# Research Planning Group

## Technology Strategy Map on $CO_2$ Fixation and Effective Utilization

### 1. Introduction

In the last issue of "RITE Today", we introduced "Technology Strategy Map on $CO_2$ fixation and effective utilization" drawn up by RITE. In this map, we showed strategies and roadmaps by 2050 in two technology areas, CCS (Carbon dioxide Capture and Storage) and terrestrial storage using large scale afforestation, which were selected as technology areas effective in both reduction potential and cost viewpoint and should be moved to implementation level. This map is revised every year.

In this report, firstly we would like to describe trends in policy and technology in both fields and then introduce the latest "Technology Strategy Map 2010".

### 2. Trends in $CO_2$ fixation and effective utilization

This section describes trends in policies and technologies of CCS, and section 2-2 focuses on trends in terrestrial storage using large scale afforestation.

2-1. CCS

1. Policy

In 2008, IEA issued the scenario for Hokkaido Toyako G8 Summit, where 50% reduction in global $CO_2$ emissions would be achieved by 2050. The followings were described in this scenario:

- Reduction of 48 $GtCO_2$ /yr from the baseline emissions will be required by the year 2050.
- CCS shows the third largest contribution (19%) to 50% reduction in $CO_2$ emissions by 2050 following energy efficiency (36%) and renewables (21%).
- If CCS is not available, the overall cost will increase by 70%.

Based on these analyses, CCS was concluded to be an essential part of the technology portfolio for achieving substantial global $CO_2$ emissions reduction.

After considering this report, leaders in Toyako Summit agreed to issue the statement: "We strongly support the launching of 20 large-scale CCS demonstration projects globally by 2010, taking into account various national circumstances, with a view to beginning broad deployment of CCS by 2020".

The next year, IEA published "Technology Roadmap, Carbon Capture and Storage" and showed that around 3,400 projects would be required worldwide by the year 2050 to meet the 50% reduction scenario, nearly half of this total number of projects would be required by the power sector, about 100 projects were needed within the next ten years, and a significant ramp-up from today's levels of CCS deployment was necessary. They also pointed out that CCS development in non-OECD regions became to be very important.

As described above, CCS has been recognized as a very important mitigation option but at the same time we noticed that there were many challenges for implementation of CCS. The first challenge is financing of CCS project. Without setting a carbon price, no income is expected from CCS implementation with some exceptions like EOR or EGR. But nations where carbon tax or emission trading systems being introduced are limited or even if carbon price is already set, for example, in EU nations, it is low or very unstable now. Thus, implementations of large-scale CCS projects have to depend on government's financial supports. As of 2010, public funding commitments were in the range of USD 26.6 billion to USD 36.1 billion.

The second challenge is to establish legal and regulatory frameworks for safe large-scale geological storage of $CO_2$. Significant progress has been made in the EU (the Directive on the Geological Storage of $CO_2$ and the EU Emissions Trade Scheme Directive), Australia (Offshore Petroleum Law Amendment), and the US (Safe Drinking Act UIC program). In Japan, the Amendment Act for the Prevention of Marine Pollution and Maritime Disasters was established in May 2008, which provides a legal and regulatory framework on subsea geological storage of $CO_2$.

As a lifetime of fossil power plant is about 40 years or more, stations which are constructed without retrofit of $CO_2$ now will continue to emit for such long years – $CO_2$ unabated for the lifetime of the plant – described as "carbon lock-in". Europe Commissions stated carbon dioxide capture-ready (CCR) mandatory for all new large combustion power stations at or over 300 MWe in CCS Directive. CCR means a design of combustion power stations to allow retrofitting of CCS once CCS technologies have been proven.

In connect with above policy progress, 80 large-scale integrated projects at various stage of development were announced around the world until 2010 with the help of government and private sectors. Many CCS projects in power sector, for example AEP's Mountaineer Project, were also included along with CCS project for natural gas origin.

