Carbon dioxide Capture and Storage (CCS) in Japan

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1 Preface

Presently it is estimated that total of approximately 24 billion metric tons of CO_2 is generated annually by the human activities in the whole world. It is reported that approximately five per cent of the total which is about 1,200 million tons is unfortunately originated in Japan. In addition to the efforts for reduction of CO_2, a new technology to collect and store CO_2 is being aggressively developed. The technology is so called CCS which means Carbon dioxide Capture & Storage.

2 Outline of CCS

(1) Separation and Collection Methods of CO_2 (positioning of CCS)

Technologies for Elimination and immobilization (Separation & Collection) of CO_2 are consisting of three categories such as physical elimination, biological immobilization and chemical immobilization.

a. Physical Elimination

(a) Separation method by Micro mesh film

(b) PSA (Pressure Swing Adsorption) method

(c) Storage in the deep ocean or underground（**CCS falls in this category**）

b. Biological Immobilization

(a) Nature of an alga

(b) Bacteria's activity

(c) Nature of micro organisms in ocean

(d) Nature of plants

c. Chemical Immobilization

(a) Absorption by the organic solvent

(b) Chemical synthesis (Mineralization etc)

(c) Electro-chemical reduction

(d) Photochemical reduction

(2) Storage of CO_2

a) Ocean (Ocean Storage)

b) Underground (Geological Storage)

c) Others (Animals, plants)

The concept of CCS is applied to the item a) and b) above, and not to the item c).

(3) Major targets for application and the concept of CCS

Thermal power stations which are a large-scale discharge source of CO_2 are the major targets for CCS operations. The concept of CCS is:

a) Separation and collection of CO_2 at the plant,

b) Transport to the high pressure storages on the ground or above the sea by pipelines, tank-lorries or ships,

c) Storing in the underground or deep ocean storages by injecting pressurized CO_2 from the high compression equipment.

3 History of CCS

In 1977 Dr. C. Marchetti, an Italian scientist, has proposed a marine isolation method of CO_2. He indicated a possibility of the CO_2 isolation in the deep sea which has drawn a great attention from the circles concerned.

In the early1980s, Mr. M. Steinberg, an American, has conducted an economic feasibility study on CO_2-EOR (Enhanced Oil Recovery) in the North American Continent. It was intended to demonstrate that CO_2-EOR is a practical technology for the underground isolation of CO_2. This technology has drawn attention as a basic technology for the underground isolation.

From the late 1980s through 1990s, CO_2-EOR (Enhanced Oil Recovery) was proposed to be placed as a counter measure to anti-global warming by Mr. Erik Lindeberg et al.

In 1996, aquifer storage of CO_2 accompanying the natural gas was started on a commercial base in an offing natural gas field Sleipner Mine in the Norwegian North Sea.

In 2000, the use of EOR at the coal gasification furnace in Weyburn in Canada was started. Storage of CO_2 at a level of one million tons per year is being practiced. .

In the No.8 third working committee of IPCC24 (The Intergovernmental Panel on Climate Change) which was held in Montreal in September, 2005, the issuance of the report "Special Report on Carbon dioxide Capture and Storage: SRCCS" has been approved.

4 A classification of the CCS technology

Ocean Storage and Underground Geological Storage are classified in more details as follows.

(1) Ocean Storage

a. Dissolution dilution (Gas CO_2 : 200-400m, Liquid CO_2 : 1,000-2,500m)

b. Deep sea-bed isolation storage (Liquid CO_2 : Deeper than 3,000m)

(2) Underground Geological Storage

a. EOR (Enhanced Oil Recovery)

b. Aquifer Storage

c. EGR (Enhanced Gas Recovery)

d. ECBM (Enhanced Coal Bed Methane recovery)

e. Sea bottom hydrate layer Storage

5 Potential of CCS（Storage potential）

The global storage capacity (storage potential) of CO_2 is estimated to be equivalent to the total quantity of CO_2 discharged in about 100 years in the whole world. Among the quantity of CO_2 reduction needed at the whole world by 2100, it is estimated under a test calculation that the contribution by means of CCS is somewhere between 15-55%.

However, the establishment of international and domestic laws concerning CCS for its practical application is the issues for the future.

(1) The storage potential of CO_2 in the whole world

In the IPCC special report (SRCCS) it is reported that there is at least a potential of underground storage for about 2,000Gt-CO_2 in the whole world.

The global ultimate CO_2 storage capacity is estimated to be 5,600 Gt CO_2 at land level and 1,500 Gt CO_2 in near-shore waters. The 10% of it is enough to store the total amount of CO_2 discharged in 100years in the world.

(2) The storage potential of CO_2 around Japan

As for the storage potential of CO_2 around Japan, it is estimated to be about 5.2Gt- CO_2 in the structure-related aquifer which are proved by a basic experiment, and in whole aquifer it is estimated to be about 150Gt - CO_2.

