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Promotion of Carbon Capture and Storage Technology Using Carbon Emissions Trading Systems

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1 Introduction

In order to mitigate global warming, it is necessary to consider the reduction of CO_2 emissions as a global issue. The 4^{th} Assessment Report (AR4)[1] of the Intergovernmental Panel on Climate Change (IPCC) illustrates that global greenhouse gas emissions need to be reduced by 50 to 85% by 2050 compared to the level of emissions produced in 2000 in order to ensure that global temperature does not rise by more than around 2 degree-C compared to when the Industrial Revolution began. In Japan, the Basic Act on Global Warming Countermeasures sets high emissions reduction targets of 25% by 2020 and 80% by 2050 based on 1990. Japan has been rigorously improving energy efficiency since the oil crisis in the 1970s, and as a global leader in energy efficiency, Japan's CO_2 emission factors are lower than those of other developed countries. This means, however, that Japan will not be able to reduce domestic CO_2 emissions further by only using the conventional method of improving energy efficiency. To reduce CO_2 emissions further, it is not sufficient for Japan to merely continue to innovate technology; it is necessary to use such systems as emissions trading. Therefore, it is essential to encourage the use of Japanese technology worldwide and contribute to emissions reduction overseas.

Japan has been using the Clean Development Mechanism (CDM), an emissions trading system, to meet the emissions reduction commitment by reducing CO_2 overseas. The CDM is a mechanism defined in the Kyoto Protocol. Using the CDM, developed countries can conduct projects to reduce greenhouse gas emissions in developing countries, acquire carbon credits by reducing CO_2 in those countries, and use the credits to meet their emissions reduction commitments (caps). Generally speaking, production and electricity supply in developing countries are not efficient in making use of energy, and as such, Japan can contribute to substantial CO_2 emissions reduction in developing countries just by transferring Japan's existing technology. Since Japan cannot expect to reduce domestic CO_2 emissions further to a great extent, this is a very useful system for Japan to receive credits as its own by transferring technology and reducing CO_2 overseas.

Japanese companies have been using the CDM; however, CDM-related emissions reduction has not been as great as originally anticipated. This is because many of the projects conducted so far have been small, and even though there have been many projects, the total reduction has not been significant. Therefore, it is necessary to combine technology and a CO_2 reduction mechianism in order to reduce CO_2 overseas more efficiently. The problem of the limited amount of emission reductions by CDM can be solved by using Carbon Capture and Storage (CCS) technology.

To prevent CO_2 arising due to combustion and the extraction of fossil fuels from diffusing into the air, CCS separates and captures CO_2, and sequesters captured CO_2 in deep geological formations for very long time spans. It is possible to store a substantial amount of CO_2 (as much as one million tons per year) by using this technology. Such reduction would be ten times larger compared to an average CDM project.

Securing storage locations is always an issue when conducting CCS. It is not clear how much geological formation suitable for a large amount of CO_2 storage exists in Japan. This issue can be solved if Japan can use its CCS technology, combined with the CDM, in countries with great potential in terms of storage capacity, such as India, China, Indonesia, and Brazil.

Companies trying to put CCS into practical use aspire to use the CDM. CCS requires a lot of new equipment and additional energy in the process of separating and capturing CO_2 in the atmosphere and sequestrating it. This may lead to a great rise in cost for energy supply and industrial products. It is difficult to promote CCS widely just by addressing technology development issues. CCS can be widely used only when there is an emissions trading system like the CDM, where carbon credits can be earned.

The inclusion of CCS projects under the CDM had long been discussed but had not been agreed upon. This was due to some concerns about the effects on the environment and safety, as well as some technological and procedural issues where monitoring, recording, and demonstration framework was not yet established. There were also concerns among CDM host countries that there might be a decrease in investment in existing projects if CCS were recognized as suitable for the CDM. However, the participants of COP16 in Cancun, Mexico agreed that CCS was eligible , on a conditional base, for the CDM and have begun creating an appropriate environment. Once technological and practical issues are resolved, it is expected that CCS will be fully implemented as CDM projects.

This article analyzes the current state of and issues facing CCS (which is just on the way to be implemented under the CDM) and makes some proposals for the future realization of CCS under the CDM.

2 Current State and Issues of CCS

2-1 Significance of promoting CCS Technology

(1) Expectation for CCS

CO_2 reduction technology can be roughly categorized into two approaches: 1) to reduce CO_2 emissions by reducing fossil energy use, for example, by promoting nuclear or renewable energy and introducing energy conservation technology, and, 2) to prevent CO_2 from diffusing into the atmosphere by isolating it. In order to isolate CO_2 arising due to combustion and the extraction of fossil fuels keeping it off from diffusing into the air, the carbon capture and storage (CCS) technology selectively extracts CO_2 and injects captured CO_2 into deep aquifer to store CO_2 in it for very long time spans. This technology is considered to have the highest potential for reducing CO_2[2] and is regarded as important technology internationally. According to "Technology Roadmap Carbon Capture and Storage" (Figure 1) compiled by the International Energy Agency (IEA),[3] as the global energy demand skyrockets, it will be very difficult to halve CO_2 emissions by 2050. In fact, it will be impossible to achieve the target only by transferring Japan's excellent energy conservation technology and introducing nuclear and renewable energy. As such, the IEA anticipates that CCS should contribute approximately 20 percent of CO_2 emissions reduction.

In recent years, CCS has been considered important technology owing to the two major factors below.

Firstly, global warming has become a more urgent problem, and and a technology has been required that can quickly and substantially reduce CO_2. CCS used to be conducted mostly in the form of enhanced oil recovery (EOR), where CO_2 is injected into unproductive oilfields in order to increase the production of oil by reducing the viscosity of the crude oil and making it flow more easily, and, at the same time, to sequester CO_2. Nowadays, however, CCS is becoming mainly for the purpose of reducing CO_2 emissions.

