Summary for
Workshop on Clean Development Mechanism (CDM) Methodological Issues in regard to Carbon Dioxide Capture and Storage (CCS)

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1. Introduction

In response to the request by the COP, in its decision 9/CP.7, IPCC Special Report "Carbon Dioxide Capture and Storage (CCS)" (IPCC SRCCS) was accepted in September 2005 and subsequently submitted to the UNFCCC. The UNFCCC, Subsidiary Body for Scientific and Technological Advice (SBSTA), at its twenty-third session, considered the Special Report and acknowledged that "carbon dioxide capture and storage is an option, in the portfolio of mitigation options, for stabilization of atmospheric greenhouse gas concentrations."

Meanwhile, two CDM methodologies for CCS projects have been submitted to the CDM Executive Board. One is for CDM project activities which involve storage of CO_2 in an oil reservoir, the other for storage of CO_2 in a deep saline aquifer.

While the CDM Executive Board decided to put on hold the methodologies for CCS projects and referred them to the COP/MOP, the COP/MOP, in its decision at its first session, established the process with a view to making its final decision at its second session to be held in November 2006, identifying the three key issues to be addressed, i.e., project boundary, leakage and permanence. In accordance to this decision, the CDM Executive Board will consider proposals for new methodologies for CCS projects and make recommendations to the COP/MOP at its second session. In addition, a workshop for considering CCS projects as CDM will be organized in conjunction with the twenty-fourth session of SBSTA scheduled in May 2006.

Against these backgrounds, the Ministry of Economy, Trade and Industry of Japan (METI) hosted "Workshop on CDM Methodological Issues in regard to CCS". The workshop was intended to develop and deepen mutual understanding among both sides of CCS and CDM, and to discuss how to implement CCS projects as CDM through examining the two proposed CDM methodologies as applied to potential actual CCS projects, focusing on the three key methodological issues.

It was expected that the result of the workshop would provide useful input for the workshop on considering CCS projects as CDM at the twenty-fourth session of SBSTA as well as for the discussions at the CDM Executive Board and the COP/MOP at its second session.

The workshop was held in Paris on April 20th and 21st. Experts from both CCS and CDM fields and governmental representatives of the countries concerned were invited to the workshop. There were 64 participants from various fields such as governments of investing countries, governments of host countries, the Methodology Panel, the UNFCCC secretariat, the IPCC, DOEs, oil majors, the IEA-GHG and the field of geology. There were 20 participating countries.

We received diverse constructive opinions at the workshop. I would like to extend my deepest appreciation to those who participated. The following content is based on the outcome of the workshop, however the author bears the responsibility for the content of this paper.

2. Overview of CCS

- Most of this section is quoted from IPCC SRCCS and IPCC 2006 Guidelines for National Greenhouse Gas Inventories, capture of CO_2 -

2.1 What is CCS?

Carbon dioxide (CO_2) capture and storage (CCS) is a process consisting of the separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere.

Capture of CO_2 can be applied to large point sources. Post-combustion capture of CO_2 in power plant is economically feasible under specific conditions. Separation of CO_2 in the natural gas processing industry, which uses similar technology, operates in a mature market.

The CO_2 would then be compressed and transported to a storage site (See Figure 2-1). Pipeline transport of CO_2 operates as a mature market technology. The pressure is around 10 MPa, which is used in general industrial processes (in the USA, over 2,500 km of pipelines transport more than 40 Mt CO_2 per year).

2.2 Geological storage

Geological storage can take place in natural underground reservoirs such as oil and gas fields, coal seams and saline water-bearing formations utilizing natural geological barriers to isolate the CO_2 form the atmosphere.

If CO_2 is injected suitable saline formations or oil or gas fields, at the depths below 800m, various physical and geological trapping mechanisms would prevent it form migration to the surface. At depths below 800-1,000m, CO_2 becomes supercritical and has a liquid-like density (about 500-800 kg/m^3), pressure (8-10 MPa) and temperature (40-50 degree C), and fills the pore. In general, an essential physical trapping mechanism is the presence of a caprock that is rock of very low permeability that acts as an upper seal to prevent fluid flow out of a reservoir.

