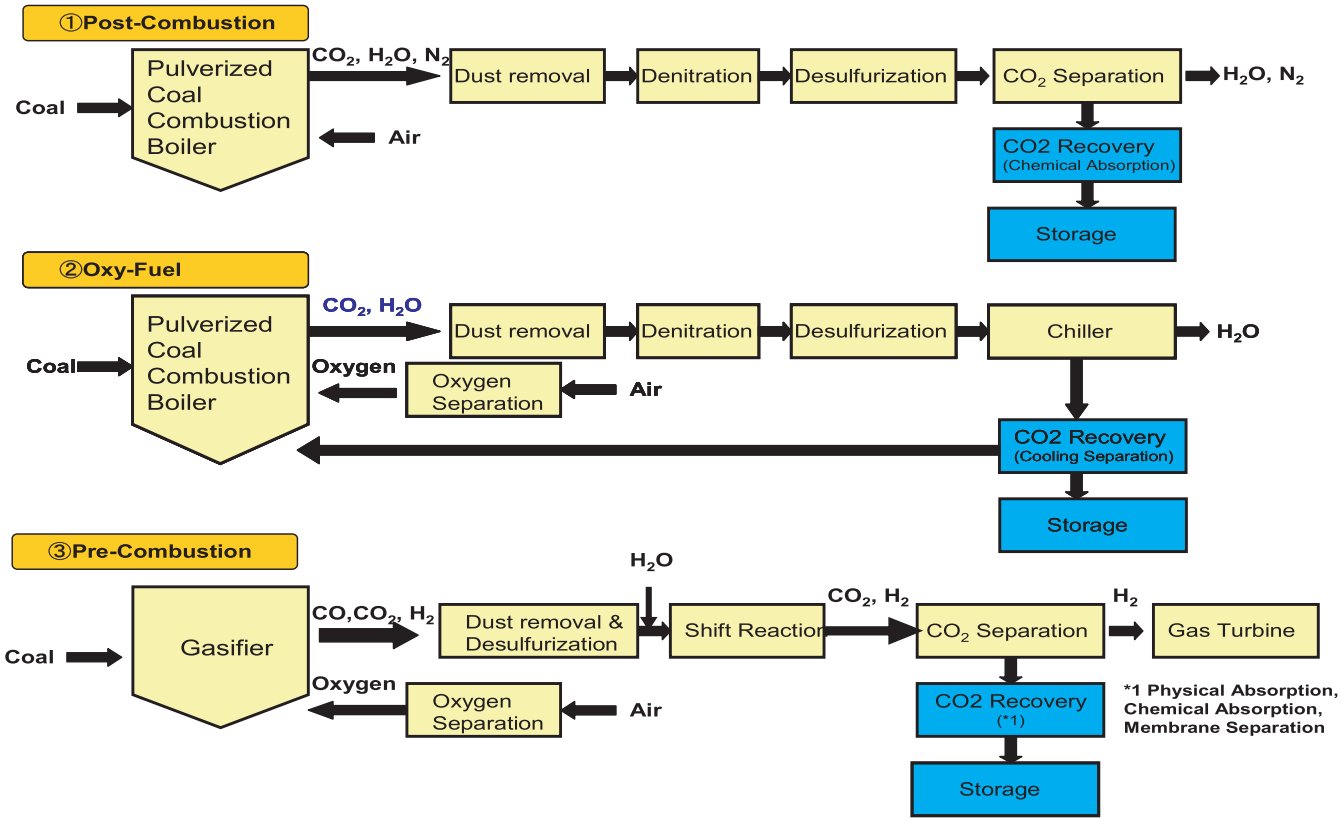


Fig.4 Concept of Coral Power Generation technologies with Storage, such as Post-Combustion, Oxy-Fuel and Pre-Combustion

To demonstrate zero emission, consolidation of a broad range of technologies and strong financial resources are required. Thus, investigating current status of zero emission coal power generation projects all over the world from both view points of technology and management and promoting and enlightening public awareness for zero emission coal power generation is of great significance in considering our comprehensive strategy for its practical use in Japan.

Reflecting the above, RITE conducts IZEC (International Zero Emission Coal) project. The major subjects are (1) Collecting and sorting information regarding zero emission coal power generation projects all over the world; (2) Collecting and sorting information regarding zero emission/CCS initiatives of nations concerned and international organizations; (3) Promoting and enlightening public awareness for zero emission coal power generation through operating "IZEC Forum", "IZEC Workshop" and so on.

In FY 2008, we are conducting surveys with regards to current status of more than forty demonstration and pilot projects mostly in EU, U.S. and Australia while mainly investigating FutureGen in FY 2007. With regards to initiatives, policies and strategies of EU, Britain, Norway, Holland, Germany, U.S., Canada, Australia and so on are investigated.

For popularization and enlightenment, we are now preparing a Web site for IZEC and will introduce schedule, finance, adopted technologies of each project and initiative of each nation and so on. In addition, we hold "IZEC Forum" which informs the related industry of the collected information and "IZEC Workshop" which invites representatives of projects and initiatives overseas.

Through these activities, our objective is to contribute to determine comprehensive strategy for the practical use of zero emission coal power generation in Japan.

RITE Bioprocess featured at the 75th Session of the Council for Science and Technology Policy and at the 34th Group of Eight Summit in Toyako, Hokkaido.

Molecular Microbiology and Biotechnology Group

To combat greenhouse gas emissions that contribute to global warming, biofuels such as bioethanol have attracted worldwide attention. However, the fact that current bioethanol sources include food crops has resulted in undesirable competition between biofuel and food supply. In collaboration with Honda, RITE has developed a biofuel production system based on non-food cellulosic biomass resources such as plant stems and leaves (RITE-Honda process).

At the 75th Session of the Council of Science and Technology Policy held on May 19, 2008, the bioprocess was featured under the theme Current Science and Technology Trends: Contribution of Genetically Modified Microorganisms to the Realization of Post-Oil Society. The characteristics of the bioprocess as a production system for bioethanol and commodity chemicals using recombinant coryneform bacteria were hailed as an innovative means to a low-carbon society of the future. Subsequently, the Cabinet Office and the Ministry of Foreign Affairs sanctioned a display of the bioprocess during the 2008 G8 Summit. The then Prime Minister of Japan Yasuo Fukuda emphasized biofuels in his discussions with the other G8 leaders. The advancements of the RITE-Honda process were afforded special mention in his session with Germany Chancellor Angela Merkel (www.mofa.go.jp).

The 75th session of the Council for Science and Technology Policy Prof. Tasuku Honjo, a full-time executive member, is in the center of the photo.

Japanese-German Leaders' session

Display of RITE bioprocess at the G8 summit

RITE-HONDA Research Team won the 18th Nikkei Global Environment Award's Grand Prize

Molecular Microbiology and Biotechnology Group

Winners of the 18th Nikkei Global Environment Technology Awards were announced on October 13, 2008. The RITE-Honda Research Team (Head; Hideaki Yukawa) was awarded the Grand Prize for "Bioethanol Production from Cellulose by Simultaneous Conversion of Mixed Sugars".

In cellulosic ethanol production, the sugar extract from cellulosic biomass saccharification contains a mixture of glucose (6-carbon sugar), and xylose and arabinose (both 5-carbon sugars). The extract also contains saccharification by-products including organic acids, furan, and phenol compounds which inhibit microbial growth and metabolism, consequently retarding the fermentation of sugars. Efficient production of bioethanol calls not only for simultaneous C5 and C6 sugar fermentation, but also high tolerance of the inhibitory substances.

The microbial growth-independent RITE-Honda process utilizing recombinant coryneform bacteria is the first in the world to meet these requirements. Its demonstrably high and efficient production of ethanol from cellulosic biomass led to this award. We continue to pursue research and development in this field in order to advance the technologies underlying the process for industrial application. By so doing, we hope to contribute positively to improved global energy as well as food security while addressing the pertinent problem of global warming.