Secondly, ocean sequestration technology (where CO_2 is transformed into hydrates or dry ice and stored on the ocean floor or under the seabed or where CO_2 gas is injected into seawater) used to be considered to have a high potential for reducing CO_2. However, the London Convention (Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972) was revised in 2006, and as a result, ocean storage is regarded as ocean dumping. Due to international law, it is now difficult to store CO_2 in the ocean.[4] The London Convention also clearly stipulates that the injection of CO_2 gas into seabed layers for the purpose of CCS should not be banned.[5] Therefore, CCS is virtually the only applicable technology to isolate a substantial amount of CO_2 from the air.

(2) Effectiveness of CCS

CCS enables us to act against global warming while continuing to use coal,[6] which is the most abundant energy source, is not concentrated in certain regions, and is therefore reliable in terms of supply.

Among fossil fuels, coal is abundant and inexpensive, and is produced worldwide without being concentrated in certain regions, and as such, it is the most stable source of energy in terms of supply for both developed and developing countries. However, coal's major drawbacks are that its CO_2 emission

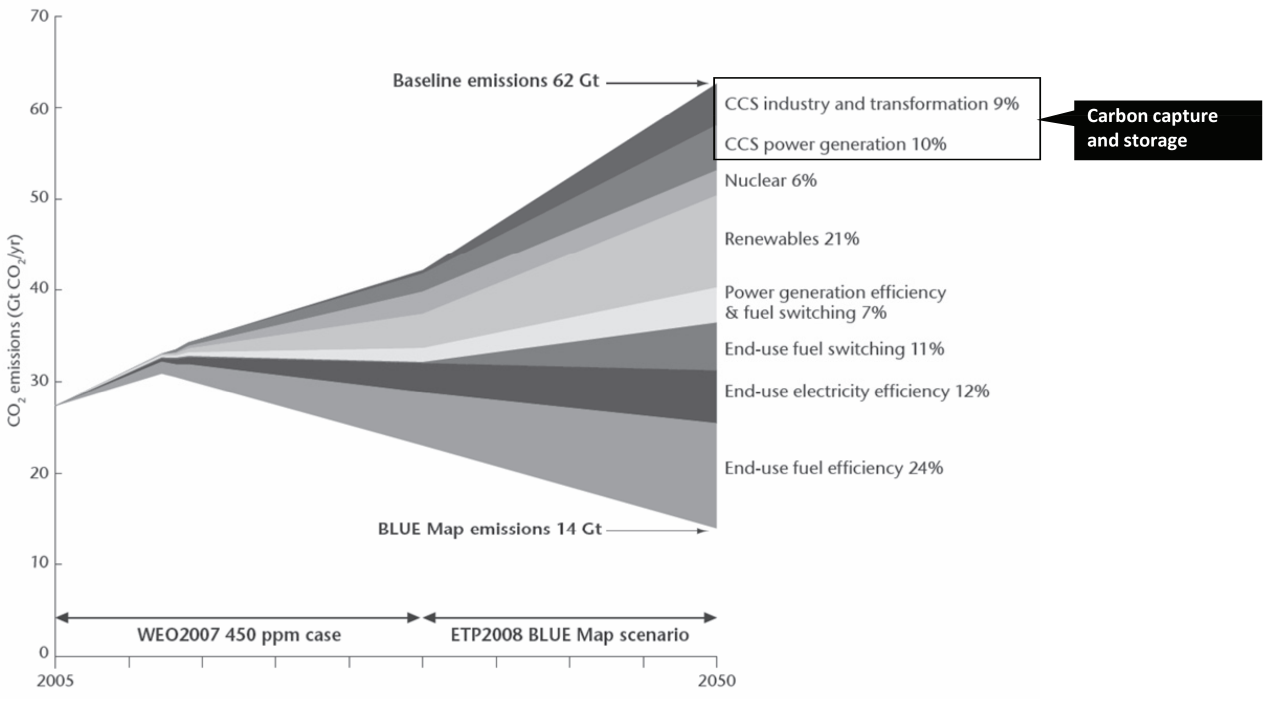

Figure 1: Roadmap for Global Warming Mitigation by IEA

Source: Reference[5]

factors are large and it has a high environmental impact. Technologies to make use of coal cleanly and highly efficiently are collectively referred to as Clean Coal Technology (CCT). CCT has been actively developed around the world. Past editions of this journal have covered, in detail, general CCT,[7] the Integrated coal Gasification Fuel Cell combined cycle (IGFC),[8] and CO_2 emission reduction efforts from the steel industry.[9] These articles suggest that appropriately isolating and storing CO_2 is an issue common to all these technologies.

Gasified coal, after going through a steam-reforming catalyst reaction, becomes gas containing high-density CO_2 and hydrogen. The same reaction can be used to separate and capture CO_2 and, at the same time, to produce fuel gas composed mostly of hydrogen. Supplying product hydrogen to Fuel Cell Vehicles (FCV) can contribute to lower CO_2 emissions in the transportation sector. In addition, compared to the process of separating and capturing CO_2 from combustion exhaust gas, it is more efficient to separate and capture CO_2 from coal-derived gas due to the high partial pressure of CO_2.

CCS simultaneously accomplishes the “3 E’s” (Economy, Environmental Protection, and Energy Security), and is therefore considered to be critical strategic technology both in developed and emerging countries.

2-2 Japan’s Efforts

In March 2008, the Ministry of Economy, Trade and Industry (METI) announced the Cool Earth Energy Innovative Technology Plan[10] and set a target to halve global greenhouse gas by 2050 compared to the current level. According to the plan, CCS is one of twenty-one innovative technologies that should be given higher priority.

