Research Planning Group

Strategy and Roadmap on Innovative Technology for Drastic Reduction of CO_2 Emission

1. Introduction

A drastic reduction of global CO_2 emission by 50% level by 2050 is required to stop global warming. Efforts in several fields such as energy saving or alternating chlorofluorocarbon have already been done to reduce green house gas emission. But, CO_2 concentration in the air is still increasing. This fact shows that present activities are not enough for quitting global warming and building sustainable society. Thus, in addition to these efforts, we also have to develop fixation and effective utilization technologies of emitted CO_2 as possible mitigation options in future.

Among CO_2 fixation and effective utilization technologies, "IPCC Special Report on Carbon Dioxide Capture and Storage" described that carbon dioxide capture and storage (CCS) was one of key technology for global warming mitigation. Furthermore, in "the Cool Earth Energy Innovative Technology Plan" submitted by Japanese Government on March, 2008, CCS was selected one of prioritized innovative technologies for 50% cut in global CO_2 emission by 2050.

On considering these circumstances, RITE built up a technology strategy on "CO_2 fixation and effective utilization" in 2004 from medium- and long-termed viewpoint and rolls it up every year. METI also issued "Technology Strategic Roadmap 2009" on the basis of our investigation and some investigations in other fields. In this paper, I would like to introduce our "Technology Strategy Roadmap on CO_2 fixation and effective utilization"

2. Overview of CO_2 fixation and effective utilization technologies and prioritization

Among a variety of mitigation technologies of global warming, we focused on "CO_2 fixation and effective utilization technologies" which are main investigation fields of RITE and on which RITE are expected to draw up a strategy roadmap by METI. In energy field, the strategy roadmap on energy saving, fuel shift from fossil to non-fossil and sift to lower carbon fuels among fossil fuels was also planed to be drawn. Thus, we draw up roadmap only on innovative conversion and utilization technologies of biomass in this field.

Overview of CO_2 fixation and effective utilization technologies is shown in figure 1. There are two different groups of CO_2 emission sources. First group is a large concentrative emission sources such as power plants, iron and steel- making works etc. Another group is small sized but large number of scattered emission sources like automobiles and houses. For the first emission group, capture and storage (CCS) are most promising. Effective utilization after capturing CO_2 is also possible. However, capture from the second emission group is very costly, and thus absorption & fixation of emitted and diluted CO_2 by living matters such as trees or grasses is considered to be promising. Not-captured CO_2 from large emission sites are also included in this field. Sub-technologies for these two emission groups are also shown in the same figure.

CO_2 capture and storage (CCS): This technology is composed of CO_2 capture and injection into geological formations or ocean in order to store or sequester CO_2. For geological storage, deep saline aquifers, coal seams, depleted oil or gas fields are available and enhanced oil or gas recoveries (EOR, EGR) are also important. In ocean sequestration technology, dissolution & dilution (mobile or stationary type), and deep sea storage are available.

Effective utilization of CO_2: This technology converts CO_2 to useful materials through chemical or biological processes. It is composed of two technology groups, decomposition to carbon and conversion to chemicals.

Absorption & fixation of CO_2 using living matters: This technology can fix CO_2 using living matters. It is composed of three groups, terrestrial storage like large scale afforestation, fixation using marine plants, and fixation using fauna like coral reef. In terrestrial storage, conversion of stacked biomass to energy or chemical materials is included.

After evaluation of effectiveness as a CO_2 mitigation option, CO_2 reduction potential, rough estimate of current cost, and cost viability in 2030 of these technologies, technologies which are effective from both reduction potential and cost viewpoint and should be moved to implementation level were selected and detailed strategic scenarios and roadmaps were written on the following focused themes:

- CCS: Capture of CO_2, geological storage in deep saline aquifer, coal seem, and depleted oil & gas field, EOR, EGR, and ocean sequestration
- Terrestrial storage using large scale afforestation: Suitable evaluation method for CO_2 fixation, increase of CO_2 fixation per unit area, expansion of vegetation into arid area, vegetation expansion by industrial uses of plant materials, and innovative biomass utilization.