In Japan, CCS is also considered to be one of the important options for substantial $CO_2$ emissions reduction. In 2008, the Action Plan for Achieving a Low-carbon Society was issued, which said: "CCS technology has the potential for massive emissions reductions in thermal power generation, which accounts for roughly 30 percent of Japan's emissions, and in the steelmaking process, which accounts for roughly 10 percent. Japan will promote the development of this technology to make the cost of capture and storage in the order of 2,000 yen per ton by around 2015, and to reduce the cost to 1,000 yen or so in the 2020s. At the same time, Japan will commence verification tests on a large scale at an early stage from 2009 onward, with the aim of implementation by 2020. Regarding application, Japan will work to resolve issues such as enhancing environmental impact assessments and monitoring, putting legislation in place, and ensuring public approval. Based on this policy, Japan CCS Co., Ltd. (JCCS) was established to accomplish comprehensive investigations for carrying out CCS total system demonstrations and started preparation of large-scale CCS demonstrations. Finally METI issued the report, "For safe operation of a CCS demonstration project" in August 2009, which gave safety and environmental standards for a large-scale CCS demonstration, including geological considerations in examining candidate sites for CCS demonstration, issues related to $CO_2$ capture and transport, monitoring items after storage, and remedies for potential problems.

2. Technology

Chemical absorption, physical absorption, and membrane separation etc. are used for capturing $CO_2$. Chemical absorption was already used for a capture process from the process gas in oil refinery plants in Japan but more cost- and energy-effective processes have been required to apply to various kind of emission sites for mitigating global warming. Such advanced solvents have been developed in Japan for many years and some solvents, for example KS-solvent, has reached a commercial level. In order to develop capture processes for iron and steel making industries, COCS (Cost-Saving $CO_2$ Capture System) project developed new absorbents with a low regeneration energy in steel works. In 2008 COURSE 50 ($CO_2$ Ultimate Reduction in Steel-making process by Innovative Technology for Cool Earth 50) project started, where some advanced solvents have been tested in 30t-$CO_2$ per day capture plant. In the US, "Chilled Ammonia" process is being tested in a pilot scale. Development of polymer and ceramic membrane is also important for capturing $CO_2$ from high pressured gasses. RITE has been developing molecular-gate membrane since 2006 after the international collaborative investigation on membrane technology with the US DOE's NETL started in 2003.

Geological $CO_2$ storage is divided to storage in saline aquifer, in depleted oil or gas field, EOR/EGR, and coal-bed methane production. Now, EOR and storage in depleted oil or gas field are conducted in the world and a large-scale injection test into saline aquifer has already begun. In Japan, RITE has conducted $CO_2$ storage projects which contained 10,000 tons of $CO_2$ injection into saline aquifer in Nagaoka gas field. As the next step, a large scale demonstration is needed for early establishment of integrated system of CCS including a capture process to accomplish a full-scaled CCS implementation in Japan. Site selection, design of facilities, and feasibility study in candidate sites for large scale demonstrations are conducted by Japan CCS Co. Ltd. Evaluation of environmental impact and safety assesment for increasing reliability of geological storage and estimation of long-termed behavior of stored $CO_2$ are also important investigation theme for safe $CO_2$ storage, on which RITE is investigating now.

2-2. Terrestrial storage using large scale afforestation

1. Policy

On the validity of terrestrial storage using large scale afforestation for $CO_2$ mitigation, "Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007 "concluded as follows:

- During the last decade of the 20th century, deforestation in the tropics remained the major factors responsible for emissions. Emissions from deforestation in the 1990s are estimated at 5.8 Gt$CO_2$/yr.
- Bottom-up regional studies show that forestry mitigation options have the economic potential at costs up to 100 US$/t$CO_2$-eq to contribute 1.3-4.2 Gt $CO_2$/yr in 2030. Around 1.6 Gt $CO_2$/yr can be achieved at a cost under 20 US$/t $CO_2$. Global top-down models predict far higher mitigation potentials of 13.8 Gt $CO_2$/yr in 2030 at carbon prices less than or equal to 100 US$/t $CO_2$.
- Carbon mitigation by forestry contains reducing deforestation, forest management, afforestation, and agro-forestry. In the short term, the carbon mitigation benefits of reducing deforestation are the greatest. Biomass from forestry can be estimated to have a mitigation potential roughly equal to 0.4-4.4 Gt $CO_2$/yr. In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks will generate the largest sustained mitigation benefit.
- Forestry can make a very significant contribution to a low-cost global mitigation portfolio. However, this has resulted in only a small portion of this potential being realized at present.
- Realization of the mitigation potential requires institutional capacity, investment capital, technology R&D and transfer, as well as appropriate policies and incentives, and international cooperation.

On the basis of this analysis, a new initiative, "the United Nations Collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD) was launched in September 2008, which is managed by three United Nation's organizations (FAO, UNDP and UNE) with the aid of Forest Carbon Partnership Facility at the World Bank and the Tropical Forest Account at Global Environmental Facility. After the discussion at COP/MOP4 in 2008, it was decided to continue efforts to put REDD into the next framework of carbon mitigations. At COP15 in 2009 six countries, Japan, the US, France, Australia, Britain, and Norway decided to give a financial support to REDD. Another effort in terrestrial storage is seen in US DOE's Regional Carbon Sequestration Partnership, which conducts management of forest-, agriculture-, and wet-land, demonstration of $CO_2$ monitoring, and economical evaluation when carbon credit being introduced.

Progresses in biomass utilization area are as follows: As clean and renewable energy was one of three high prioritized areas in "American Recovery and Reinvestment Act of 2009", US DOE released funding to bio-fuel and bio-refinery projects. In EU "Climate and Energy Package" was agreed by the European Parliament and Council in December 2008 and became law in June 2009, which suggested that the portion of renewables should be increased to 20% of the total energy consumption.

In February 2007, Japanese Government set a goal to extend the amount of bio-fuel production to 6 million kL, (10% of annual gasoline consumption) by 2030 and presented a technology roadmap including cellulosic ethanol production. In order to promote development of innovative technologies for effective cellulosic bio-fuels production in a manner consistent with "Roadmap for increased production of domestic bio-fuels", the Ministry of Economy, Trade and Industry (METI) cooperated with the Ministry of Agriculture, Forestry and Fisheries (MAFF) to develop the "Bio-fuel Technology Innovation Plan" in March 2008 which contained required innovative technologies, milestones, and roadmap. This plan also provided a benchmark for the cost of ethanol production, 40 yen per liter, which should be attained through drastic cost cutting of raw materials and enzymes.

2. Technology

Terrestrial storage using large scale afforestation is the only a technology capable of competing with CCS from a viewpoint of large decrease in $CO_2$ concentration in the air but more cost cutting is required. In order to increase absorbing amount of $CO_2$ per unit area and expand vegetation into unsuitable areas for plants like arid area, we should conduct selection of elite plants and soil improvement at early stage and develop genetically-engineered plants step by step, with stimulating information about safety and showing their advantages for $CO_2$ reduction. Development of adequate monitoring procedures is also necessary. In addition to these, it is important to develop conversion or utilization technologies for industrial and innovative use of biomass.

RITE developed a new effective alcohol production process from cellulose using an engineered strain of growth-arrested *Corynebacterium glutamicum*. This process is much evaluated as it shows a high tolerance against fermentation inhibitors. As further steps, RITE has been developing new production processes for various kinds of energy and chemical products including butanol, lactic acid, and succinic acid from non-food biomass based on this technology.

## 3. Technology Strategy Map 2010

After considering these trends in policies and technologies, "Technology Strategy Map 2010 on $CO_2$ fixation and effective utilization" was prepared. In this year, we investigated the number of papers issued (Fig. 1) or cited (Fig.2) in the field of capture, geological storage, ocean sequestration, terrestrial storage using large scale afforestation, and biomass utilization and the position of Japan was grasped in the world by benchmark comparison of Japan to other countries. We also tried portfolio evaluation to clear up the position in $CO_2$ mitigation technologies.