The New Growth Strategy (determined by the Cabinet in June 2010) also sets CCS (in its strategy for becoming an environment and energy power) as one of the innovative technological developments that should be prioritized.[11]

In Japan, the Research Institute of Innovative Technology for the Earth (RITE) (established in 1990) has been conducting research on the technology of CCS and other related studies. In particular, one of the largest demonstration tests was conducted at the Iwanohara test site (in Nagaoka city in Niigata prefecture), where 10,000 tons of CO_2 was stored between fiscal 2000 and 2004. CO_2 stored underground has been monitored, and it is in a good condition even after two major earthquakes (the 2004 Mid-Niigata Chuetsu Earthquake and the 2007 Chuetsu-oki Earthquake in Niigata prefecture).[12]

In response to the government’s promotion of CCS technology development, some major companies that have CCS related technology (in fields such as power, oil refinery, oil field development) established

Japan CCS Co., Ltd. This is the world's first privately incorporated CCS organization. Japan CCS is conducting detailed research on the sub-seabed aquifers at the candidate sites for demonstration tests (Tomakomai offshore and northern Kyushu). The company is also conducting CCS feasibility studies (FS) at a depleted natural gas reservoir in the Iwaki offshore site.

In addition, J-Power and other companies are involved in a joint Japan-Australia CCS demonstration project in Australia.[13] Some research institutes and other companies are also developing technology to capture CO_2.

In August 2009, the METI released a guideline titled, "For safe operation of a CCS demonstration project," for large-scale CCS demonstrations.[14] The guideline lays out related laws and regulations, as well as action to be taken before and after starting CO_2 injection for the safe implementation of a demonstration test.

2-3 Overseas Trends

One of the world's largest and most notable CCS projects is the Sleipner project, which began in Norway in 1995. The project stores CO_2 separated during the refining process of extracted natural gas rather than CO_2 from combustion. The CO_2 is compressed and injected into an aquifer formation from an offshore platform in the central North Sea, about midway between Norway and the United Kingdom. One million tons of CO_2 are stored in the sub-surface annually, and 11 million tons of CO_2 has been stored so far over an area stretching several kilometers.[15]

In April 2009, the European Union issued the CCS Directive, stipulating a CCS-related legal framework. The European Union also issued a directive that a new fossil power station with a rated power output of 300 MW or more must ensure space availability for a CO_2 capture facility. In November 2009, the United Kingdom enacted a domestic law based on the directives.[16] The European Union has also been conducting six CCS projects based on the European Energy Recovery Programme (EERP).

In the United States, there are abundant coal resources. In August 2010, the Department of Energy (DOE) announced that the government and the industry would jointly conduct a project called "FutureGen 2.0" and conduct demonstration tests.[17] The project will add CO_2 separation and capture units and a pipeline to the 200 megawatt pulverized coal boiler in a power plant in Illinois, aiming to store one million tons of captured CO_2 underground annually. In addition, several CCS demonstration projects are being prepared. President Obama established an interagency task force to smoothly introduce a CCS project, and in August 2010, the task force submitted a policy report that laid out action required to start CCS commercial demonstration projects. The Environment Protection Agency (EPA) has been making legislative preparations to promote CCS, for example, by clarifying regulations concerning the conservation of drinking water in the surrounding areas as well as monitoring, recording, and verification.

China also has been developing CCS technology at several locations. In recent years, China has been conducting joint projects with other countries, and the European Union, the United Kingdom, the United States, and the IEA have begun joint development efforts and financial cooperation.[18] There is a movement to introduce low-cost CCS technology developed in China to the United States. In Korea, with a view to future global business, related governmental offices are working together, aiming to conduct a demonstration test by 2016 and to realize commercialization by 2020.[19]

2-4 Technological Issues for the Commercialization of CCS

Many elemental technologies are required for CCS, including separation and capture technology to extract CO_2 from combustion exhaust gas, civil engineering to excavate wells, and exploration technology to find suitable storage locations. CCS is involved in a wide range of industries, such as chemical engineering, mining, and civil engineering. It is also an integrated technology, deeply related to power generation, steel production, and other industries. Some technologies for CCS are in practical use or have similar results. However, there are four major issues to be addressed as shown below to promote the commercialization of CCS.

(1) Securing safety and establishing preliminary assessment technology

The potential risk of CCS is that underground CO_2 might leak in substantial quantities and reach the surface, causing health problems such as anoxia and toxicosis. Even if CO_2 does not reach the surface, it might affect the quality and the level of underground water.

CO_2 behaves as a supercritical fluid (indistinguishable between a gas and a liquid) above 31.1°C and 7.4 MPa. In CCS, CO_2 is compressed to a supercritical state and injected into an aquifer. An aquifer is an underground layer of water-bearing permeable rock (such as sandstone), sandwiched between two shielding layers (caprock). CO_2 expands under high pressure and spreads into the surrounding area. However, a CO_2-filled area only gradually expands due to resistance factors. Such resistance mechanisms include structural trapping (where caprock prevents CO_2 from spreading), solubility trapping (where CO_2 dissolves into underground water, increasing density), and mineral trapping (where CO_2 chemically reacts with minerals to become carbonic acid compounds).

CCS assessment simulation is to, in the short term, estimate such gradual diffusion during an injection period, and in the long term, estimate the diffusion over thousands of years based on the existing characteristic data. However, it is necessary to conduct monitoring for at least several years after a CO_2 injection in order to find whether such assessment simulation is accurate.