Dr. Yukawa at the award ceremony


第十八回日経地球環境技術賞
大賞
財団法人地球環境産業技術研究機構
RITE-HONDAバイオケミカルグループ
代表 湯川英明様
研究成果
「セルロースからの混合糖同時発酵によるエタノール製造技術」
あなたは世界的な環境保護の動きに呼応していち早く研究に取り組み「地球環境保全と持続的な発展に貢献する優れた成果を挙げられました
日経地球環境技術賞 審査委員会による審査の結果 頭書の賞に選定されましたのでここにその功績を称え表彰いたします
二〇〇八年十一月十二日
日本経済新聞社
社長 喜多恒雄

Global Climate & Energy Project(GCEP)

Chemical Research Group

The RITE has conducted the developmental work "Sub-nano structure controlled materials: development of innovative gas separation membranes" from the Global Climate and Energy Project (GCEP) of Stanford University, USA. In this project, the synergy of research into both organic and inorganic materials has led to innovative materials for gas separation membranes. In September 2008, RITE has received a new award for the research "Advanced CO_2/H_2 separation materials incorporating active functional agents" from GCEP.

Organic membrane

In the organic materials approach, sub-nanostructure control technologies will provide novel membranes with an excellent CO_2 separation performance for various practical gas sources.

A RITE's novel carbon membrane involving cesium atom shows good tolerance of humidity in feed gas to be of great advantage in CO_2 separation from industrial gas mixtures. Figure 1 shows carbon membranes fabricated on alumina porous substrate.

RITE is now conducting new method of creating CO_2 separation membranes using super-critical CO_2 atmosphere.

Fig.1 Carbon membrane modules incorporating cesium atom

International Workshop "Geological Storage of Carbon Dioxide" CCS Workshop 2008 – Status and Environment for the Technology of CCS–

CO_2 Sequestration Research Group

The workshop, where the current status and issues of the development of CCS technology were reported, was held at Grand Palace Hotel, Tokyo on 26th September 2008.

This workshop was organized by RITE and co-organized by Engineering Advancement Association of Japan and supported by the Ministry of Economy, Trade, and Industry of Japan, New Energy Development Organization, National Institute of Advanced Industrial Science and Technology, Japan Coal Energy Center, Central Research Institute of Electric Power Industry, The Japanese Association for Petroleum Technology, Japan Society of Energy and Resources, Society of Exploration Geophysicists of Japan and Mining and Materials Processing Institute of Japan. A total of 490 people attended from companies, research institutes and government official.

In the workshop, invited speakers from home and abroad introduced efforts toward practical application of CCS in Japan, trends of demonstration study and project of CCS in overseas, global deployment of CCS, CCS project in Australia, MASDAR CCS Project in UAE for a low carbon future, and full-scale CCS enterprise in Japan. This workshop helped to promote a much better understanding of CCS technology development.

Workshop, Grand Palace Hotel

For more information, Please visit the web site of RITE.

International Workshop "Geological Storage of Carbon Dioxide" FutureGen Workshop 2008 – CO_2 Zero Emission Coal fire Plant demonstration Project–

CO_2 Sequestration Research Group

The workshop was held at Dai-ichi Hotel, Tokyo on 25th February 2008. This workshop was organized by RITE and supported by Ministry of Economy, Trade and Industry, Ministry of Foreign Affairs of Japan, Embassy of the United States, Japan Coal Energy Center, the Institute of Energy Economics, Japan. A total of 350 people attended from companies, research institutes and government official.

In the workshop, invited speakers from home and abroad introduced "Update on the FutureGen Initiative for Near-Zero Emissions Coal", "Clean Coal Technology in Japan", "European Coal Gasification Projects", "Overview of China's IGCC and Co-production Technology Research and Development" and efforts toward practical application of CCS in Japan.

Invited speakers and researchers in Japan participated in the panel discussion about the object of large-scale CCS demonstration projects and issues to be solved. A lot of comments were made by the audience.

For more information, Please visit the web site of RITE.

Workshop, Dai-ichi Hotel,Tokyo

IIASA-RITE International Symposium

System Analysis Group

The IIASA-RITE international symposium: Global warming and sustainable development was held at Keidanren Kaikan in Tokyo on February 18, 2008. The symposium was organized by the International Institute for Applied Systems Analysis (IIASA), the Japan Committee for IIASA, the Research Institute of Innovative Technology for the Earth (RITE), and supported by the Ministry of Economy, Trade and Industry, Japan.

The objectives of this symposium were to present the findings of new project called "Alternative pathways toward sustainable development and climate stabilization (ALPS)" with the aim of the project, and to invite distinguished researchers from Japan and abroad to give a lecture on the related research, and to offer opportunities to communicate with not only researchers working on global warming, but also with participants from administrative agencies, industries and from the public.

We had an attendance of 230 people including participants from industries, ministries, universities, and research institutes, and had active discussions on global warming and sustainable development.

In the symposium, the speakers explained about the observed rise in temperature and sea level during 20th century, and projections for the rise in temperature by 1.4 to 5.8 °C relative to 1990 by the end of 21st century. In addition, it was pointed out that there were a number of people with less access to foods and electricity in the world, and suggested that a paradigm change in technologies, policy frameworks and human behaviors be necessary to build a society where sustainable development was achievable.

Symposium, Keidanren Kaikan

International Symposium on Technologies for Mitigating Global Warming -Sectoral Approach: as an Effective Measure against Global Warming-

Planning, Survey, and Public Relations Group

This symposium entitled "International Symposium on Technologies for Mitigating Global Warming -Sectoral Approach: as an Effective Measure against Global Warming-" was held on 27th of November in 2008 at Hyatt Regency Osaka in Osaka. This symposium was organized by RITE and supported by Ministry of Economy, Trade and Industry (METI) and Kinki Regional Countermeasures Promotion Meeting on Energy and Global Warming.

Symposium, Hyatt Regency Osaka

There was a high attendance of 285 people, including participants from various ministries such as METI, Ministry of Land, Infrastructure, Transport and Tourism, and Ministry of Education, Culture, Sports, Science and Technology, and also participants from embassies and foreign organizations from France and South Korea.

Under the theme of "Sectoral Approach:

as an Effective Measure against Global Warming", presentations about challenges for the approach and measures for reducing CO_2 emissions were given by the following speakers: Dr. Gwyn Prins, Professor of the London School of Economics & Political Science from United Kingdom, Mr. Duncan Macleod, Vice president of Shell International Petroleum Company Ltd. from United Kingdom, Dr. Hyeon Park, Environment Team Leader of Environment & Energy Department, POSCO from South Korea, Mr. Hiroshi Watanabe, General Manager, Siting & Environment of the Federation of Electric Power Companies, Mr. Hisatsugu Kitaguchi, Senior Manager of Global Environment Affairs Dept. Environment Affairs Div. of Nippon Steel Corporation, Mr. Michio Shinohara, General Manager, Environment & Safety Planning Office of Honda Motor Co., Ltd., and Dr. Keigo Akimoto, Group Leader of System Analysis Group of RITE. The closing speech was given by Mr. Takashi Honjo, Senior Managing Director of RITE.

The Symposium promoted greater understanding of the Sectoral approach and measures for mitigating global warming.

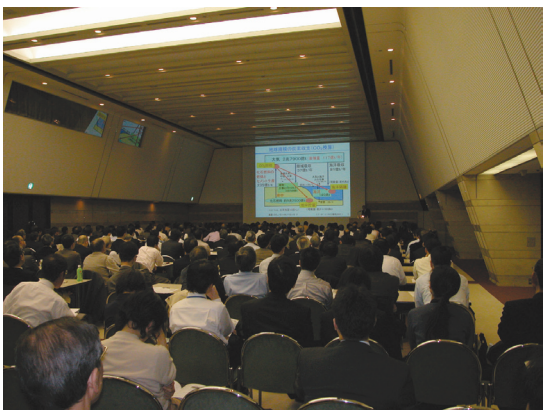
Symposium on Innovative Environmental Technologies

Research Planning Group

Symposium on Innovative Environmental Technologies was held at Mielparque-Kyoto on October 21 2008, and at Nadao Hall ,Kasumigaseki in Tokyo on December 8 2008, supported by Ministry of Economy, Trade and Industry (METI), Kyoto Prefecture and Kinki Regional Countermeasures Promotion Meeting on Energy and Global Warming..