6 Embodiments of the CO_2 underground storage

(1) The embodiments in the world

The underground geological storage of CO_2 is already put into the practical use.

The present situations and the projects being planned are as follows.

a. The present situations

① Embodiments of aquifer storage of CO_2 accompanying natural gas

1) Sleipner (North Sea, Norway) 1 million tons- CO_2 per year, From 1996

2) In Salah (Algeria) 1.2 million tons-CO_2 per year, From 2004

② The EOR use of coal gasification furnace outbreak CO_2 :

1) Weyburn (Canada) 1million tons- CO_2 per year From 2000

b. Projects planning underway

1) Snohvit (Norway) 750,000 tons- CO_2 per year, From 2006

2) Gorgon (Australia) 5 million tons-CO_2 per year, From 2008

c. Others（The movement of the private enterprise）

1) Mitsubishi Heavy Industries (MHI) – Royal Dutch Shell (Middle East) EOR with CO_2 collected in the power station
2) Statt Oil – Shell (Norway) EOR with CO_2 collected in the power station
3) RWE (Germany) Coal-fired station and underground storage

(2) An embodiment in Japan

Nagaoka Project (Japan) Aquifer storage, Total 10,000 tons- CO_2, From 2000 to 2007

7 Problems of the practical use and Future prospects

(1) Issues to be studied

a. Risk of leakage

No questions are raised from the experts about the certainty of the isolation technology for CO_2. (It is reported that no leakage is expected to occur for the period of 5,000 years.) However, clarification of the concern to the influence on marine lives is a problem.

b. Adjustment with the London Treaty

In April 2006, the WG concerning to the Law and Related Matters, together with the WG concerning to the Scientific Matters discussed as to how the isolation of CO_2 in the bottom of the sea should be handled in London Treaty. As a result, an agreement was reached to revise the Attachment Book 1 (Reverse-List: The list of items that can examine abandonment) of the Protocol 96 which took effect in March, 2006. In addition, a reform bill of the Attachment Book **1** was submitted on April 28, 2006 by Australia (joint suggestion: France, Norway, UK), and it was voted at the Contracting Party Meeting held in October, 2006.

Note) London Treaty was adopted in 1972 as an international law to prohibit the abandonment of wastes in the sea.

It is a well-known agreement which has taken a form of an international agreement to prohibit the abandonment of high-level atomic waste in the sea.

The Protocol was revised in 1996. Before the revision it enumerated in the Protocol the things which must not abandon to the ocean. But after this revision the things which can be abandoned to the ocean are enumerated in the Protocol.（So called the Reverse-List）

c. Handling as the CDM (Kyoto Mechanism)

The decision of the Kyoto Protocol No. 1 Contracting Party Meeting (COP/MOP-1) about treating CCS as CDM was to examine the matter mainly on three points such as project boundary, leakage and permanency. The concrete examination process is as follows.

In May 2006, a Workshop was held at Bonn concerning to the Clean Development Mechanism (CDM) of CCS.

The outcome of the Workshop was reported to the International Strategy Specialty Committee in July, 2006.

The Guideline of how to handle the CCS as CDM was decided in COP/MOP-2 (held in November, 2006) by the CDM Board of Directors.

d. Other international wrestles（The law concerned, a scientific matter etc）

Other than the London Treaty and the Kyoto Protocol, there are IPCC (Intergovernmental Panel on Climate Change), APP (Asia Pacific Partnership), etc. for an international decision related to CCS.

(2)Cost appraisal

a. Cost of liquefaction

The energy that is required to liquefy 1kg of CO_2 is 36kcal. When coal is combusted at a thermal power station, and 1kg of CO_2 is produced, about 40% of the calorific value (that is 2,600kcal) will be converted to electricity. Therefore, the necessary energy for CO_2 liquefaction is equivalent to 4.3% of provided electricity when the energy efficiency of CO_2 liquefaction is 80%.

b. Cost of transportation

・ Reduction of transportation cost of the CO_2 will be possible by increasing transportation pressure and increasing of the transport volume.

・ It is difficult to extend transportation distance under the constraint of total cost target (3,000 yen/t - CO_2)

・ When transporting a large quantity of CO_2, a pipeline system up to the length of 1,000 km is economically advantageous.

・ In the case of limited amount of volume or longer distance for shipment, transportation by means of vessel is economically feasible.

c. The total cost of separation, collection and storage of CO_2

・ The additional cost target for CCS in the thermal power generation is about 10% of the output electricity, around 6,000 yen (US$50) per the 1 ton- CO_2 for the time being.

・ Total cost of CCS under the present conditions in Japan is in the range of 5,000 yen (US$42) to 10,000 yen (US$84) per ton of CO_2.