It is of course necessary to preliminarily conduct every risk assessment one can think of when assessing environmental impact and safety assurance; however, things beyond our estimation may happen. To gain trust from society, there is no other way but to steadfastly accumulate accident-free results just like when aeronautical, nuclear power, and other new technologies were introduced. It is also important to engage in efforts to avoid major accidents by accumulating countermeasure technology against smaller problems that will be experienced during the process. In particular, it is necessary to conduct demonstrations at a utility scale at locations with different geological conditions and gradually scale up the efforts.

Securing safety and establishing preliminary assessment methods are still in the demonstration phase.

(2) Establishing monitoring, recording, and verification framework

CCS is technology to store CO_2 in deep geological formations for very long time spans, and as such, it is very important to monitor changes in CO_2 stored underground during and after an injection, as well as whether there is any CO_2 leakage to the surface. CO_2 measurement methods include remote nondestructive measurements (such as the seismic prospecting method and the gravitational method, which are conducted at the surface level and elsewhere) and, using many monitoring wells surrounding the injection well, electric resistance measurement (of temperature, pressure, and underground water) or elastic wave tomography and electromagnetic wave tomography. Such results from various methods have been analyzed and compared. In addition, two-dimensional and three-dimensional CO_2 maps have been created to conduct follow-up studies on the changes.

Monitoring technology can only be developed and verified at an actual CO_2 storage site, and as such, it is still in the phase of being developed through demonstrations conducted in Japan and overseas. It is necessary to verify the characteristics of monitoring technologies at least in several representative geological conditions.. To realize commercialization, it is essential to conduct demonstrations at many locations and establish monitoring technologies.

At the same time, to calculate the total greenhouse gas emissions by a country, it is necessary to internationally identify the amount of captured and stored CO_2 in a fair manner. Since the CDM is involved with emissions trading, it is important to accurately determine the amount of stored CO_2. To appropriately identify CO_2 emissions reduction as a result of CCS, monitoring, recording, and verification (MRV) framework is required.

The Sleipner project in Norway reports that CO_2 distribution maps (based on the seismic prospecting method) and predictive simulations are relatively consistent from the perspective of monitoring CO_2 behavior to thoroughly grasp signs of CO_2 leakage. However, as to the amount of CO_2 stored underground, the figures from the CO_2 maps and the actual amount of CO_2 injected are different (over 20 percent).[20] It is necessary to improve accuracy.

(3) Economic issues

CCS requires additional large-scale facilities and also additional energy input in order to prevent CO_2 from diffusing into the atmosphere, and as such, economic efficiency has always been an issue.

According to a RITE estimate, it costs about 7,300 yen per ton of CO_2 to separate and capture one million tons of CO_2 annually at a newly established large coal-fired power plant (870 MW) and store it in an aquifer, 20 km apart.[21] This is much higher than 10 to 15 euros per ton (about 1,100 to 1,700 yen), the CO_2 emissions trading price in Europe as of December 2010. Operating a coal-fired power plant costs about 6 yen per kWh, but the cost will double to about 12 yen per kWh if the CCS cost is added.[22]

The RITE roadmap aims to reduce the cost of the separation and capture process (over half of the entire process) to the 1,000 yen level in order to have a more competitive CCS cost.[23]

The aforementioned economic estimate is based on the assumption that 20 percent of CO_2 from a new large-scale coal-fired power plant is separated and captured, and then stored at a location 20 km away from the plant. The assumption uses favorable conditions: the amount of CO_2 to be separated and captured is small, and the transport distance is short. In reality, even if a picked location has less favorable conditions, it is necessary to reduce the total CCS cost to a level equal to other technologies to counteract global warming.

(4) Uncertainty in storage locations in Japan

According to RITE, Japan's potential CO_2 storage capacity is about 146 billion tons, combining both the land and the sea (under the seabed).[24] The annual emissions were 1.34 billion tons in 2006, and the capacity has the potential to store 100 years worth of CO_2. However, the potential storage capacity is somewhat similar to resource storage and is an estimate of a physical capacity under certain assumptions. As such, it is different from something like recoverable reserves and is not economically viable storage capacity. Generally speaking, it is desirable that a single location can store a large amount of CO_2 and have geological conditions permitting a high injection rate (tons per year).

The New Energy and Industrial Technology Development Organization (NEDO) estimates that there are 29 promising structural aquifers (both in the land and the sea areas) with a total capacity of about 1.5 billion tons.[25] The average capacity in one location is about 50 million tons, but the actual storage capacity and acceptable injection rate for each location needs to be studied in detail.

Coal-fired plants are large sources of CO_2 emissions, and a 1,000MW plant produces about 5 million tons of CO_2 annually. Therefore, the CO_2 storage capacity of a location, as mentioned earlier, may store 10 years worth of CO_2 generated by a 1,000MW coal-fired plant. In Japan, there are 40 of 500–1050MW coal-fired power plants. Among them, 12 are either 1,000 or 1,050MW units. Therefore, if we try to achieve the goal (proposed in the mid- and long-term roadmap by the Ministry of Environment [MOE]) to capture most CO_2 emissions from fossil power plants (not limited to coal-fired ones)and to store it underground and elsewhere,[26] it is expected to use up all the capacities of the 29 promising locations in about 10 years only for coal-fired plants. Unless we find many other appropriate locations that have equal or larger capacities or economical injection rates, we will be left with locations that have less CO_2 storage capacities. However, considering the CO_2 storage capacity, the cost to excavate a well at these locations will not be economical.

The caprock at the Iwanohara test site in Nagaoka has a dome-like folded shape, and the anticline structure can hold CO_2. This is the most desirable geological formation to store CO_2. However, Japan has many disadvantages: for example, aforementioned desirable geological formations are rare,[27] and since Japan has many earthquakes, there are many faults that may cause leakage.

Many demonstrations need to be conducted at various geological formations to fully understand capacities and injection rates, so it is uncertain whether Japan has appropriate locations to store a large amount of CO_2.