At Mielparque-Kyoto, the outcomes of Programmed Research and Development in 2007 were presented mainly, and we had 269 participants from various field including industry, academia and government. Including the speech of Dr. Akimoto, the leader of Systems Analysis Group, the outcomes of Fundamental Research and Reading Research were presented by oral speech and poster exhibition, and the outcomes of Joint Research Program of Technological Development in the Private Sectors in 2007 were presented at the same time.

At Nadao Hall, the symposium entitled "Strategy and Perspective of Innovative Technology Development to Achieve Cool Earth 50" was held and we had 306 participants from various field including industry, academia and government. The reader of each Research Group of RITE presented the technical issue and the current world situation toward the achievement of the goal '50% reduction of global carbon dioxide emissions by 2050', and research outcomes of CCS and Bio-refinery in RITE.



Symposium, Nadao Hall

Poster exhibition, Mielparque-Kyoto

GHGT-9 Participation Report

Research Planning Group

9th International Conference on Greenhouse Gas Control Technologies (GHGT-9) was held on 16-20 November at The Omni Shoreham Hotel in Washington D.C. This is the largest international conference that focuses on mitigation technologies especially CCS (Carbon dioxide capture and storage) and are held every two years.

1. Overview of the conference

The number of the attendee was record-high 1,469 people. Since Vancouver (Canada) in 2004, the number of attendee grew by 1.5 times every time. This shows CCS as a mitigation technology has drawn much attention in the world. The largest attendee group was the US, followed by Canada, Japan, the UK, Norway, France, the Netherlands, Germany, and Australia.

After two opening plenary lectures, oral presentations were held in 66 technical sessions as follows: geological storage 23, other storage like oceanic sequestration 2, capture 17, integrated system 11, policy 8, issued forum 5. From Japan, there were two oral presentations with regard to the CO_2 trapping mechanism in Nagaoka project and CO_2 storage potential survey in Japan. Besides that, five poster presentations about geological storage, four capture, and two system analysis were carried out by RITE. The next GHGT-10 will be held in Amsterdam, the Netherlands on 19-23 September, 2010.

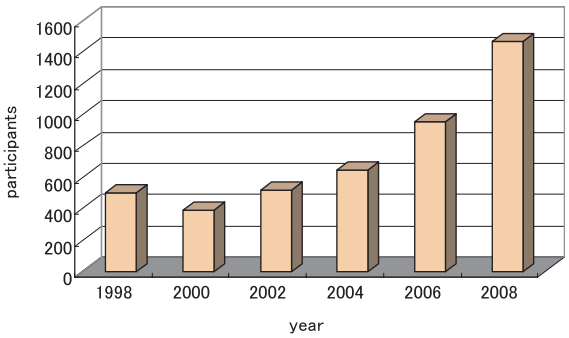


Fig. 1 Number of participants

2. Topics in each field of technical sessions

Policy and Project

CCS has become more realistic compared with two years ago when GHGT-8 was held. The importance of CCS as a CO_2 reduction technology has been well recognized and the legal standards and regulations of CCS, for example EU directive, law for the prevention of marine pollution in Japan, the Australian petroleum Act, and US EPA safe drinking water act, are being enacted. Further, in financial aspect, the EU decided to apply EU-ETS to CCS projects that start from 2013.

CCS demonstration project: The US plans to launch nine Regional Carbon Sequestration Projects, each of which will be able to capture and store more than 1 million tons of CO_2 per year. Concerning pipeline network Canada has started a project. It was announced that 21 million tons of CO_2 per year would be stored in the ground by 2012 throughout the world.

Developing countries: China promotes several CCS projects actively cooperating with the UK, the US and Australia, etc. and has launched the first post-combustion capture pilot plant.

Many CCS projects have been planned as described above but some of them have been cancelled or restructured because financial support is not sufficient. Improvements in financial systems including stabilizing EU-ETS are strongly required.

Capture

In capture sessions, noteworthy reports are (a) chemical absorption and retrofit, (b)

pilot test of chilled ammonia, and (c) pilot test of oxyfuel combustion. In the UK, a detailed study on chemical absorption has been done under the government initiative which aims to construct demonstration plants by 2014 at the latest. Many engineering studies using existing technologies have been done rather than R&D of cutting-edged capture technologies considering that application of capture technology will start from retrofit to powder-coal firing power plants in developed countries. Concerning chilled ammonia process, 30MW pilot plant test was carried out in the US and the operational results were reported, but no specific numerical value relating to superiority in energy decrease or CO_2 capture pressure was appeared. This verification seems to be done from now on. As Vattenfall's 30MW oxyfuel pilot plant in Europe was already in operation, its operational report has drawn attention but no specific data was released either. Few specific topics were presented concerning IGCC with CCS because FutureGen project is at the stage of candidate selection and is scheduled to announce the results in January, 2009. Demonstration of IGCC seems to be postponed. The EU and the US might have a strategy that they use post combustion and oxyfuel to accelerate practical application of CCS in the short term and grow IGCC with CCS as a next-generation technology.

Storage

Looking back this year's conference, GHGT-9 seemed more practical and project-oriented compared with the former conferences. In geological storage sessions, more specific discussions were presented, such as "how we should apply what we learned from mega-ton-CO_2 demonstrations to giga-ton commercial projects" or "different standard to select storage site is required between the earthquake-ridden country such as Italy and other countries". Concerning monitoring, more reports of on-site investigation and experiment were presented than before. Increasing the number of reports dealing with safety assessment and public acceptance also seems to be the key feature in this conference.

GHGT-9, The Omni Shoreham Hotel

System Analysis Group

■2008 Original Paper (Peer-reviewed)

	Title	Researchers	Journal
1	Impact Assessment of the Increase in Fossil Fuel Prices on the Global Energy System, with and without CO_2 Concentration Stabilization	U. K. Rout, K. Akimoto, F. Sano, J. Oda, T. Homma, T. Tomoda	Energy Policy, Volume 36 ,No. 9, 3437-3484 , 2008
2	Global Emission Reductions through a Sectoral Intensity Target Scheme	K. Akimoto, F. Sano, J. Oda, T. Homma, U. K. Rout, T. Tomoda	Climate Policy, Vol. 8, S46-S59, 2008
3	Technology Spillovers and Stability of International Climate Coalitions	M. Nagashima, Rob Dellink	International Environemntal Agreements: Politics, Law and Economics (in Press)
4	Stability of International Climate Coalitions – A Comparison of Transfer Schemes	M. Nagashima, Rob Dellink, Ekko van Ierland, Hans-Peter Weikard	Ecological Economics (in Press)

■2008 Other Paper (e.g., Review, Comment)

	Title	Researchers	Journal
1	A Desired Stabilization Target of Atmospheric CO_2 Concentration	J. Oda, K. Akimoto, A. Hayashi, T. Homma, F. Sano, T. Tomoda	Communications of the Operations Research Society of Japan, Vol. 53, No. 4, April 2008
2	Post-Kyoto Regime – Achievement both of Environmental Measures and Economic Growth	K. Akimoto	Economic Trend, April 2008
3	Is It Possible to Achieve Halving Greenhouse Gases until 2050?	K. Akimoto	Journal of Japan Electric Association, June 2008
4	Toward Sustainable Development Low Carbon Society-The ALPS Project-	K. Akimoto	Journal of Japan Environmental Management Association for Industry, June 2008,

■2008 Oral Presentaion (Domestic Conference)