・ It is necessary to set the cost target at about 3,000 yen (US$25) per ton of CO_2 in order that CCS has economically favorable than the greenhouse gas reduction measure.

・ CCS at the power station requires additional energy by 10-40 percent, however reduction rate of CO_2 discharge is practically 80-90 percent.

・ Power generation cost by CCS application is estimated at about 0.01 - 0.05US$/kWh up.

・Total cost of CCS is estimated at about US$15 - 90 per ton of CO_2. The cost of the capture process represents majority of the total expense.

d. The CCS cost comparison of Japan and overseas

Presently, the total cost of CCS (from capture to storage) in Japan is higher than the cost of many other foreign countries

e. The cost comparison with the other measures

The generation cost in case of coal heat + CCS-90% will increase to around 2 times of the present coal thermal power generation.

8 Afterword

Japan is an island country. Therefore there are favorable chances to utilize the surrounding oceans for CCS operations. However, we know that the use of the ocean storage is a matter to be carried out under an international consensus. We anticipate therefore that the actual ocean storage operations to start from 2020.

The technology related to the underground geological storage has already been an established technology to collect oil, natural gas or Methane gas. It has been used more than 15 years in the US and Canada on a profitable commercial bases. As an example, 5,000 tons of CO_2 is shipped daily from North Dakota of the US to Weyburn in Canada using a pipeline with a diameter of 30cm now.

In Japan, a national project which is called “Nagaoka Project” is going on to evaluate the technological feasibility of underground geological storage. It is still a study stage for the basic engineering with very high operation cost. It is reported that the current cost for the separation and storage operations for a ton of CO_2 is about US$60. It is also reported that the volume for the first storage plan during the initial seven years between 2000 and 2007 is 10,000 tons in total.

A great effort is being paid to reduce the cost drastically in order to realize commercial based operations by the targeted year of 2015.

References

1) IPCC WG Ⅲ Sept. 2005: IPCC Special Report Carbon Dioxide Capture and Storage

2) Takao Matsumoto June 2005: Technique of Underground Storage of CO2, *3 rd Report of The Global Environmental Study 2005 by IPEJ* pp 198-207

3) Tetsuya Kohya June 2007: Environmental technology to grasp the key to human fate, *4 th Report of The Global Environmental Study 2007 by IPEJ* pp 1-5

4) Takashi Ohsumi, Apr. 2006: Study Trend of CCS, *Total Energy Engineering vol.29 No.1 (Apr. 2006)*

5) Global Environment Technology Room, METI 2005: A proof experiment for the practical use of CCS *CCS2020 (Oct. 2006)*

Tab.1 Storage place and potential of CCS

Classification	Method	Global Storage Potential	
Geological Storage	EOR (Enhanced Oil Recovery)	73 ～ 238 Bt	
	EGR (Enhanced Gas Recovery)	Oil Well：367 Bt Gas Well：1,467 Bt	
	ECBM (Enhanced Coal Bed Methane recovery)	147 Bt	
	Aquifer Storage	3,667 Bt	
	Sea bottom hydrate layer Storage	More than 3,667 Bt	
Ocean Storage	Dissolution dilution		Gas CO2 : 200-400m, Liquid CO2 : 1,000-2,500m
	Deep sea-bed isolation storage		Liquid CO2 : Deeper than 3,000m
Others	Animals		
	Plants	4.4Bt/Yer (phanerophyte)	

From 3 rd Report of The Global Environmental Study 2005 by IPEJ (T. Matsumoto)

Tab.2. Overseas Example of Geological Storage Project

	Sleipner Norway	Weyburn Canada	In Salah Algeria	Gorgon Australia
Executer	Stat-Oil	PTRC	BP	Chebron Exxon Mobile Shell
Destination	Aquifer over Gas field	EOR	Gas field	Aquifer
	Ocean	Land	Land	Land / Ocean
The start time	Act. 1996	Sept. 2000	July 2004	2008 ?
Quantity (Discharge ratio)	1 M t / year (2.9%)	1 M t / year (0.2%)	1.2 M t / year (1.7%)	5 M t / year (1.5%)
Total deposit	20 Mt	20 Mt	17 Mt	———
CO2 source	Accompany with natural gas	From coal gasification furnace	Accompany with natural gas	Accompany with natural gas