2-5 Necessity of overseas development

As discussed earlier, it is uncertain whether Japan can secure appropriate large-scale locations to store CO_2, and as a result, the storage cost may increase. In contrast, it is estimated that there are many potential storage locations overseas (Figure 2).[28] RITE estimates that the world's potential underground CO_2 storage capacity is 26 trillion tons (7.1 trillion tons in carbon-equivalent terms).[29]

When considering promoting Japanese CCS technology, it may be necessary to transport CO_2 arising in Japan to overseas locations to store it. Currently, CO_2 is not regulated by the Basel Convention on the Control of Transboundary

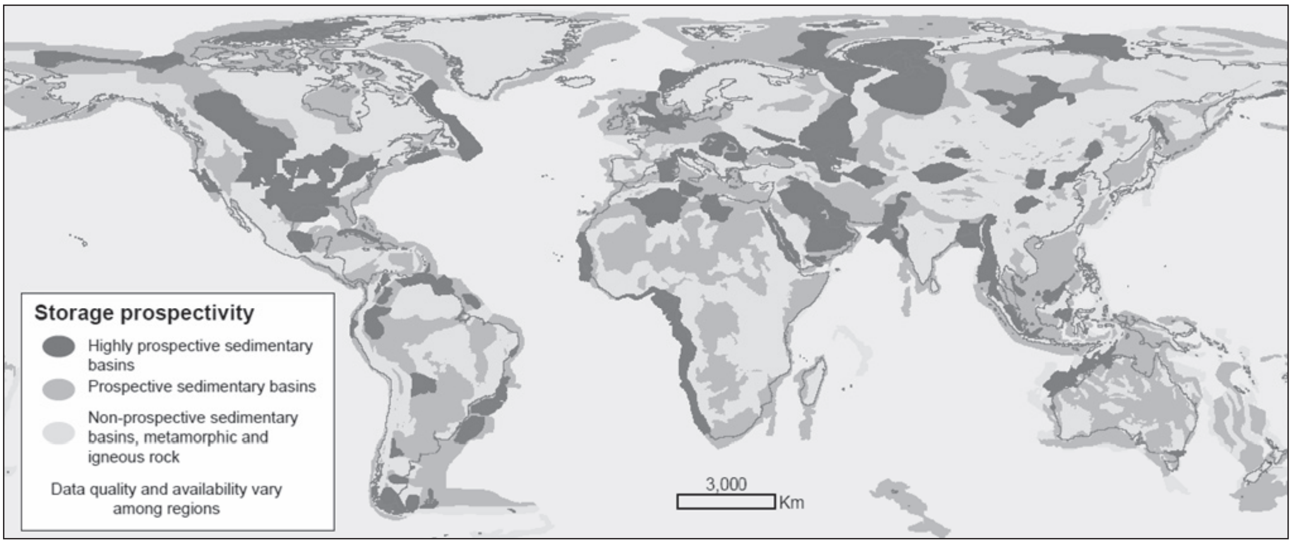

Figure 2: Estimated potential CO_2 storage capacity of the world

Source: Reference[28]

Movements of Hazardous Wastes and their Disposal. Therefore, transporting CO_2 generated in Japan to overseas locations is not a problem. However, it is apparent that such transport will generate more CO_2 emissions and increase costs.

Given that CO_2 emissions will affect global warming equally regardless of which country they originate from, it is more reasonable to use Japan's technology overseas to capture and store locally-generated CO_2 than to transport CO_2 produced in Japan to overseas locations for storage. Based on the CDM (an emissions trading system) specified in the Kyoto Protocol, contributing to the reduction of CO_2 emissions overseas using Japan's technology and acquiring emissions rights is one way to finance CCS costs. This is an advantageous method considering the aforementioned economical issue.

It is expected that conducting CCS projects under the CDM will overcome such issues as economical inefficiency and the uncertainty of securing appropriate storage locations. The current state of the CDM and some issues to be addressed to conduct CCS under the CDM are discussed below.

3 Current State of the Clean Development Mechanism (CDM)

3-1 What is the CDM?

The CDM is defined as a mechanism whereby Annex I countries (developed countries, such as Japan, which need to meet their caps under the Kyoto protocol) can, to reduce greenhouse gas emissions, invest in emissions reduction projects in non-Annex I countries (which do not have caps) while contributing to their sustainable development. Investors can earn carbon credits to meet their caps. Figure 3 illustrates the summary of the CDM.

3-2 Examining CDM methodologies

For greenhouse gas reduction projects to be recognized as CDM projects, methodologies for each type of projects need to be developed and approved. For example, when determining emissions reduction by a project, it is necessary to set a baseline amount of emissions that would be generated in the absence of the project. The difference between the baseline and the predicted emissions is considered the amount of reductions generated by the given project. The way a baseline is set depends on the type of project. Different types of projects will have different methodologies.

Once a methodology is established, it needs to be approved by the CDM Executive Board. A Designated Operational Entity then validates the case. The project is then registered as a project approved by the CDM Executive Board. Investors can then implement the project according to the methodology to earn carbon credits. After the onset of a project (not only after the construction of a facility but after actual operation for a certain period), a Designated Operational Entity will verify the project and, only if it approves the amount of CO_2 reduction will it issue credits (Figure 4). The MRV framework plays a critical role during this process, but the technology for CCS has not been fully established.