	Title	Researchers	Forum
1	An Integrated Assessment of Global Warming and the Long-term Stabilization Target	A. Hayashi, K. Akimoto, S. Mori, T. Homma, F. Sano, J. Oda, T. Tomoda	24th Conference on Energy, Economy, and Environment 30-31, January, 2008
2	Analysis on Factors of Change in GHG Emissions and Pollicy Effects in Major Countries	K .Tokushige、K. Akimoto, J. Oda	24th Conference on Energy, Economy, and Environment 30-31, January, 2008
3	Proposal and Evaluation of Global Sectoral Intensity Target Scheme	F. Sano, K. Akimoto, J. Oda, T. Tomoda	24th Conference on Energy, Economy, and Environment 30-31, January, 2008
4	Discussions on Cap & Trade and Sectoral Intensity Target Schemes	K. Akimoto	24th Conference on Energy, Economy, and Environment 30-31, January, 2008
5	An Analysis and Survey of Recent Technological Progress and Long-term Perspectives	J. Oda, K. Akimoto, F. Sano, T. Homma, T. Tomoda	24th Conference on Energy, Economy, and Environment 30-31, January, 2008
6	Impacts Assessment of Increase in Crude Oil, Natural Gas and Coal Prices on Global Energy System without and with Carbon Concentration Stabilization	U. K. Rout, K. Akimoto, F. Sano, J. Oda, T. Homma, T. Tomoda	24th Conference on Energy, Economy, and Environment 30-31, January, 2008
7	Evaluation of Long-Term Global CO_2 Emission Reduction Target -Regional Costs and mitigation technologies-	F. Sano, K. Akimoto, J. Oda, T. Tomoda	27th Annual Meeting of Japan Society of Energy and Resources, 5 June, 2008
8	Effects of Sectoral Benchmarking on Global CO_2 Emission Reductions	K. Akimoto, F. Sano	Society for Environmental Economics and Policy Studies 2008, 27-28, September, 2008
9	An Analysis of Steel Supply and Demand and Mitigation Scenario until 2050	J. Oda, K. Akimoto, F. Sano	156th Autumn Conference, The Iron and Steel Institute of Japan, 24 September, 2008
10	Study on the socio-economic aspect of bio-fuel sustainability in Asia	M. Kii, A. Maruyama, S. Kai	38th Conference on Infrastructure Planning, 1 November, 2008

■2008 Oral Presentaion (International Conference)

	Title	Researchers	Forum
1	Mitigation potentials in energy supply and end-use sectors	K. Akimoto,	International Workshop on Sectoral Emission Reduction Potential, May, 2008
2	Sectoral analysis of mitigation potential	F. Sano, K. Akimoto,	Sectoral Approaches to International Climate Policy Workshop, May, 2008
3	Evaluation of Sectoral and Regional CO_2 Emissions: Production-Based and Consumption-Based Accounting Measurements	T. Homma, K. Akimoto, T. Tomoda	GTAP Conference 2008(Annual Conferences; Eleventh Annual Conference, 2008) , 12-14, June, 2008
4	Integrated Assessment for Climate Change in Asia Consisting with Global Scenarios	M.Kii	AEEMF 5th Annual Workshop, 3, June, 2008
5	Activities for Global Scenario Development by RITE	K. Akimoto	IAMC (Integrated Assessment Modeling Consortium) Meeting, 23, September, 2008
6	Technology Development and Diffusion and Global Warming Mitigation through Sectoral Approach	K. Akimoto	International Symposium on Technologies for Mitigating Global Warming, 27 November, 2008
7	Global Emission Reduction Potentials and Scenarios in Energy Supply and End-use Sectors	K. Akimoto, F. Sano	2nd International Workshop on Sectoral Emission Reduction Potential, 22 October, 2008
8	Overview of DNE21+ model	F. Sano, K. Akimoto,	2nd International Expert Meeting on Bottom-up Based Analysis on Mitigation Potential, 21 October, 2008
9	Long- and Mid-Term Emission Reduction Targets to Keep Continued Fight against Climate Change	K. Akimoto	International Meeting on Mid-Long Term Strategy for Climate Change, 30 June, 2008
10	Diffusion of CCS and Energy Efficient Technologies in Power and Iron & Steel Sectors	J. Oda, K. Akimoto, F. Sano	GHGT9, 16-20, November, 2008
11	A Framework to Add Incentives for Managements after CO_2 Injections	K .Tokushige, K. Akimoto	GHGT9, 16-20, November, 2008

■2008 Non-Journal Publication

	Title	Researchers	Magazine, Newspaper, etc.
1	Global Warming Issue and Post-Kyoto Framework	K. Akimoto	Instrumentation & Process Control Engineers' Association, 14 November, 2008
2	International Emission Reduction Frameworks and Targets after KP -Investigation from a Desirable Long-Term Stabilization Level, and of Cost-Potentials of Emission Reduction by Nation and by Sector-	T. Tomoda, K. Akimoto	2nd Japan-Germany Meeting Towards Copenhagen Summit, 2 December,2008
3	Scenarios Toward Low Carbon Future - Technology Diffusions and Developments -	K. Akimoto	The Asia-Pacific Partnership on Clean Development and Climate, 4th Steel Task Force Workshop, 16 April, 2008
4	Energy Strategy toward Low-carbon Society and Issues	K. Akimoto	Japan Society of Energy and Resources, 10 June, 2008
5	Post-Kyoto: Sectoral Approach	K. Akimoto	Japan Society of Energy ans Resources, 11 July, 2008
6	Mitigation cost of global warming - The ambitious target should be discussed considering the costs	K. Akimoto	Asahi Shinbun, Opinion 14 June, 2008
7	Low Carbon Economy	K. Akimoto	Nikkei Publishing Inc. 21 November, 2008

Molecular Microbiology and Biotechnology Group

■2008 Original Paper

	Title	Researchers	Journal
1	Technological Options for Biological Fuel Ethanol.	A.A. Vertès, M. Inui and H. Yukawa.	J. Mol. Microbiol. Biotechnol. 15:16–30. 2008.
2	Regulation of the expression of phosphoenolpyruvate, carbohydrate phosphotransferase system (PTS) genes in *Corynebacterium glutamicum* R.	Y. Tanaka, N. Okai, H. Teramoto, M. Inui and H. Yukawa.	Microbiology. 154:264–274. 2008.
3	Engineering of an L-arabinose metabolic pathway in *Corynebacterium glutamicum*.	H. Kawaguchi, M. Sasaki, A.A. Vertès, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. 77:1053–1062. 2008.
4	Production of isopropanol by metabolically-engineered *Escherichia coli*.	T. Jojima, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. 77:1219–1224. 2008.
5	Expression of *Clostridium acetobutylicum* butanol synthetic genes in *Escherichia coli*.	M. Inui, M. Suda, S. Kimura, K. Yasuda, H. Suzuki, H. Toda, S. Yamamoto, S. Okino, N. Suzuki and H. Yukawa.	Appl. Microbiol. Biotechnol. 77:1305–1316. 2008.
6	Transcription of *Corynebacterium glutamicum* genes involved in tricarboxylic acid cycle and glyoxylate cycle.	S.O. Han, M. Inui and H. Yukawa.	J. Mol. Microbiol. Biotechnol.15:264–276. 2008.
7	DivS, a novel SOS inducible cell-division suppressor in *Corynebacterium glutamicum*.	H. Ogino, H. Teramoto, M. Inui and H. Yukawa.	Mol. Microbiol. 67:597–608. 2008.
8	Regulation of expression of general components of the PTS by the global regulator SugR in *Corynebacterium glutamicum*.	Y. Tanaka, H. Teramoto, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. 78:309–318. 2008.
9	Production of D-lactic acid by *Corynebacterium glutamicum* under oxygen deprivation.	S. Okino, M. Suda, K. Fujikura, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. 78:449–454. 2008.
10	ArnR, a novel transcriptional regulator, represses expression of the *narKGHJI* operon in *Corynebacterium glutamicum*.	T. Nishimura, H. Teramoto, A.A. Vertès, M. Inui and H. Yukawa.	J. Bacteriol. 190:3264–3273. 2008.
11	Random genome deletion methods applicable to prokaryotes.	N. Suzuki, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. 79:519–526. 2008. (Mini-Review)
12	Group 2 sigma factor SigB of *Corynebacterium glutamicum* positively regulates glucose metabolism under conditions of oxygen deprivation.	S. Ehira, T. Shirai, H. Teramoto, M. Inui and H. Yukawa.	Appl. Environ. Microbiol. 74:5146–5152. 2008.
13	Identification of a gene encoding a transporter essential for utilization of C4-dicarboxylates in *Corynebacterium glutamicum*.	H. Teramoto, T. Shirai, M. Inui and H. Yukawa.	Appl. Environ. Microbiol. 74:5290–5296. 2008.
14	Effect of carbon source availability and growth phase on expression of *Corynebacterium glutamicum* genes involved in tricarboxylic acid cycle and glyoxylate bypass.	S.O. Han, M. Inui and H. Yukawa.	Microbiology 154:3073–3083. 2008.
15	An efficient succinic acid production process in a metabolically engineered *Corynebacterium glutamicum* strain.	S. Okino, R. Noburyu, M. Suda, T. Jojima, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. 81:459–464. 2008.
16	Expression of the *gapA* gene encoding glyceraldehyde-3-phosphate dehydrogenase of *Corynebacterium glutamicum* is regulated by the global regulator SugR.	K. Toyoda, H. Teramoto, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. 81:291–301. 2008.
17	Transcriptional regulation of *Corynebacterium glutamicum* methionine biosynthesis genes in response to methionine supplementation under oxygen deprivation.	M. Suda, H. Teramoto, T. Imamiya, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. 81:505–513. 2008.
18	Simultaneous utilization of D-cellobiose, D-glucose, and D-xylose by recombinant *Corynebacterium glutamicum* under oxygen-deprived conditions.	M. Sasaki, T. Jojima, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. 81:691–699. 2008.
19	Deletion of cgR_1596 and cgR_2070, encoding NlpC/P60 proteins, causes a defect in cell separation in *Corynebacterium glutamicum* R.	Y. Tsuge, H. Ogino, H. Teramoto, M. Inui and H. Yukawa.	J. Bacteriol. 190:8204–8214. 2008.
20	Characterization of a new 2.4-kb plasmid of *Corynebacterium casei*, and development of stable corynebacterial cloning vector.	Y. Tsuchida, S. Kimura, N. Suzuki, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. (in press)
21	Identification of new secreted proteins and secretion of heterologous amylase by *C. glutamicum*.	N. Suzuki, K. Watanabe, N. Okibe, Y. Tsuchida, M. Inui and H. Yukawa.	Appl. Microbiol. Biotechnol. (in press)
22	Involvement of the LuxR-type transcriptional regulator, RamA, in regulation of expression of the *gapA* gene encoding glyceraldehyde-3-phosphate dehydrogenase of *Corynebacterium glutamicum*.	K. Toyoda, H. Teramoto, M. Inui and H. Yukawa.	J. Bacteriol. (in press)
23	Scanning the *Corynebacterium glutamicum* R genome for high efficiency secretion signal sequences.	K. Watanabe, Y. Tsuchida, N. Okibe, H. Teramoto, N. Suzuki, M. Inui and H. Yukawa.	Microbiology (in press)