Source : IPCC, SRCCS

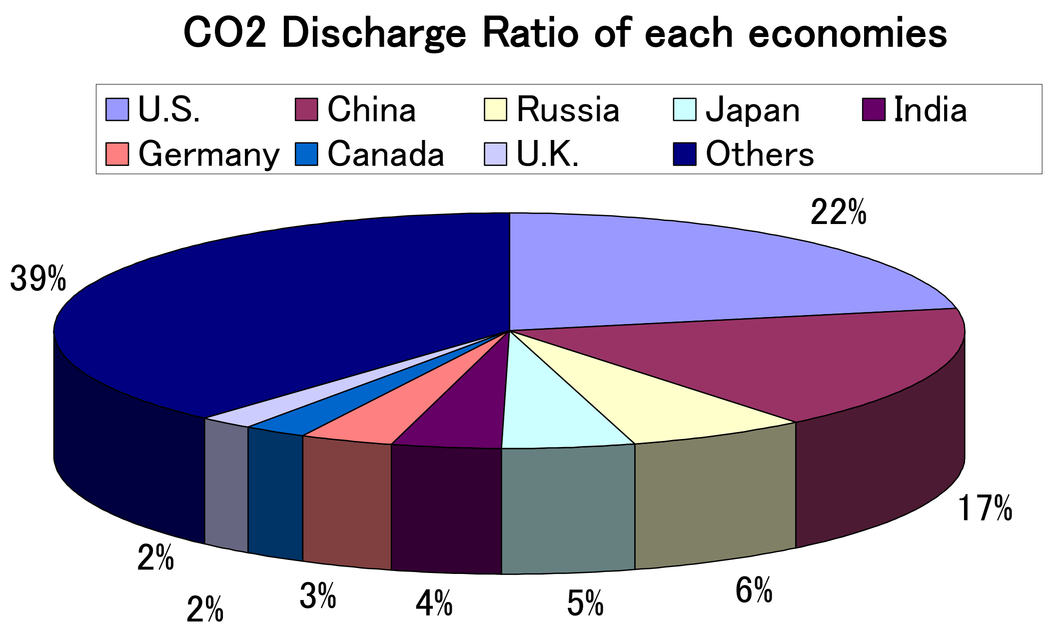

Fig.1 CO2 discharge ratio
Sorce : Energy Information Administration International Energy Annual 2004