3. Strategy and roadmap on CCS

CCS is composed of capture and storage (geological or ocean) processes.

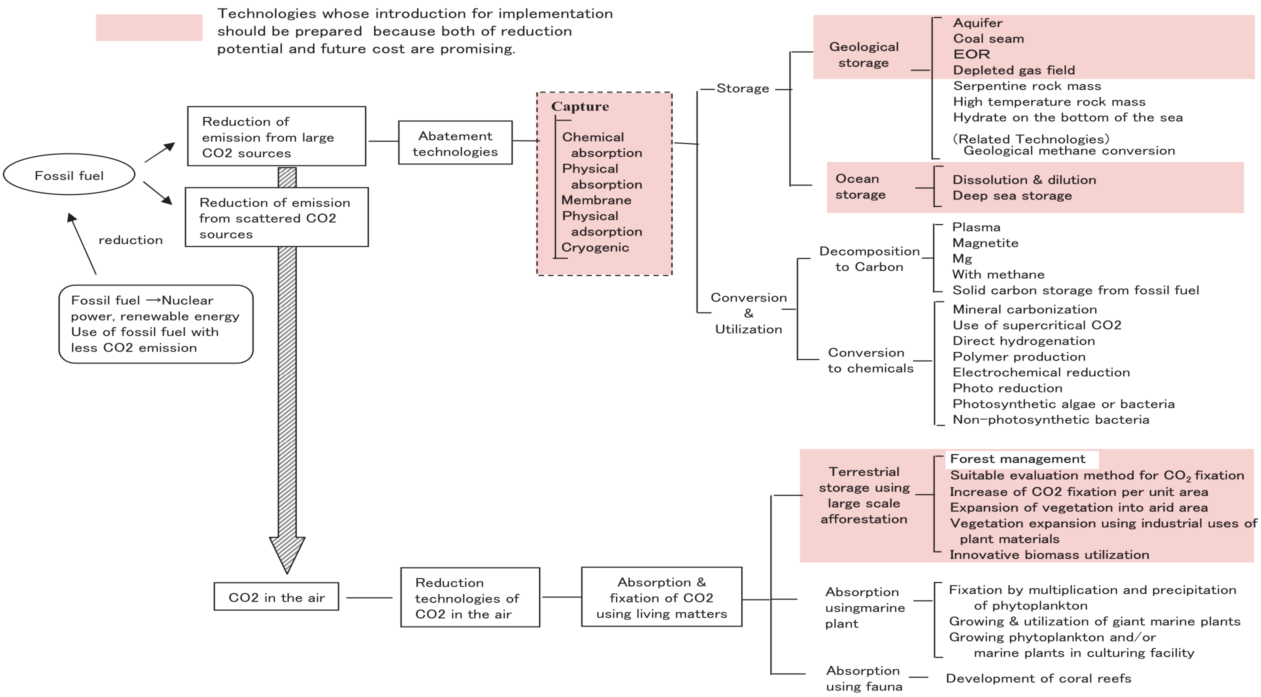


Figure1 Technology Overview of CO_2 Fixation and effective CO_2 utilization

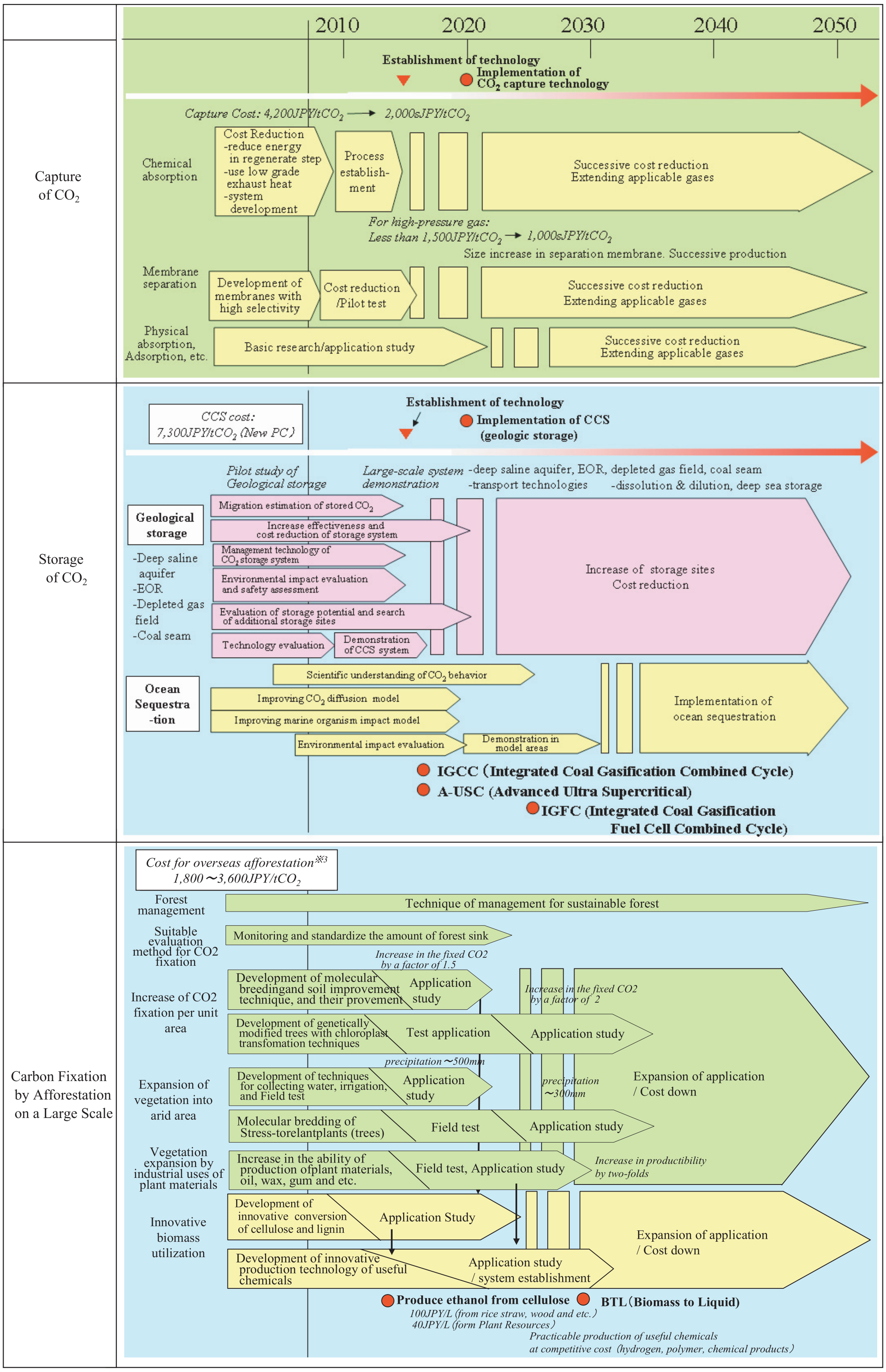
In capture process, target emission sites are power plants, iron & steel making plants, and cement works etc. As capture technologies for power plant, three processes, post-combustion for ordinary flue gas, pre-combustion for synthetic gas derived from partially fuel oxidation process like IGCC, and oxyfuel process in which fuel is oxidized by oxygen instead of air to produce flue gas with a high CO_2 concentration are known. Chemical absorption, physical absorption, membrane separation, adsorption, and cryogenic separation are available for separation technology of CO_2. Chemical absorption is promising for flue gases, and chemical absorption, physical absorption and membrane are adapted for pressured gas. Chemical absorption and physical absorption are already commercialized. But a drastic reduction in capture cost is required because cost reduction of CCS is required as a mitigation option of global warming. Current capture cost is high and estimated to be about 70% of total CCS cost. Reduction in energy consumption in capture process is another important aspect. Power plant with CO_2 capture requires 20-30 % additional energy compared to that without capture. To solve this problem, a lot of innovative low-energy capture processes have been investigated aggressively in the world on chemical absorption, physical absorption, membrane separation, and adsorption.