■2008 International Oral Presentation

	Title	Researchers	Forum
1	Bioethanol and biobutanol production from C6 and C5 sugars	H. Yukawa	Developing and Commercialising Next Generation Biofuels, 13 February 2008
2	Growth-arrested corynebacteria as whole-cell biocatalysts for biochemicals/biofuels production	H. Yukawa	235th ACS National Meeting, 8 April 2008
3	Production of biofuels/biochemicals from soft biomass by the RITE Bioprocess	H. Yukawa	The 5th World Congress on Industrial Biotechnology and Bioprocessing, 29 April 2008
4	Production of isopropanol by metabolically-engineered *Escherichia coli*.	T. Jojima, M. Inui, and H. Yukawa	The 5th World Congress on Industrial Biotechnology and Bioprocessing, 29 April 2008
5	Expression of *Clostridium acetobutylicum* butanol synthetic genes in *Escherichia coli*.	M. Suda, S. Kimura, K. Yasuda, H. Suzuki, H. Toda, S. Yamamoto, S. Okino, N. Suzuki, M. Inui, and H. Yukawa	The 5th World Congress on Industrial Biotechnology and Bioprocessing, 29 April 2008
6	Regulation of Expression of Genes Encoding General Components of the Phosphoenolpyruvate: Carbohydrate Phosphotransferase System (PTS) in *Corynebacterium glutamicum*.	Y. Tanaka, H. Teramoto, M. Inui, and H. Yukawa	108th ASM General Meeting, 2-5 June 2008
7	Biofuel production from mixed sugars derived from lignocellulosic biomass by the RITE Bioprocess	H. Yukawa	4th International Symposium on Energy, Informatics and Cybernetics, 1 July 2008
8	Transcriptional Regulation of the *gapA* Gene Encoding Glyceraldehyde-3-phosphate Dehydrogenase in *Corynebacterium glutamicum* R.	K. Toyoda, H. Teramoto, M. Inui, and H. Yukawa	SIM Annual Meeting, 10-11 August 2008
9	Transcriptional Regulation of the *narKGHJI* Operon Involved in Nitrate Respiration System in *Corynebacterium glutamicum*.	T. Nishimura, H. Teramoto, A.A. Vertès, M. Inui, and H. Yukawa	SIM Annual Meeting, 10-11 August 2008
10	The Group 2 Sigma Factor SigB Positively Regulates Glucose Metabolism under Oxygen-deprived Conditions in *Corynebacterium glutamicum*.	S. Ehira, H. Teramoto, M. Inui, and H. Yukawa	SIM Annual Meeting, 10-11 August 2008
11	Biofuel production by simultaneous utilization of C5&C6 sugars	H. Teramoto and H. Yukawa	2008 Pacific Rim Summit on Industrial Biotechnology and Bioenergy, 10 September 2008
12	Biofuel production from lignocellulosic biomass by the RITE bioprocess	M Inui and H. Yukawa	Next Generation Biofuelmarkets, 7 October 2008
13	Production of biofuels from C6 & C5 sugars by the RITE bioprocess	H. Yukawa	BIO KOREA 2008, 9 October 2008
14	Take off scenario of Biofuels and Bio-Refinary (Green chemistry: shift from petrochemical)	H. Yukawa	International Environmental Forum commemorating the Centenary of Japanese Immigration in Brazil and the Year of Brazil-Japan Exchange "Japan-Brazil Cooperation to tackle the Global Warming", 13 October, 2008
15	Production of biofuels/biochemicals from C6 & C5 sugars by the RITE bioprocess	H. Teramoto and H. Yukawa	The 13th International Biotechnology Symposium & Exhibition(IBS2008), 15 October 2008
16	Biofuels/Biochemicals production from mixed sugars derived from lignocellulosic biomass by the RITE bioprocess	T. Jojima and H. Yukawa	The 20th Annual Meeting and International Conference of the Thai Society for Biotechnology Thailand-Japan Joint Symposium on Bioproduction by Efficient Utilization of Thai Bioresorces, 16 October 2008
17	Production of biofuels by simultaneous utilization of mixed sugars	N. Suzuki and H. Yukawa	AIChE 2008 Annual Meeting, 19 November 2008

■2008 International Publication etc.

	Title	Researchers	Forum
1	L-aspartic acid.	S. Okino, M. Inui and H. Yukawa.	The Encyclopedia of Industrial Biotechnology: Bioprocess, Bioseparation, and Cell Technology., John Wiley and Sons, Inc (in press)
2	L-isoleucine.	T. Jojima, M. Inui and H. Yukawa.	The Encyclopedia of Industrial Biotechnology: Bioprocess, Bioseparation, and Cell Technology., John Wiley and Sons, Inc (in press)