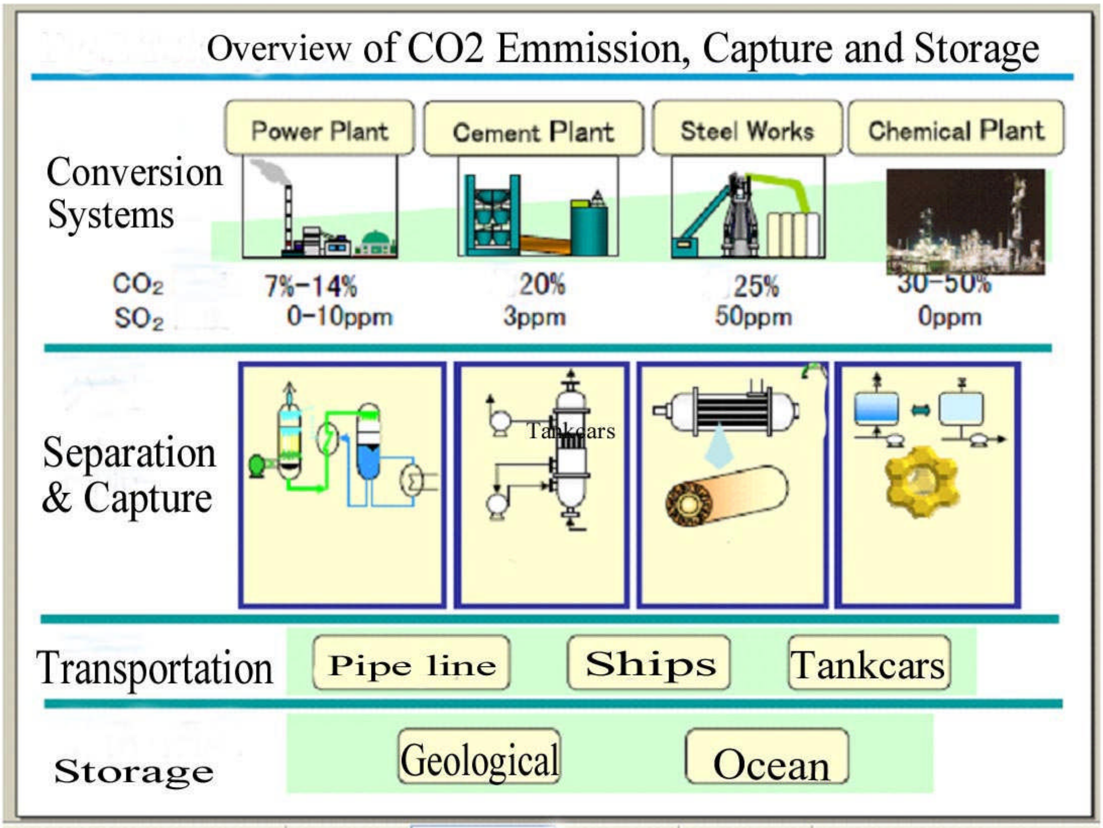

Fig.2 Overyiew of CO2 Emission, Capture and Storage Source: METI

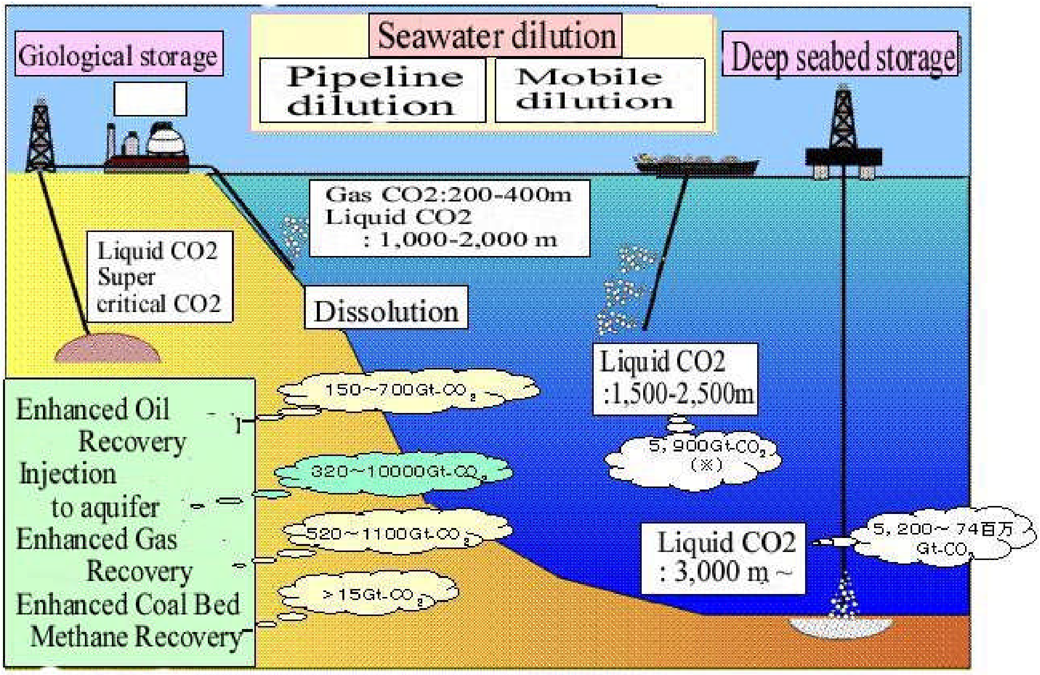

Fig.3 Storage Technology From IEAGHG & RITE