In another respect, development of capture process has to be synchronized with development of geological storage process. We have to complete the development of low energy and low cost capture processes before the start of implementation of geological storage. Purity of captured CO_2 is also restricted to be in the required level for geological storage.

RITE has been developing CO_2 storage or sequestration technologies. Ten thousand tons of CO_2 was injected into a saline aquifer in Nagaoka gas field, Niigata Prefecture. This injection experiment demonstrated safe storage of CO_2 in deep saline aquifer which is expected to be a most promising CO_2 reservoir in Japan. Injected CO_2 was monitored using several kind of monitoring techniques and numeric simulation to seek long-termed migration of CO_2 was examined. Besides, a lot of validity studies, including cost or potential evaluations, that confirmed CCS as a useful mitigation option in Japan, were carried out. Safety assessment and some other investigations on regulation and public acceptance were also done. On the basis of these investigations, issues to resolve before implementation of CCS were discussed in “CCS Study Group” formed by METI in fiscal year 2007 and large scale demonstrations were concluded to be necessary along with R&D on cost effective but safer CCS technologies and development of required regulations.

On the basis of above considerations, R&D strategy and roadmap on CCS were built up (figure 2).

Figure 2 Strategic Technology Roadmap “CO2 fixation and effective CO_2 utilization”



⁎ 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

Ocean sequestration is important technology having large reduction potential but it will take long time to build up international consensus to use it because biological impacts of CO_2 injection have not been clear. Thus, it is important to start the development of geological storage at first, which is going to be recognized a key technology for quitting global warming in the world. For example, a vigorous promotion of geologic storage was adopted in G8 summit and IEA, CSLF and other institutes clarified problems for implementation and made roadmaps for introducing CCS. These roadmaps in the world show that establishment of necessary technologies and regulatory framework are finished by around 2015. Thus, in our roadmap we also set the year of establishment of CCS technology in Japan in around 2015. By then, various validations or safety studies are necessary along with developments of CCS technologies including a large scale demonstration. On CCS regulations, the exsiting laws in Japan firstly should be considered and then, if necessary, new CCS regulatory frameworks should be established in accordance with international regulatory works like in London Convention. Especially, assignment of long-termed responsibility of stored CO_2 will have to be examined sufficiently. Besides, we also have to promote public understanding on CCS as early as possible. Meanwhile, we set the year of implementation of ocean sequestration in 2030. We have to accumulate more scientific knowledge and numerical simulation data on biological impacts by then.

Regarding capture, low energy and low cost technologies have to be completed by 2015 in harmony with the start of storage implementation. A drastic cost decrease is expected. The more capture cost decrease, the far reservoirs from emission site becomes economically available and then the storage potential becomes larger. Capture cost is plausible to be about two thousand yen in 2015 and 1000's yen/t-CO_2 is required as a final goal on considering emission trading price and competitiveness with foreign vendors. We have to develop innovative technologies to attain such cost targets and extend practical applications.

In accordance with this roadmap, Japan CCS Corp. which was the first company specialized in CCS, was established in 2008 and candidate sites for a large scale demonstration have been examined and conceptual design studies are being done now. Furthermore, safety and environmental issues that should be observed in implementing a large-scale CCS demonstration project in Japan were discussed in the CCS study group and the report titled “For safe operation of a CCS demonstration project” was issued in 2009. A large demonstration of CCS in Japan is being ready to start.

4. Strategy and roadmap on terrestrial storage using large scale afforestation

Terrestrial sequestration using large scale afforestation enables sequestration of emitted and diluted CO_2 in the air and should be developed together with biomass utilization. This is only technology capable of competing with CCS from a viewpoint of large decrease in CO_2 concentration in the air. For example in the US, the cost target for R&D of environmental forestation was set in 2008. Furthermore, development of ethanol or chemicals production from biomass becomes vigorous in the world. The US is most active and has some projects to build commercial plants.