The roadmap is shown in Fig. 3. In this revised version, "demonstration of integrated processes of CCS" was drawn with a more emphatic.

## 4. Conclusion

RITE publicizes this roadmap via the Internet, invites opinion from the public, and rolls up the roadmap every year. Innovative technologies are required to stop global warming. We have to gather more knowledge and wisdom from universities, institutes, and companies etc. On the basis of these, purpose-fitting and effective developments and promotion of applications should be carried out. We wish that our roadmap contributes to such effective developments.

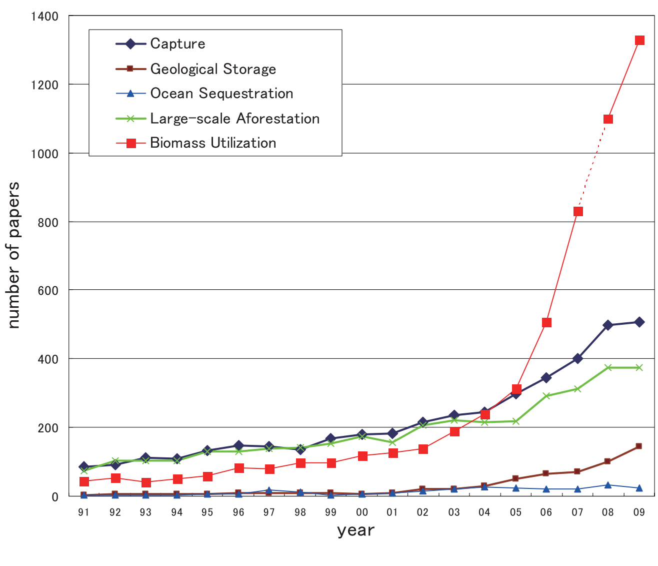
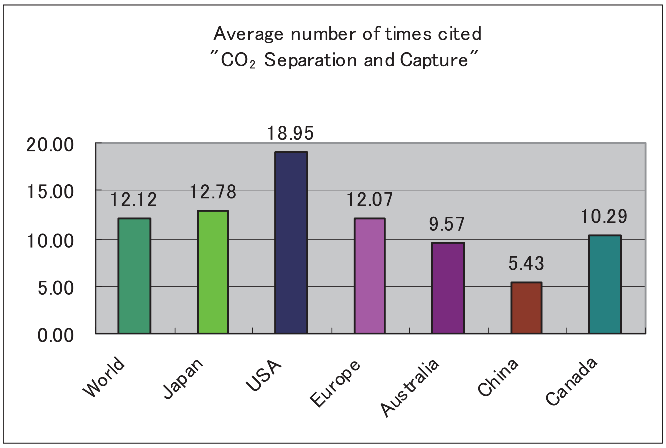
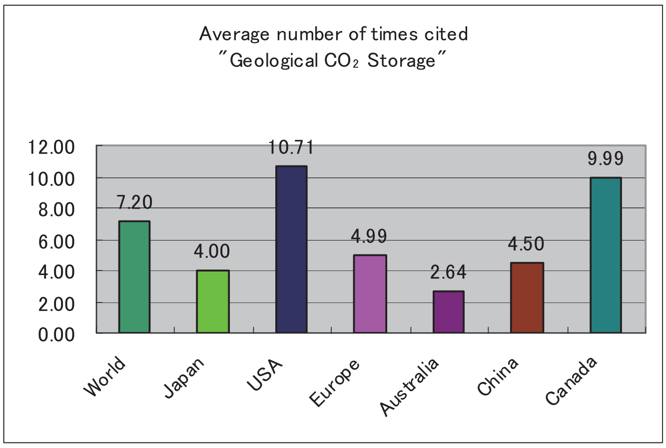
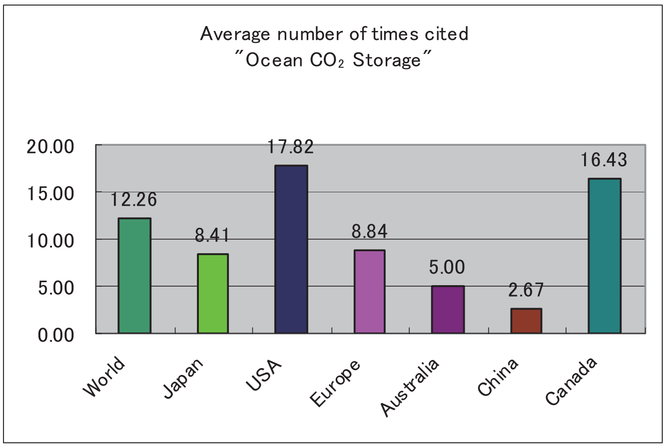
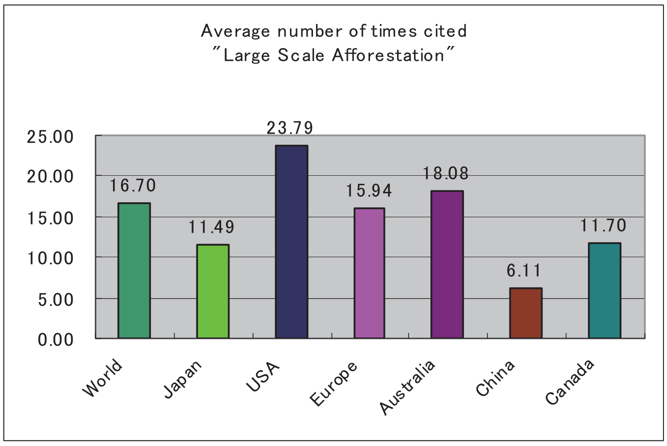