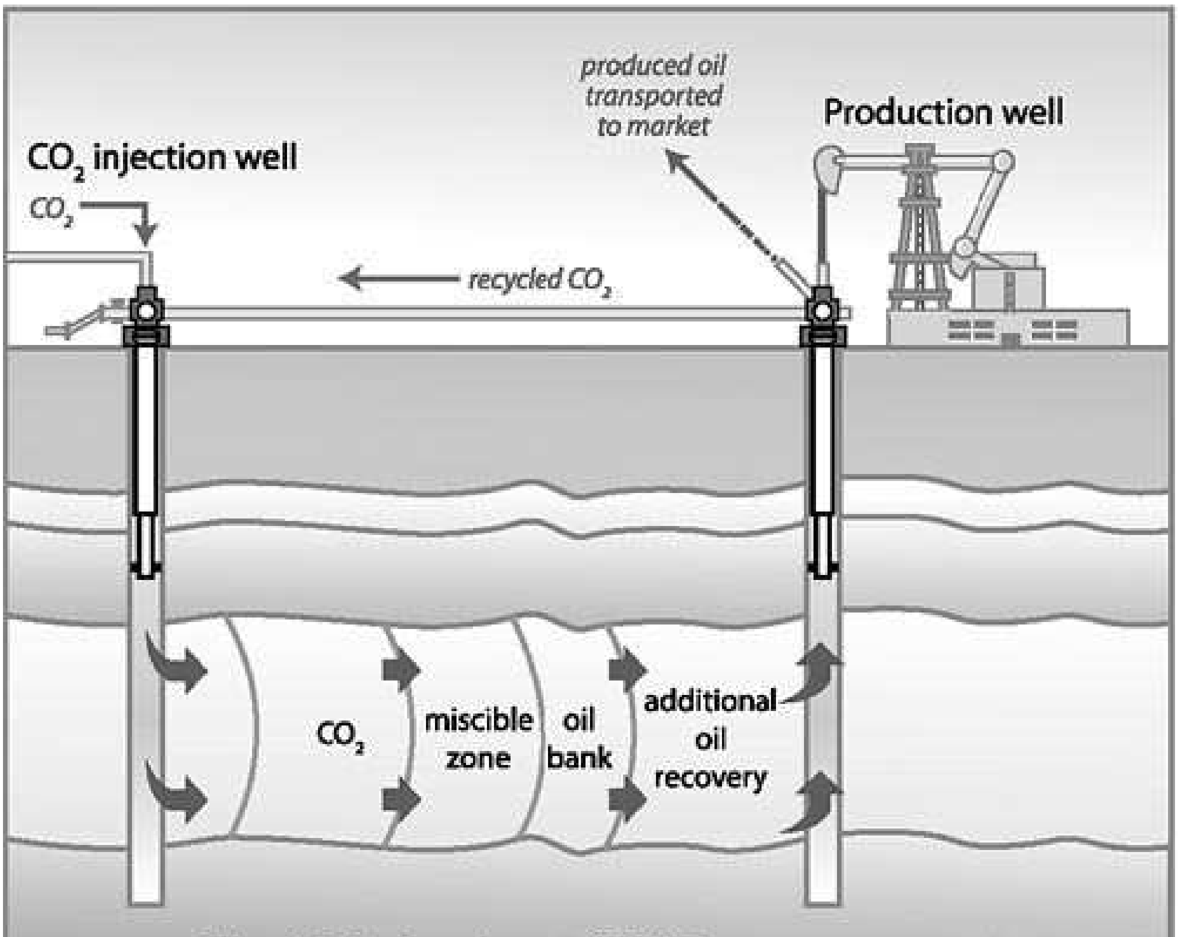

Fig.4 Mechanism of EOR Source:IPCC, SRCCS

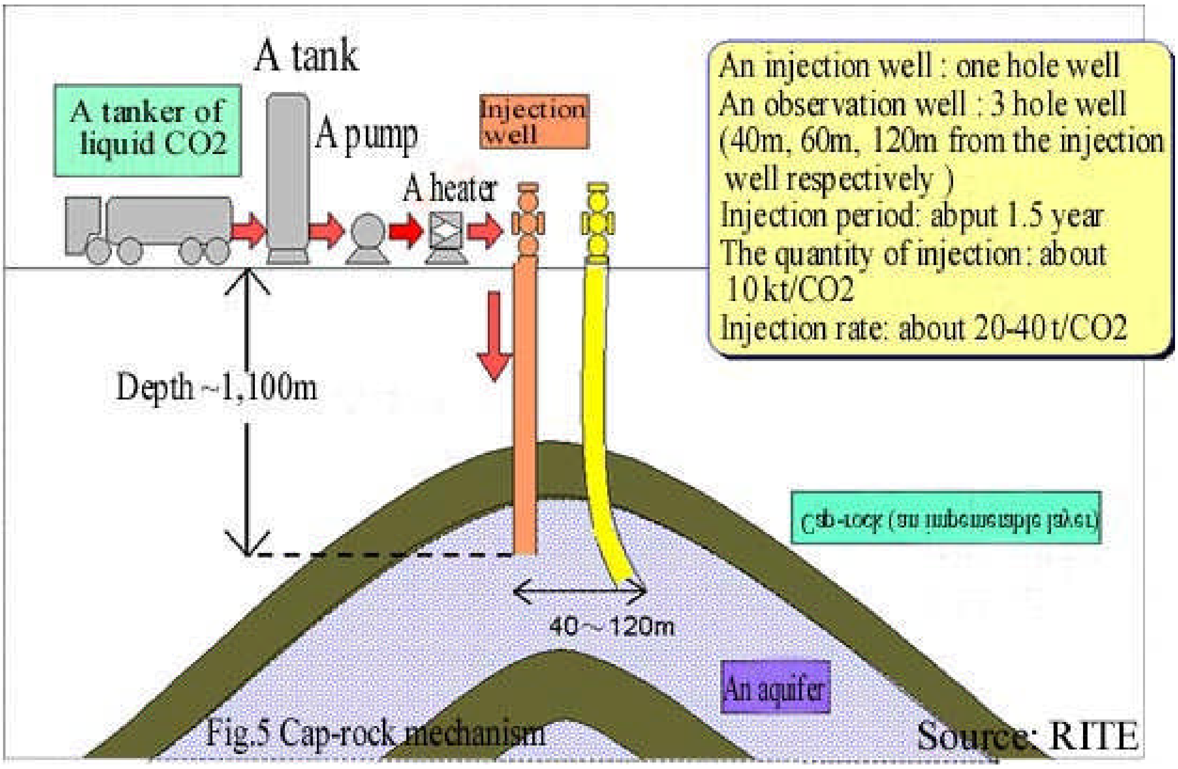

Fig.5 Cap-rock mechanism