Prior to implementation of terrestrial sequestration using large scale afforestation, technologies on selecting proper sites and type of plants, system evaluations such as water balance for forestation, environmental impact evaluations, and estimation of absorbing amount of CO_2 are required to be developed. In order to increase reduction potential of CO_2, increase of absorbing amount of CO_2 per unit area and expansion of vegetation into arid area are required. For preparing environment for promoting afforestation etc, consolidating regulatory framework, making standard of CO_2 monitoring, evaluating various advantages of forest and approving genetic recombination are pointed to be important. Biotic diversification is also a factor required to be considered. International cooperation such as co-development of innovative technologies, management cooperation to promote afforestation, and capacity building in advancing countries also should be undertaken.

In biomass utilization, efficient conversion technologies to energy or useful material and the technologies enabling to use wide variety of biomass species are important. Various kinds of chemicals are produced on the basis of petroleum platform now. Substitution of them for green chemicals from biomass is effective for cutting CO_2 emission and decrease of oil consumption, and thus we need innovative technologies which can convert biomass to useful chemicals effectively at lower cost. This stream from environmental afforestration to industrial use of biomass becomes world-wide paradigm shift.

Thus, we need to carry out R&D on increase of CO_2 fixation per unit area, vegetation expansion into arid area, and vegetation expansion using industrial uses of plant materials by 2010-2015. The year of technology combination between afforestation and biomass utilization is set in around 2020. Building up of wide variety of biomass utilization systems and large scale demonstrations are necessary by around 2030.

The roadmap in this field is also shown in figure 2. Targets and milestones are follows:

Increase of CO_2 fixation per unit area: First, application study of the technologies without genetic modification like molecular breeding and soil improvement should be started for earlier use. In technologies with genetic modification, we have to carry out R&D to attain the target of increasing CO_2 fixation by a factor of 2 and to ensure safety of genetic modified plants. On these technologies, test applications should be started from around 2015 before starting commercial applications in around 2030.

Expansion of vegetation into arid area: First, application study of technologies without genetic modification like collecting water, irrigation, and molecular breeding are to be started for earlier use. In technologies with genetic modification, we have to continue R&D on new species which can make industrial forestation under small precipitation conditions. The target is 500 mm in around 2020 and 300 mm in around 2030. We also have to ensure safety of genetic modified plants and carry out field test in around 2015 and finish commercial application by 2030.

Vegetation expansion in harmony with bio-energy utilization is composed of improving plants to produce more plant materials and innovative conversion and utilization technologies of biomass as follows:

Improving plants: Double production of energy materials like fatty oil and wax from plants is a target. Field demonstration and application study are to be started in around 2015

Innovative biomass conversion: Production of alcohol or other useful chemicals from sugar becomes in practical level now, but competition between energy utilization of corn or other grains and food production is pointed to be a problem. In order to avoid this, we have to choose cellulosic materials as a starting biomass. However, it becomes another problem that conventional saccharification of cellurosic materials is very costly. Thus, innovative saccharification techniques of cellurosic materials at low cost are strongly required. In the process of using cellurosic materials, lignin comes up as by-product. Especially, as woody materials contain much lignin, we have to consider the effective use of lignin. In the roadmap, it was described that basic R&D was to be completed by around 2010 and then application studies should be started.

Innovative biomass utilization: We need to develop highly effective and economical production technologies of fuels like alcohols, hydrogen and useful chemicals like polymers which are currently produced from petroleum. In around 2015, these utilization technologies are to be combined with innovative conversion technologies and application studies on coherent production systems from biomass to chemicals should be started.

The point of the coalition between large-scale afforestation and biomass utilization is set in around 2020. As small sized effective gas conversion system, liquid fuel production there, alcohol fermentation, innovative utilization systems described earlier are expected to be accomplished by then, we will be able to use the biomass grown by large scale afforestation. Total biomass utilization system including gathering and transportation should also be built up by then.

5. Conclusion

RITE publicizes this roadmap via the Internet, invites opinion from the public, and rolls up 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.