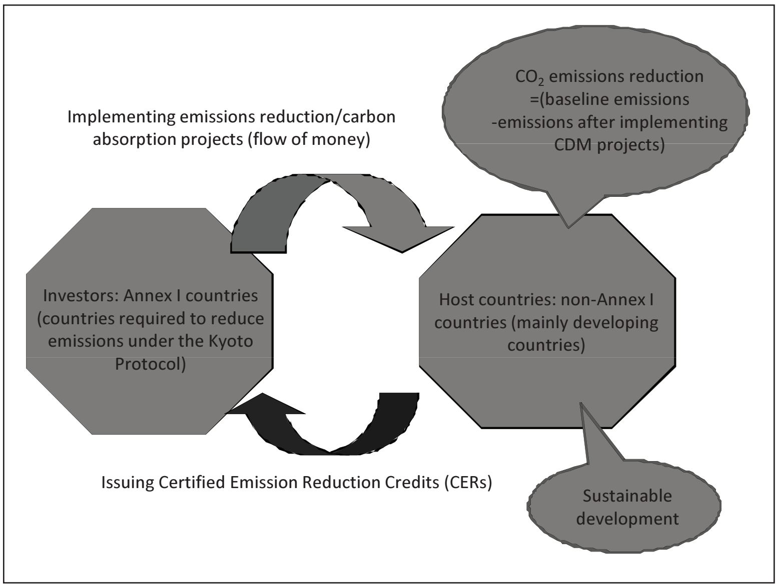

Figure 3: Summary of the CDM

Prepared by the STFC

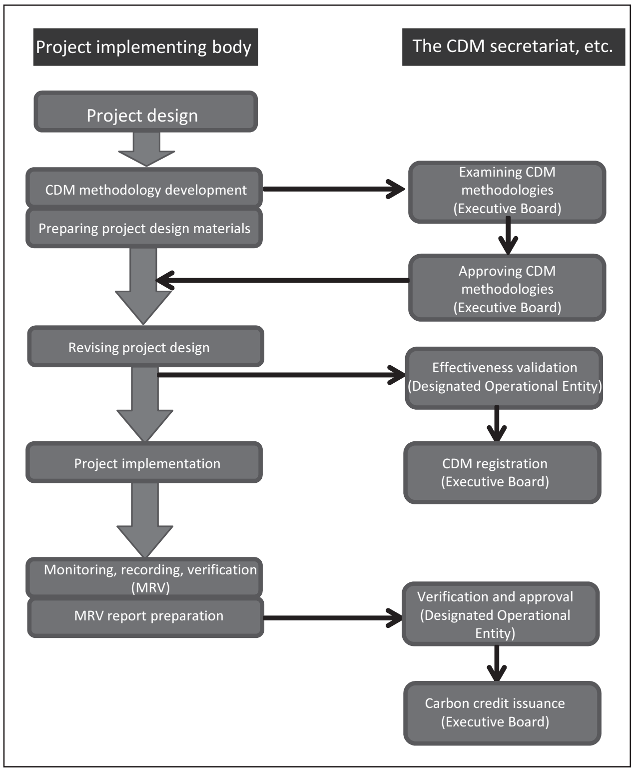

Figure 4: Approval process of CDM methodologies

Prepared by the STFC

3-3 Registered projects

More than 100 methodologies have been developed for CDM projects. Based on these methodologies, renewable energy (wind power, hydropower, etc.), methane capture, and other projects have been implemented. Figure 5 illustrates the proportions of different kinds of projects registered as of January 2011. The figure shows that more than half the projects are relatively small (in terms of emissions reduction), such as wind power and hydropower generation projects (the proportions of six projects have been rounded to 0%).[30]

As of January 2011, 2712 projects have been registered, and a total of 1.97 billion tons of CO_2 has been credited (by the end of 2012). By 2030, a total of 7.7 billion tons of CO_2 will be credited. Moreover, as of January 2011, more than 200 projects are applying to be registered and more than 3,000 projects are applying to be validated.[30]