Fig.6 Weyburn Project

IWANOHARA Base
MINAMI NAGAOKA Mine
4912 IWANOHARA,
NAGAOK, JAPAN

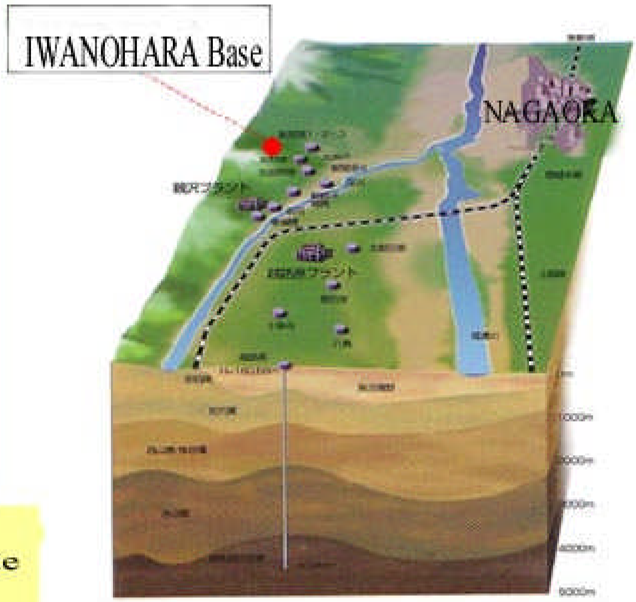

Fig.7 IWANOHARA Base (NAGAOKA Project)