Chemical Research Group

■2008 Original Paper

	タイトル	研究者	掲載先
1	Removal Properties of Diesel Exhaust Particles by a Dielectric Barrier Discharge Reactor	K.Suzuki, N.Takeuchi, Y.Nihei, K.Madokoro, C.Fushimi, S.Yao, Y.Fujioka	Analytical Science.24, 253-256 (2008)
2	Development of a new PH-swing CO_2 mineralization process with a recyclable reaction solution	S.Kodama, T.Nishimoto, N.Yamamoto, K.Yogo, K.Yamada	Energy 33 776-784 (2008)
3	PAMAM dendrimer composite membrane for CO_2 separation : addition of hyaluronic acid in gutter layer and application of novel hydroxyl PAMAM dendrimer	S.Duan, F .A . Chowdhury, T.Kai, S.Kazama, Y.Fujioka	Desalination 234 278-285 (2008)
4	Microstructures formed by secondary growth of fired ZSM-5 seed crystals	S.Uemiya, A.Tanigawa, T.Koike, Y.Sasaki, T.Ban, Y.Ohya R.Yoshiie, M.Nishimura, N.Yamamoto, K.Yogo, K.Yamada	J Porous Matter 15, 405-410(2008)
5	An Acid Dissociation Constant(pKa)-based Screening of Chemical Absorbents that Preferably Capture and Release Pressurized Canbon Dioxide for Greenhouse Gas Control	K.Tomizaki, S.Shimizu, M.Onoda, Y.Fujioka	Chemistry Letters 7(5), 483-562 (2008)
6	Facile Fabrication of a Navel High Performance CO2 Separation Membrane: Immobilization of Poly(amidoamine) Dendrimers in Poly(ethylene glycol) Network	I.Taniguchi, S.Duan、S.Kazama, Y.Fujioka	Journal of Membrane Science 322 277-280(2008)
7	Influence of Polarity and Rise Time of Pulse Voltage Waveforms on Diesel Particulate Matter Removal Using an Uneven Dielectric Barrier Discharge Reactor	C.Fushimi, K.Modokoro, S.Yao, Y.Fujioka, K.Yamada	Plasma Chem Plasma Process 28 511-522(2008)
8	Effects of O_3 and NO_2 on Catalytic Oxidation of Diesel PM	S.Yamamoto, S.Yao, S.Kodama, C.Mine, Y.Fujioka	Chemistry Letters 37(9), 998-999(2008)
9	Separation and recovery of carbon dioxide by a membrane flash process	K.Okabe, H.Mano, Y.Fujioka	International Journal of Greenhouse Gas Control 2 485-491 (2008)
10	Development of commercial-sized dendrimer composite membrane modules for CO_2 removal from flue gas	T.Kai, T.Kouketsu, S.Duan, S.Kazama, K.Yamada	Separation and Purification Technology 63 524-530(2008)
11	Highly Permeable Mesoporous Silica Membranes Synthesized by Vapor Infiltraition of Tetraethoxysilane into Non-Ionic Alkyl Poly(oxyethylene)Surfactant Films	M.Miyamoto, K.Yogo, (Department of Engineering Science, Osaka University) K.Nagata, T.Maruo, N.Nishiyama, Y.Gashira, K.Ueyama	Journal of Membrane Science325 698-703 (2008)
12	Adsorption of Carbon Dioxide on Amine-modified MSU-H Silica in the Presence of Water Vapor	K.Yogo (National Institute of Advanced Industrial Science and Technology(AIST)) N.Hiyoshi (Nihon Unibersity)T.Yashima	Chemistry Letters 37(12), 1266-1267 (2008)
13	Oxidation Mechanism of Diesel Particulate Matter in Plasma Discharges	S.Kodama, S.Yao, S.Yamamoto, C.Mine, Y.Fujioka	Chemistry Letters 38(1), 50-51(2009)
14	Investigation of Transition Metal Oxide Catalysts for Diesel PM Removal under Plasma Discharge Conditions	S.Yamamoto, S.Yao, S.Kodama, C.Mine, Y.Fujioka	The Open Catalysis Journal 1,11-16(2008)

■2008 Other Paper (e.g., Review, Comment)

	タイトル	研究者	掲載先
1	Separated at Source	Y.Fujioka	The Japan Journal Vol.4 No.10 25-26(2008)
2	SCIENCE WATCH "Biogas Breakthrough"	H.Mano (Taiyo Nippon Sanso Corp.)T.Tomioka	The Japan Journal, Vol.5 No.7 25 (2008)

■2008 Oral Presentaion (International Conference)

	タイトル	研究者	掲載先
1	Development of Poly(amidoamine)(PAMAM)Dendrimer Composite Membrane Module for CO_2 Separation	T.Kai, S.Duan, F. A. Chowdhury, S.Kazama, Y.Fujioka	2008AIChE Spring National Meeting New Orleans,LA 7 April 2008
2	Recent CO_2 Capture Technology in Japan	M.Onoda	IISI TECHCO 2008 The Westin Bund Center Shanghai 5 May 2008
3	Preparation and H_2 Separation Properties of Palladium-Mesoporous Silica Composite Membrane	M.Miyamoto, K.Yogo, Y.Fujioka (NAIST) K.Nagata	International Symposium NANOPOROUS MATERIALS-V(NANO-5) Vancouver 27 May 2008
4	Energy contribution analysis in a DBD reactor	S.Yao, S.Kodama, SYamamoto, Y.Fujioka	35th IEEE International Conference on Plasma Science Germany 15 June 2008
5	Immobilization of Poly(amidoamine) Dendrimers in Poly(ethylene glycol) Network for a Novel CO2 Separation Membrane	I.Taniguchi, S.Duan, R.Shimizu, S.Kazama, Y.Fujioka	MRS International Materials Research Conference China 10 June 2008
6	Development of novel CO2 affinity-enhanced carbon membranes:characterization and CO_2 separation performance	T.Kai, S.Kazama, Y.Fujioka	2008 International Congress on Membranes and Membrane Processes(ICOM2008) Honolulu 18.July. 2008
7	Basic Geometry of DBD Reactors for Diesel PM Removal	S.Yao, S.Kodama, S.Yamamoto, C.Mine, K.Madokoro, Y.Fujioka	Asia Pacific Confederation of Chemical Engineers(APCChE) Dalian 5.August 2008
8	Mechanism of Diesel PM Removal in Plasma Discharges	S.Kodama, S.Yao, S.Yamamoto, C.Mine, Y.Fujioka	Asia Pacific Confederation of Chemical Engineers(APCChE) Dalian 5.August 2008
9	Pulsed Plasma PM Removal from Diesel Exhaust Emissions:Influences of Reaction Conditions	S.Yamamoto,S.Yao, S.Kodama, C.Fushimi, C.Mine, Y.Fujioka (Daihatsu Motor Co)K.Madokoro, K.Naito, Y-H.Kim	Asia Pacific Confederation of Chemical Engineers(APCChE) Dalian 5.August 2008
10	Hydrogen separation membrane encapsulating Pd nanoparticles in a silica layer	M.Miyamoto, K.Yogo, Y.Fujioka (NAIST) K.Nagata	The 10th International Conferences on Inorganic Membranes(ICIM10) Tokyo 19.August.2008
11	Development of novel CO_2 affinity-enhanced carbon membranes for CO_2 separation	T.Kai, S.Kazama, Y.Fujioka	The 10th International Conferences on Inorganic Membranes(ICIM10) Tokyo 20.August.2008
12	OBSERVATION OF PARTICULATE MATTER COMBU STION IN A PULSED DISCHARGE DURATION	S.Yao, S.Kodama, S.Yamamoto, Y.Fujioka	ICPP2008：International Congress on Plasma Physics Fukuoka 10 September.2008
13	EVALUATION OF NOVEL ABSORBENT FOR CO_2 CAPTURE	K.Goto, H.Okabe, S.Shimizu, M.onoda, Y.Fujioka	20th International Symposium on Chemical Reaction Engineering (ISCRE20) Kyoto 10.September.2008
14	Diesel Aftertreatment System Using Non-Thermal Plasma for Light-Duty Vehicle	K.Naito, Y.Kim, K.Madokoro, T.Ogawa, H.Fujikawa, I.Tan, K.Hasegawa, H.Tanaka, S.Yao	32nd FISITA World Automotive Congress Germany 18.September.2008
15	Development of Innovative gas separation membranes through sub-nanoscale materials control	Y.Fujioka	GCEP Annual Symposium 2008 Palo Alto 3.October.2008
16	Application of a dielectric barrier discharge reactor for diesel PM removal	S.Yao, S.Kodama, S.Yamamoto, C.Mine, Y.Fujioka, (University of Tokyo) C.Fushimi	Eleventh International Conference on Electrostatic Precipitation(ICESP-XI) Hangzhou 23.October.2008
17	An Innovative After-Treatment System for Diesel PM Removal	S.Yao,S.Yamamoto, S.kodama, C.Mine, C.Fushimi, Y.Fujioka (Daihatsu Motor Co)K.Naito, K.Madokoro, Y-H.Kim (JARI)S.Soma, T.Nakajima, G.Sugiyama	ICAT(International Conference on Automotive Technologies) Istanbul 13.November.2008
18	PM Removal System for Diesel Passenger Vehicle Using Non-Thermal Plasma	S.Yamamoto, S.kodama, C.Mine, S.Yao, Y.Fujioka (Daihatsu Motor Co)K.Madokoro, Y-H.Kim, K.Naito, T.Ogawa, H.Fujikawa, K.Hasegawa, H.Tanaka (JARI)S.Soma, T.Nakajima, G.Sugiyama	ICAT(International Conference on Automotive Technologies) Istanbul 13.November.2008
19	Techno-economic evaluation of the coal-based integrated gasification combined cycle with CO_2 capture and storage technology	R.Nagumo, S.Kazama, Y.Fujioka	9th International Conference on Greenhouse Gas Control Technologies Washington DC 17.November.2008
20	Evaluation Method of Novel Absorbent for CO_2 Capture	K.Goto, H Okabe, S.Shimizu, M.Onoda, Y.Fujioka	9th International Conference on Greenhouse Gas Control Technologies Washington DC 17.November.2008
21	Development of Novel Tertiary Amine Absorbents for CO_2 Capture	Firoz Alam Chowdhury, H Okabe, S.Shimizu, M.Onoda, Y.Fujioka	9th International Conference on Greenhouse Gas Control Technologies Washington DC 17.November.2008
22	Separation and recovery of carbon dioxide by a membrane flash process	K.Okabe, S.Kodama, H.Mano, Y.Fujioka	9th International Conference on Greenhouse Gas Control Technologies Washington DC 17.November.2008
23	Mechanism of the Diesel PM Removal by Dielectric Barrier Discharges	S.Kodama, S.Yao,S.Yamamoto, C.Mine, Y.Fujioka	2008 AIChE Annual Meeting Philadelphia 18.November.2008
24	Catalytic Activities of Transistion Metal Oxides for Plasma PM Removal	S.Yamamoto, S.Yao, C.Mine, S.kodama, Y.Fujioka	2008 AIChE Annual Meeting Philadelphia 18.November.2008