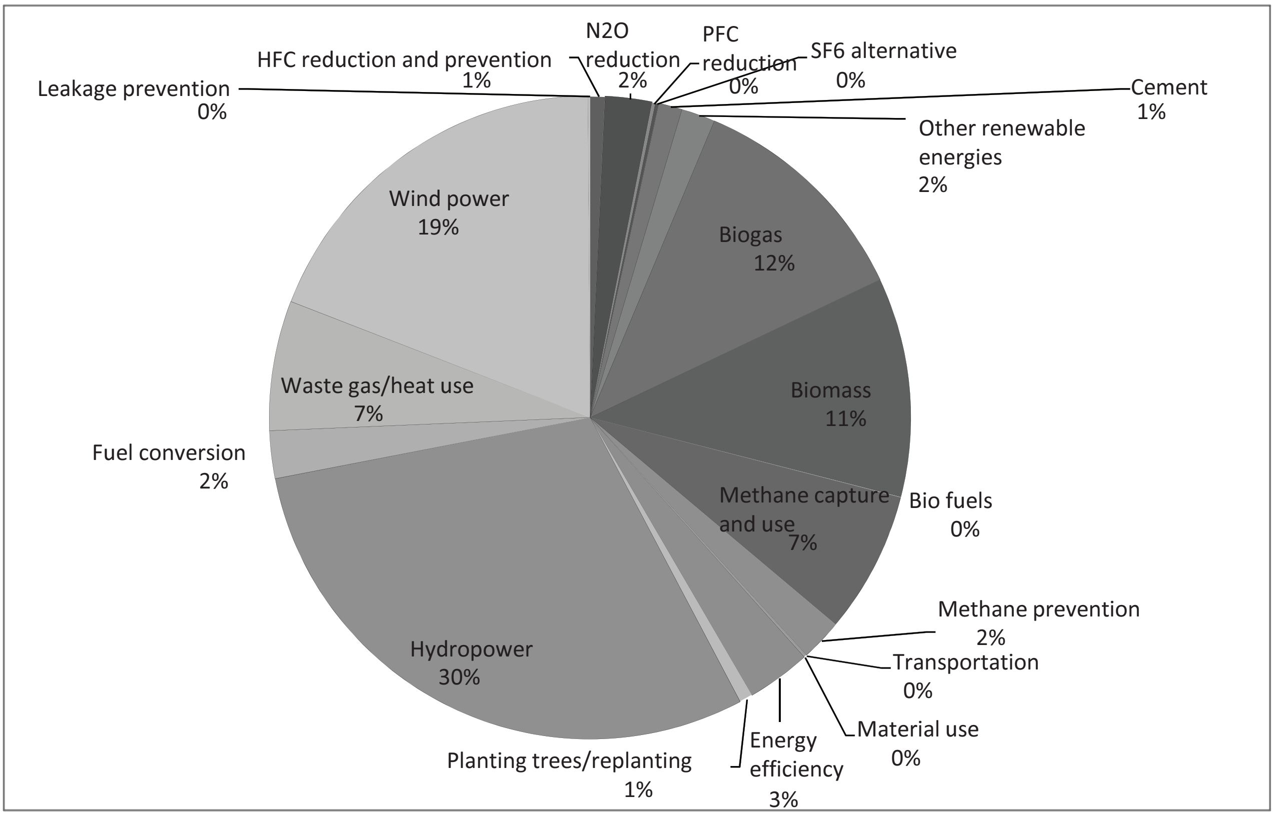

Figure 5: Registered CDM projects by type (as of January 2011)

Prepared by the STFC based on the IGES database[30]

4 Implementing CCS as CDM Projects

4-1 Current state of CCS as CDM Projects

Japan has submitted some CDM methodology applications for CCS projects. In September 2005, Mitsubishi UFJ Securities Co. submitted a methodology application for CCS projects to store CO_2 in spent oil/gas reservoirs. In January 2006, Mitsubishi Research Institute, Inc. and JGC Co. submitted a CDM methodology for CCS projects to separate and capture CO_2 from natural gas and store it in underground aquifers or spent oil/gas reservoirs.

These two applications are being examined by the CDM Executive Board and have not yet been approved. Before finalizing its decisions, the CDM Executive Board receives guidance from the Subsidiary Body for Scientific and Technological Advice (SBSTA), which was established based on the United Nations framework convention on climate change. As can be seen in the following section, the SBSTA clearly specified what issues to be addressed in order for CCS projects to be approved as appropriate CDM projects. The issues were discussed at COP15 in Copenhagen in December 2009, but there were both pros and cons. As such, it was determined that the issues would be discussed again at the next meeting.

The discussion on the inclusion of CCS projects under CDM did not easily reach an agreement. This was due to some practical issues discussed later as well as some concerns among the CDM host countries that CCS might lead to a reduction of investment in energy efficiency, renewable energy, and other existing projects.[31] However, at COP16 in Cancun, Mexico in December 2010, an agreement was reached that CCS technology was appropriate for CDM projects.[32] It was a great step forward. If the practical issues (discussed in the next section) are resolved, CDM methodologies for CCS technology may be established.

4-2 Practical issues

Before the Cancun agreements were made, the SBSTA suggested some practical issues that one can face in the implementation of CCS projects under CDM. The following two are the major issues.

(1) Environmental impact, safety, and attribution of responsibility

The CDM emphasizes sustainability, and as such, the SBSTA pointed out some environmental and safety issues to be addressed for CCS technology. These include securing safety in CO_2 transport and in establishing related facilities, the possible impact of CCS on the surrounding environment, and in the case of CO_2 leakage, the impact on humans, the eco system, and underground water. If there might occur leakage or if there happened an environmental damage or human suffering that might have been caused by leakage, claims for compensation for damage may arise. Even if an unexpected problem arises during the process of CO_2 injection, there will be arguments relating the CCS project and the problem. If a problem arises long after the injection, such causal arguments will be more intense.

In case of leakage, even if there is no human suffering, at least part of the carbon credits issued in the past will become invalid. How to handle such invalidation of carbon credits due to leakage is also an issue.

(2) Establishing and creating international standards of monitoring, recording, and verification framework

Another important issue presented by the SBSTA is the establishment of the aforementioned MRV framework. In order for CCS projects to be approved as CDM projects, it is necessary for MRV framework to be fully established and internationally accepted.

Even when a highly reliable MRV framework is established, it needs to be internationally accepted. It is necessary to make international standards for the total process of monitoring, recording, and verification, including some contract matters, such as how long the process should continue after the completion of CO_2 injection.

4-3 Future direction of CCS under the CDM

Technological issues of CCS (discussed in 2-4) and practical issues of CDM (discussed in 4-2) are correlated. Solutions to one will effectively work on the other, and as a result, it is expected that more CO_2 emissions will be reduced (Figure 6). Below, this article proposes what Japan, in particular, should do to solve the issues.

(1) Implementing demonstration tests

The safety of CCS technology and the validity of MRV framework can only be veryfied at a demonstration test site. There is no other way to earn the trust of society than conducting continuous demonstration tests. It is essential to conduct demonstrations at a practical scale in terms of storage capacities and injection rates, at several sites having some Japan's major geological formations.