Fig.8 NAGAOKA Project. Source:.RITE

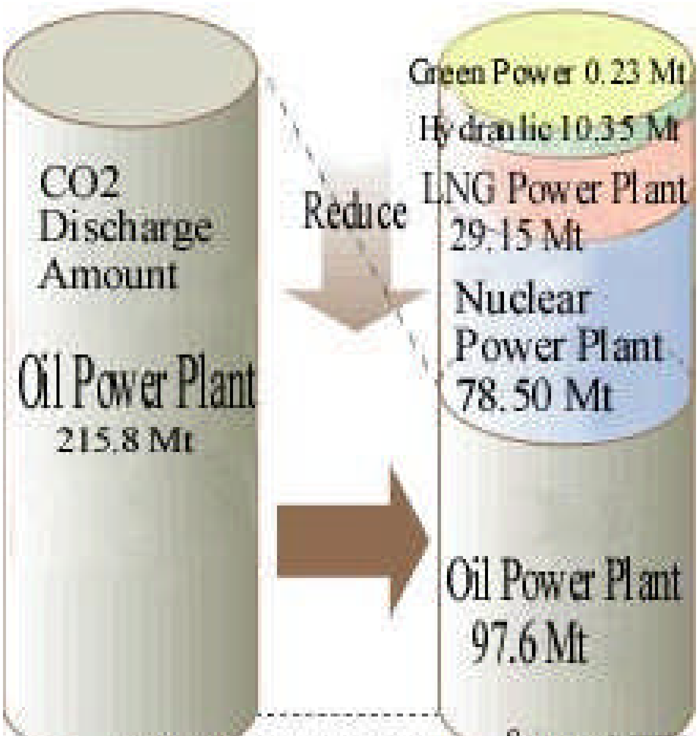

Fig.9 Effect of CCS in JAPAN Source: METI

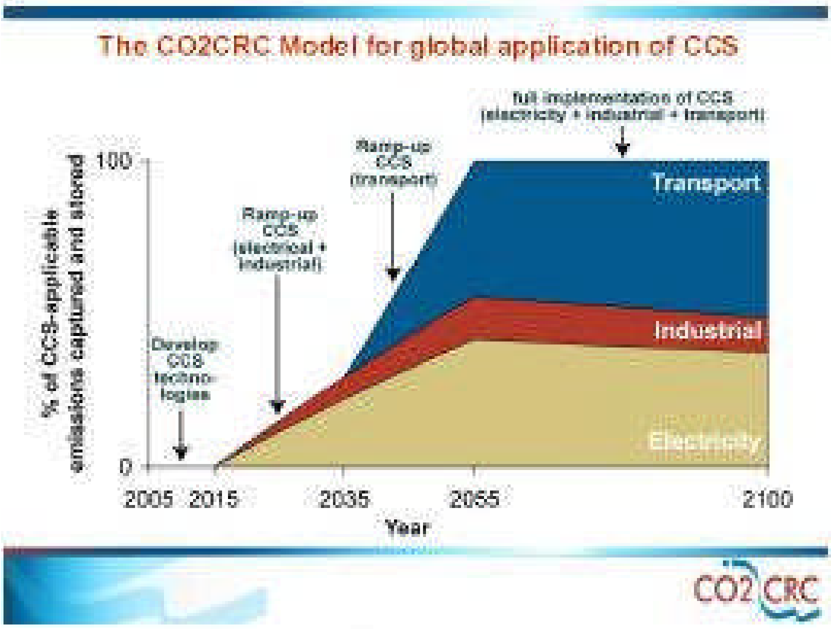

Fig.10 Global application model of CCS. From CO2 CRC by Cook

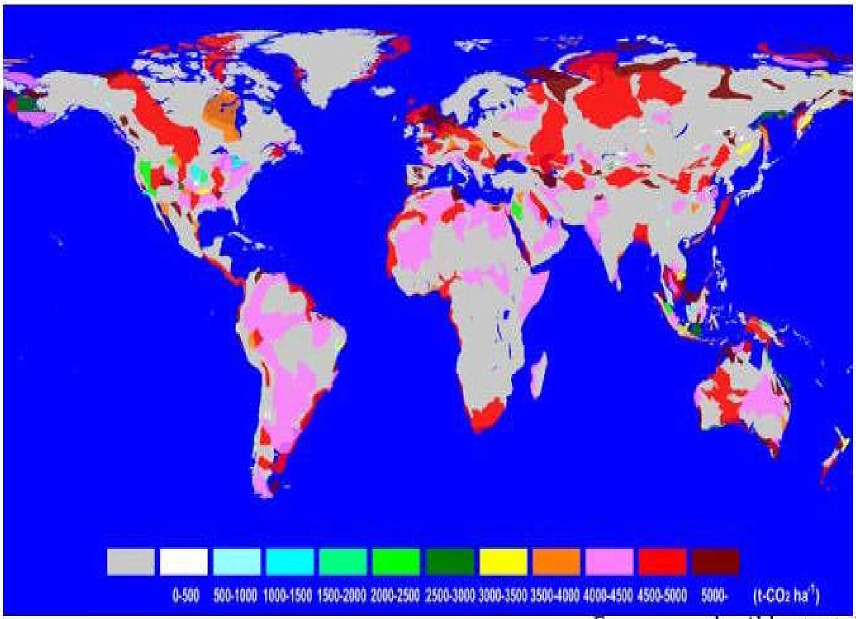

Fig.11 Global Presumed Potential to store CO2 in aquifer   From a paper by Akimoto et al.

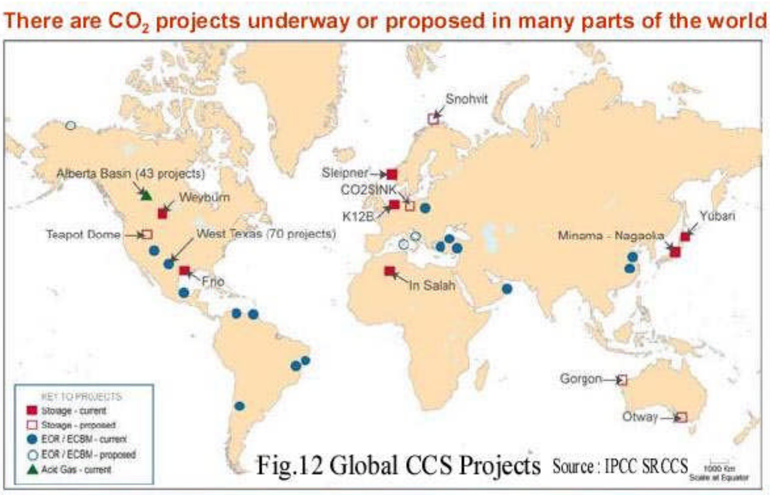

Fig.12 Global CCS Projects Source : IPCC SRCCS

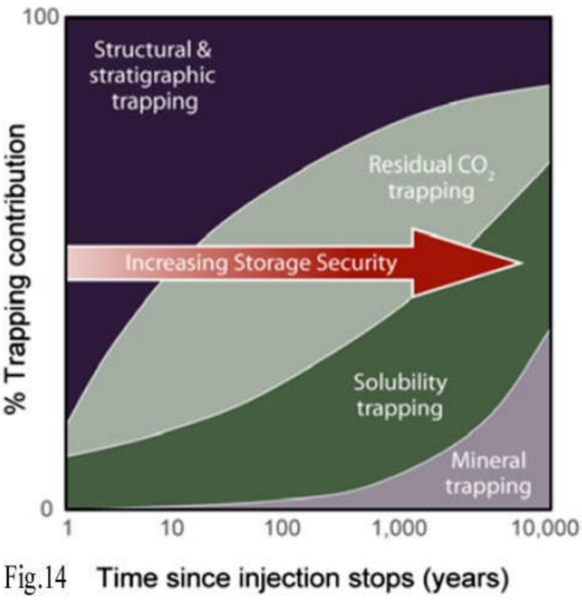

Fig.14