CO_2 Storage Research Group

■2008 Original Paper [CO_2 Geological Storage Project]

	Title	Researchers	Journal
1	Geochemical aspects of a geological storage of CO2: A case study based on a formation water analysis at the Nagaoka pilot-scale CO2 injection site	Saeko Mito, Ziqiu Xue, Takashi Osumi	Journal of Geology, vol.117, No.4, 753-767, 2008
2	Case study of geological reactions at the Nagaoka CO_2 injection site, Japan	Saeko Mito, Ziqiu Xue, Takashi Osumi	International Journal of Greenhouse Gas Control, Vol. 2, No.3、2008
3	Experimental study on injection of ethanol-bentonite slurry into porous media and its pore plugging behavior	Shigemi Naganawa, Kozo Sato, Eiichi Arakawa	Journal of the Association for Petroleum Technology, Vol.73, No.4, 287-295
4	Lessons from the First Japanese Pilot Project on Saline Aquifer CO2 Storage	Ziqiu Xue, Toshifumi Matsuoka	Journal of Geology, vol.117, No.4, 743-752, 2008
5	CO2 Geological Storage: International Technology and policy Trends and Research and Development	Ziqiu Xue, Shinsuke Nakao	Journal of Geology, vol.117, No.4, 722-733, 2008

■2008 Oral Presentation [CO_2 Geological Storage Project]

	Title	Researchers	Forum
1	Nagaoka, Japan Monitoring/Verification Program Design, Deployment and Case History	Kozo Sato, Tadashi Horie, Daiji Tanase, Tsukasa Yoshimura	Japan Geoscience Union Meeting, May, 2008
2	Time-laspe well logging for monitoring injected CO_2 in a saline aquifer, Nagaoka	Jiro Watanabe, Saeko Mito, Kozo Sato, Daiji Tanase, Tsukasa Yoshimura	Japan Geoscience Union Meeting, May, 2008
3	Time-laspe crosswell seismic tomography for monitoring CO_2 geological sequestration in Nagaoka pilot-scale project	Hideki Saito, Hiroyuki Azuma, Kozo Sato, Daiji Tanase, Tsukasa Yoshimura	Japan Geoscience Union Meeting, May, 2008
4	Simulation Study of Iwanohara Pilot Carbon Dioxide Injection	Hiroshi Ohkuma, Yuko Kawata, Kozo Sato, Daiji Tanase, Tsukasa Yoshimura	Japan Geoscience Union Meeting, May, 2008
5	Simulation Study of Iwanohara Pilot Carbon Dioxide Injection	Hiroshi Ohkuma, Yuko Kawata, Kozo Sato, Daiji Tanase, Tsukasa Yoshimura	Japan Geoscience Union Meeting, May, 2008
6	Estimation of CO_2 saturation considering patchy saturation at Nagaoka	Hiroyuki Azuma, Chisato Konishi, Dai Nobuoka, Ziqiu Xue, Jiro Watanabe	The 70th EAGE (European Association of Geoscientists and Engineers) Conference & Exhibition, June, 2008
7	Experimental study of residual CO_2 saturation in the sandstones with different pore structures	Keigo Kitamura	European Geophysical Union 2008, April, 2008
8	Nagaoka CO_2 injection and monitoring project; a gateway of the intimate understanding of CO_2 behavior in the deep reservoir	Daiji Tanase, Tsukasa Yoshimura	The 33rd International Geological Congress, August, 2008
9	Estimation of CO_2 Aquifer Storage Potential in Japan	Toshihiro Takahashi, Takashi Ohsumi, Kazuo Nakayama, Kazuo Koide, Hideaki Miida	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
10	CO_2 Aquifer Storage Capacity Assessment Methodology in Japan: Overview of the Project	Shigetaka Nakanishi, Takumi Shidahara, Yasunobu Mizuno, Tadahiko Okumura, Hideaki Miida, Shin-ichi Hiramatsu	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
11	Comparative evaluation of the CO_2 aquifer atorage capacities across regions: in CO_2 aquifer Storage Capacity Assessment in Japan	Takumi Shidahara, Toyokazu Ogawa, Takashi Yamamoto, Kazuyuki Yoneyama, Tadahiko Okumura, Tsutomu Hashimoto	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
12	Sensitivity Analysis of CO_2 Migration in Deep Saline Aquifer of Ise Bay, Japan, Using Heterogeneous and Homogeneous 2D Models Based on Depositional Facies Anaalysis	Yuko Kawata, Hiroshi Ohkuma, Kazuyuki Yoneyama, Shigetaka Nakanishi, Satoru Yokoi, Tsutomu Hashimoto	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
13	Evaluation of CO_2 Aquifer storage capacity in the vicinity of a large emission area in Japan: Case history of Osaka Bay	Tsutomu Hashimoto, Shin-ichi Hiramatsu, Takashi Yamamoto, Hiroshi Tanano, Manabu Mizuno, Hideaki Miida	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
14	MW2 Concept of CO_2 Monitoring for Offshore Reservoirs in Japan	Daiji Tanase, Shigeyuki Suda, Koji Kano, Hironori Furukawa	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
15	Estimation of residual CO_2 saturation using core flood test	Komei Okatsu, Ryo Ueda	The First International Petroleum Environmental Coference and Exhibition , May 2008
16	RST Saturation Evaluation for CO_2 Sequestration	Xingwang Yang、Tadashi Horie, Tsukasa Yoshimura	SEG(Society of Exploration Geophysicists)/EAGE (European Association of Geoscientists and Engineers) Summer Research Workshop 2008, September, 2008
17	Key aspects og geochemical trapping at the pilot-scale CO_2 injection site, Nagaoka, Japan	Saeko Mito, Ziqiu Xue, Takashi Ohsumi	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
18	A monitoring framework for assessing underground mitigation and containment of carbon dioxide sequestered in an onshore aquifer	Kozo Sato, Manabu Mizuno, Saeko Mito, Tadashi Horie, Hiroshi Okuma, Hideki Saito, Jiro Watanabe, Daiji Tanase, Tsukasa Yoshimura	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
19	Case study:trapping mechanisms at the pilot-scale CO_2 injection site,Nagaoka, Japan	Ziqui Xue, Saeko Mito, Keigo Kitamura, Toshifumi Matsuoka	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
20	Methodology of CO_2 aquifer storage capacity assessment in Japan and overview of the project	Shigetaka Nakanishi, Yasunobu Mizuno, Tadahiko Okumura, Hideaki Miida, Takumi Shidahara, Shin-ichi Hiramatsu	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
21	Trapping mechanisms in CO_2 geological sequestration	Ziqui Xue, Saeko Mito, Keigo Kitamura, Toshifumi Matsuoka	The 33rd International Geological Congress, August, 2008