**Figure 1 Changes in number of papers released in the related fields (based on research using "Web of Science" by RITE)**



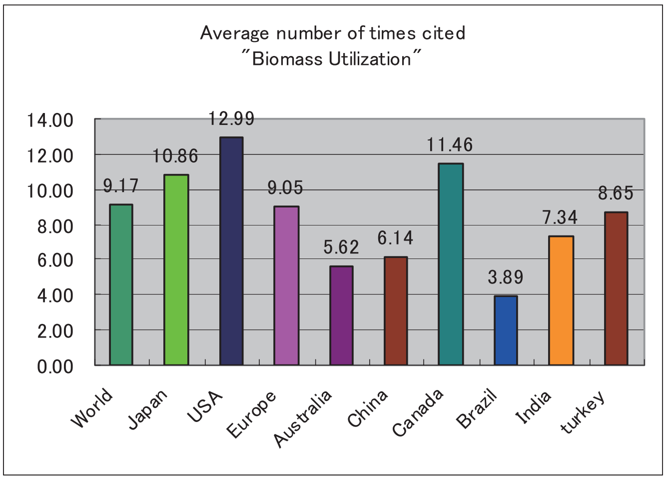
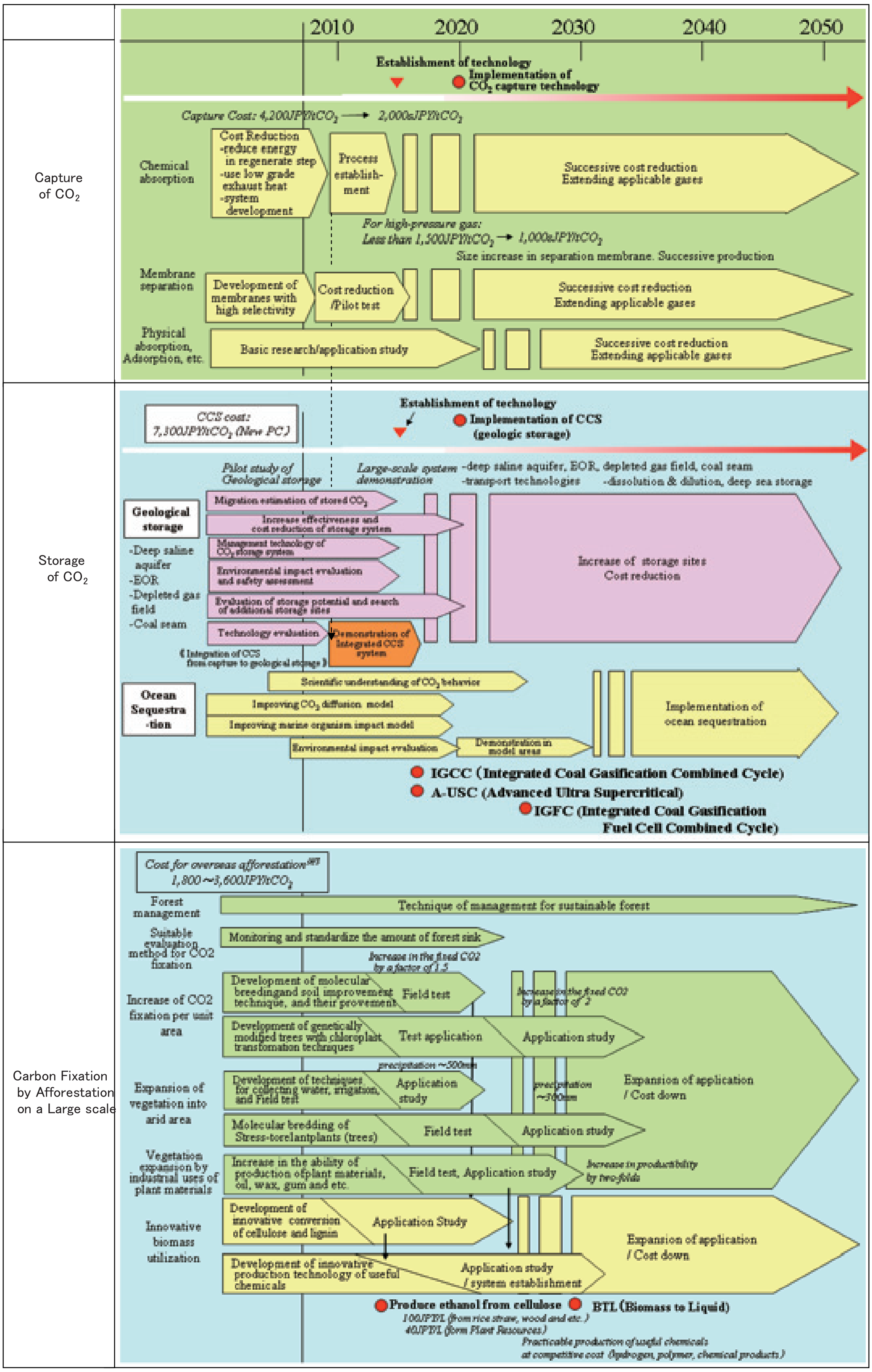




**Figure 2 An example of investigation the number of papers cited (based on research using "Web of Science" by RITE)**




＊ $CO_2$ capture: New PC(830MW), Amount of CCS:1Mt-$CO_2$/yr, compression:7MPa, Steam extract from steam cycle of power plant
＊ Geological storage :Cost of $CO_2$ capture+pipeline transport 20km+injection (compression:15MPa, 0.1Mt-$CO_2$/yr/well)
＊ Afforestation: Afforestation cycle 7years(Cut down and sprout reafforestation), Biomass quantity of production 20m$^3$/hr/yr, Cost for afforestation management:17~31%, Cost of land lease:$50/hr·yr

**Figure 3 Strategic Technology Roadmap "$CO_2$ fixation and effective $CO_2$ utilization"**