(2) Standardizing monitoring, recording, and verification framework and safety assessment methods through international cooperation

In order to reduce CO_2 in a CDM project to be approved, the accuracy of the data needs to be acknowledged internationally. It is effective to work

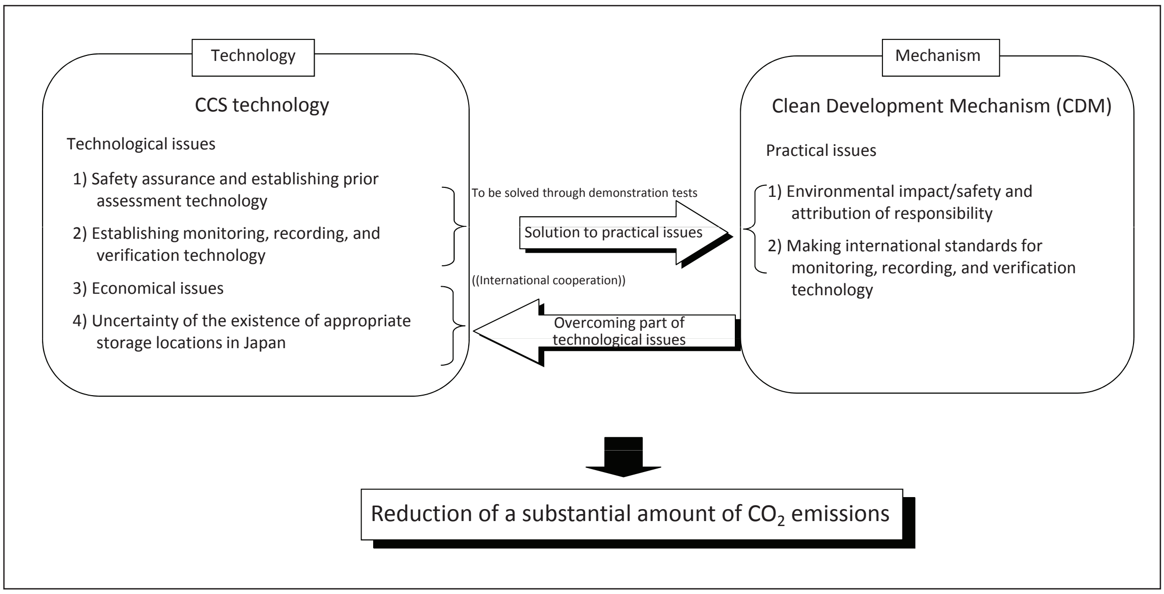

Figure 6: Resolving CCS technological issues and CDM practical issues

Prepared by the STFC

with other countries conducting CCS demonstration efforts and to efficiently implement verification research. It is expected that international cooperation will improve the level of the global efforts. If Japan continues to participate in such global efforts, global warming counteraction will speed up, and Japan's contribution to the world will be recognized.

At the same time, in order for Japan to conduct conduct CCS in a foreign country in the future smoothly, Japan needs to take the initiative in creating international standards for technological matters and frameworks (including safety assessment methods, monitoring/recording/verification methods, attribution of responsibility, and verification methods for reduction effectiveness). In the CDM, a private organization (Designated Operational Entity, certified by the United Nations CDM Executive Board) verifies the amount of CO_2 reduction. To establish MRV framework, this article proposes that the government should help set opportunities up where Designated Operational Entity's officials and Japanese engineers can team up to develop technology.

(3) Establishing favorable relations with counties with storage capabilities

To smoothly conduct CCS projects under the CDM in the future, it is essential to build good relations with the countries that have storage capabilities. It will be effective to conduct international exchange programs with the countries conducting or planning to conduct demonstration tests, for example, by having Japanese researchers and engineers participate in projects overseas, as well as by inviting foreign researchers and engineers to demonstration projects in Japan.

J-Power Co. and other Japanese companies have already started a joint project with Australia. Japan should, however, cooperate with not only developed countries but also countries that can become CDM hosts.

We would like to point out that some countries are potentially good partners where Japan may be able to conduct CCS under the CDM. These countries include India, China, Indonesia, Brazil, and other countries, with their high CO_2 storage potentials and growths and coal consumptions that are expected to increase. Other countries such as Southeast Asian and Middle East countries are also good candidates because of their high CO_2 storage potentials and high CO_2 emissions due to fossil fuel excavation. If these countries trust Japan through personnel exchange, searching for appropriate storage locations and starting to conduct projects will be done smoothly there in the future. In addition, such good relationships will work favorably for Japan during negotiation processes to determine international standards for monitoring, recording, and verification framework, etc.

5 Conclusion

Japan has already improved energy efficiency to a great extent, and as such, it will be difficult to further reduce domestic greenhouse gas emissions. A promising method for further contributing to greenhouse gas reduction efforts is to reduce emissions overseas. In particular, the use of an emissions trading scheme of the CDM will be the key. The internationally approved CDM projects in the past have been small-scale and have been insufficient to achieve high reduction targets. Therefore, it is desirable to implement CCS projects under the CDM to reduce CO_2 emissions.

The international community agrees that CCS is technology to simultaneously accomplish the 3 E's (Economy, Environmental protection, and Energy security). It is also a technology that the IEA is expecting the diffusion to a certain extent. There is still a lot of improvement in terms of performance and cost reduction, but the technology required to conduct demonstrations has mostly been established. Even so, there are no incentives for CCS investors, and as such, it will be difficult to commercialize CCS unless, for example, investors can earn carbon credits overseas using the CDM.

Previously, CCS had not been recognized as appropriate for CDM projects even though it had been discussed. However, at COP16 in December 2010, an agreement was reached that CCS was eligible for CDM projects, at least on a conditional basis. Creating an environment to put this into practice is under way, but there are still some technological and practical issues. In particular, it is essential to eliminate concerns over environmental impact and safety as well as to establish monitoring, recording, and verification framework. CCS projects under the CDM will soon be realized by accomplishing technological development through international cooperation and facilitating efforts to create international standards for the technology.

It is unclear whether Japan has appropriate storage locations in the country, and as such, realizing CCS projects under the CDM is more desirable. It would be beneficial to the international community and also in the country's interest if Japan could smoothly conduct CCS projects overseas and steadily earn carbon credits by developing technology through domestic demonstrations and creating international standards for monitoring, recording, and verification framework.

This proposal is also effective for the bilateral credit framework, which has been discussed by the Japanese government.

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