	Title	Researchers	Forum
21	Investigation on natural gas behavior in shallow geologic strata: natural analogue of leaked natural gas in the Mobara gas field, Japan	Shiro Tanaka, Hiroshi Suenaga, Eiji Nakata, Kameichiro Nakagawa, Takumi Shidahara	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
22	Nagaoka CO_2 injection and monitoring project; a gateway of the intimate understanding of CO_2 behavior in the deep reservoir	Tsukasa Yoshimura, Daiji Tanase	AIST-KIGAM Joint Workshop on CO_2 Geological Storage, December, 2008
23	A Sensitivity Study of CO_2 Mineralization using GEM-GHG Simulator,	Ikuo Okamoto, Saeko Mito, Takashi Ohsumi	The 9th International Conference on Greenhouse Gas Technologies, November, 2008

■2008 Others [CO_2 Geological Storage Project]

	Title	Researchers	Forum
1	Estimation of CO_2 Aquifer Storage Potential in Japan	Toshihiro Takahashi, Takashi Ohsumi, Kazuo Nakayama, Kazuo Koide, Hideaki Miida	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
2	Evaluation of CO_2 Aquifer storage capacity in the vicinity of a large emission area in Japan: Case history of Osaka Bay	Tsutomu Hashimoto, Shin-ichi Hiramatsu, Takashi Yamamoto, Hiroshi Tanano, Manabu Mizuno, Hideaki Miida	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
3	Sensitivity Analysis of CO_2 Migration in Deep Saline Aquifer of Ise Bay, Japan, Using Heterogeneous and Homogeneous 2D Models Based on Depositional Facies Anaalysis	Yuko Kawata, Hiroshi Ohkuma, Satoru Yokoi, Shigetaka Nakanishi, Kazuyuki Yoneyama, Tsutomu Hashimoto	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
4	Storage Capacity Assesement in Japan: Comparative Evaluation of CO_2 aquifer storage capacities across regions	Toyokazu Ogawa, Takumi Shidahara, Shigetaka Nakanishi, Takashi Yamamoto, Kazuyuki Yoneyama, Tadahiko Okumura, Tsutomu Hashimoto	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
5	A monitoring framework for assessing underground mitigation and containment of carbon dioxide sequestered in an onshore aquifer	Kozo Sato, Saeko Mito, Tadashi Horie, Hiroshi Ohkuma, Hideki Saito, Jiro Watanabe Tsukasa Yoshimura	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
6	Investigation on natural gas behavior in shallow geologic strata: natural analogue of leaked natural gas in the Mobara gas field, Japan	Shiro Tanaka, Hiroshi Suenaga, Eiji Nakata, Kameichiro Nakagawa, Takumi Shidahara	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
7	A Sensitivity Study of CO_2 Mineralization using GEM-GHG Simulator,	Ikuo Okamoto, Saeko Mito, Takashi Ohsumi,	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
8	Natural gas behavior in shallow geologic layers as natural analogues of discharge of CO_2	Kameichiro Nakagawa, Shiro Tanaka, Hiroshi Suenaga, Eiji Nakata,Yuki Ito	The 9th International Conference on Greenhouse Gas Technologies, November, 2008
9	The seismic tomography image of residual CO_2 in the porous sandstone	Keigo Kitamura, Ziqiu Xue	The 9th International Conference on Greenhouse Gas Technologies, November, 2008

■2008 Original Paper [CO_2 Ocean Sequestration Project]

	Title	Researchers	Journal
1	Public acceptance of the oceanic carbon sequestration	Toru Sato, Norihiro Kamishima	Marine Policy
2	A numerical study with an eddy-resolving model to evaluate chronic impacts in CO_2 ocean sequestration.	Masuda, Y., Y. Yamanaka, Y. Sasai, M. T. Ohsumi.	International Journal of Greenhouse Gas Control. 2, 89-94, 2008

■2008 Oral Presentation [CO_2 Ocean Sequestration Project]

	Title	Researchers	Forum
1	Prediction of Acidification in the Ocean Surface,and Benefits and Risks of the CO_2 Ocean Sequestration as a Mitigation Technology.	Michimasa Magi	KOBE-TECHNO-OCEAN'08(OTO'08)
2	Methodology for impact assessment of ocean CO_2 sequestration on deep-sea organisms	Yuji Watanabe	KOBE-TECHNO-OCEAN'08(OTO'08)
3	Effects of CO_2 Ocean Sequestration on Deep-Sea Animals	Atsushi Ishimatsu,Masahiro,Hayashi, Yuki Kojima	KOBE-TECHNO-OCEAN'08(OTO'08)
4	Ecosystem model of deep-sea plankton community for CO_2 ocean sequestration	Yasuyuki Kishi,Hiroshi Ishida, Yuya Yamamoto,Kisaburo Nakata	KOBE-TECHNO-OCEAN'08(OTO'08)
5	Strategy of environmental assessment for CO_2 ocean sequestraion	Kiminori Shitashima,Yoshiaka Maeda , Takashi Ohsumi	KOBE-TECHNO-OCEAN'08(OTO'08)
6	System Plan of CO_2 Marine Transport and Release in Deep Waters for Moving-ship Type of CO_2 Ocean Storage	Junichi Minamiura,Masahiko Ozaki, Sasaki,Masami Mtsuura	KOBE-TECHNO-OCEAN'08(OTO'08)
7	Evaluation of CO_2 Dilution in Ocean sequestration	Shuichiro Hirai,Shohji Tsushima	KOBE-TECHNO-OCEAN'08(OTO'08)
8	Simulation of 50Mton CO_2 injection per year into the ocean using an ocean general circulation model	Yoshio Masuda,Yasuhiro Yamanaka	KOBE-TECHNO-OCEAN'08(OTO'08)
9	Numerical Simulation on Mesoscale Diffusion of CO_2 Sequestrated in the Deep Ocean in Practical Scenario	Se-min Jeong,Toru Sato,Baixin Chen	KOBE-TECHNO-OCEAN'08(OTO'08)
10	Observation of emission and Diffusion of natural CO_2 from seafloor Hydrothermal systems	Kiminori Shitashima	2008 Western Pacific Geophysics Meeting
11	Resent Trend of the Vertical Distribution and the Size Composition of Chlorophyll-A in the Western North Pacific Region	Hiroshi Ishida, Yutaka W Watanabe,Joji zaka, Toshiya Nakano,Naoki Nagai,Yuji , Watanabe, Nobuhiro Maeda Michimasa	2008 AGU Fall Meeting

■2008 Others [CO_2 Ocean Sequestration Project]

	Title	Researchers	Forum
1	Development of monitoring for the assessment of Carbon Dioxide And Storage(CCS)	Kiminori Shitashima	2008 AGU Fall Meeting
2	NATURAL ANALOGUE FOR OCEAN ACIDIFICATION	Kiminori Shitashima	Second Symposium on The Ocean in a High-CO2 World
3	EFECTS OT HIGH CO2 ON DEEP-SEA FISHES	Atsushi Ishimatsu,Masahiro Hayashi, Yuki Kojima	Second Symposium on The Ocean in a High-CO2 World
4	HIGH CO2 RETAINED FRACTION IN OCEAN SEQUESTRATION ESTIMATED BY A HIGH RESOLUTION MODEL	Yoshio Masuda,Yasuhiro Yamanaka	Second Symposium on The Ocean in a High-CO2 World
5	IN SITU ENCLOSURE EXPERIMENT DEVICE FOR ASSESSING DEEP-SEA ECOSYSTEMS WITH HIGH CO2 CONCENTRATIONS	Hiroshi H Ishida,Yuji Watanabe, Michimasa Magi,Yoshihisa Shirayama	Second Symposium on The Ocean in a High-CO2 World
6	DECREASING OF AGGREGATE SIZE OF MARINE SUSPENDED PARTICLES UNDER HIGH CO2 CONDITIONS	Yuji Watanabe,Nobuhiro Maeda,Koh	Second Symposium on The Ocean in a High-CO2 World
7	Monitoring strategy for CO2 storage in the ocean environment	Kiminori Shitashima	2008 Western Pacific Geophysics Meeting

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