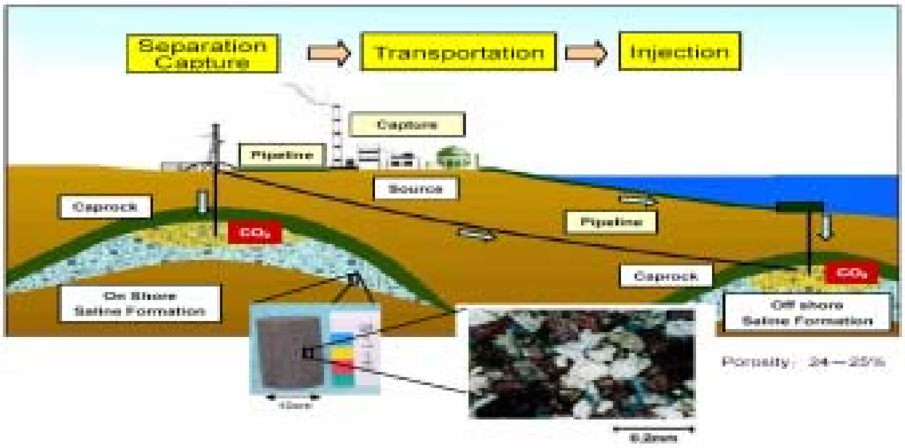

Figure 2-1 : Overview of CCS Concepts

(Source) Some introductory remarks on geological storage, AIST

2.3 Geological distribution and Storage capacity

According to the IPCC SRCCS, the capacity of geological storage worldwide is at least 2,000Gt-CO_2, which means there is considerably high potential for geological storage as a climate mitigation option.

The capacity is scattered from Africa, Middle East, South Asia to Middle and South America. While the current implementation of CDM projects is dominated by several developing countries, many developing countries have a potential to benefit from CCS – CDM projects. Figure 2-2 shows prospective areas in sedimentary basins where suitable saline formations, oil or gas fields, or coal beds may be found. Locations for storage in coal beds are only partly included. Prospectivity is a qualitative assessment of the likelihood that a suitable storage location is present in a given area based on the available information.

2.4 Underground condition

It is possible to select reservoirs where the underground water hardly ever moves and injected CO_2 is expected to move a mere several km in 1,000 years. This means that CO_2 dissolved in formation water hardly ever leaks.

Generally speaking, the underground water in deep aquifers hardly ever moves when compared with that in shallow aquifers because of the lower permeability and porosity. The actual flow rate of the groundwater will be estimated for a candidate reservoir selected for CO_2 storage through a site characterization following a geomorphologic evaluation in a preliminary planning phase.

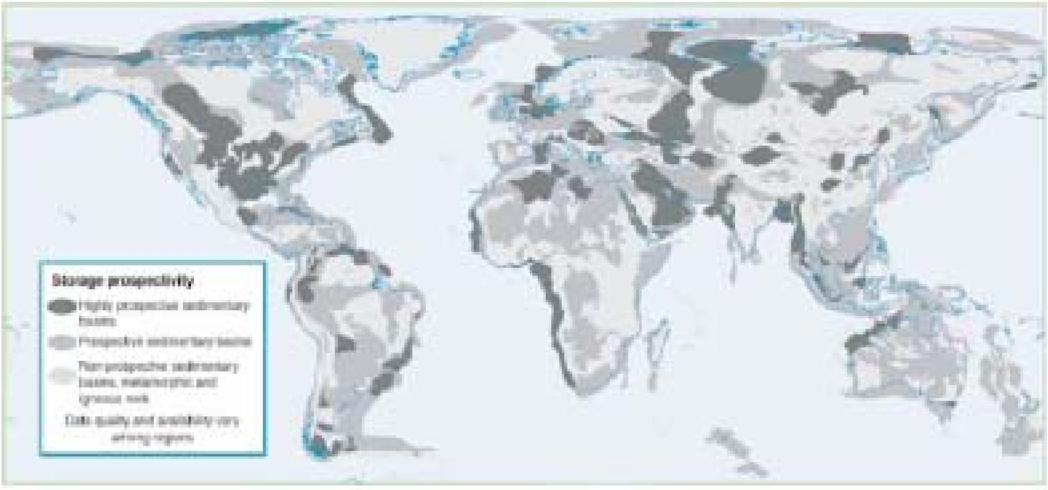

Figure 2-2 : Prospective areas in sedimentary basins

(Source) IPCC SRCCS

2.5 Earthquake

The CCS project in Nagaoka, Japan attacked by the large earthquake shows that geologically stored CO_2 did not leak out to the ground surface.

There was a large earthquake in Japan on Oct.23, 2004 (Niigata Chuetsu Earthquake), of which the epicenter was about 20km from the injection site of the Nagaoka project. The magnitude of the earthquake on the Richter scale was 6.8; the depth was 10km; the maximum acceleration was 1,722 gal. Injection was automatically stopped at the main shock. Safety inspections such as Surface Inspection, Press & Temp, Geophysical Logging, Acoustic Borehole Televiewer and Cross Well Seismic Tomography were made. Injection was carefully resumed after confirmation of safety on Dec. 6, 2004. There was no damage to the project.

In general, the deep underground shock of an earthquake is much less than the surface shock., because small shaking in the deep underground is magnified to larger shaking at the surface, moving like a long wand (See Figure 2-3).

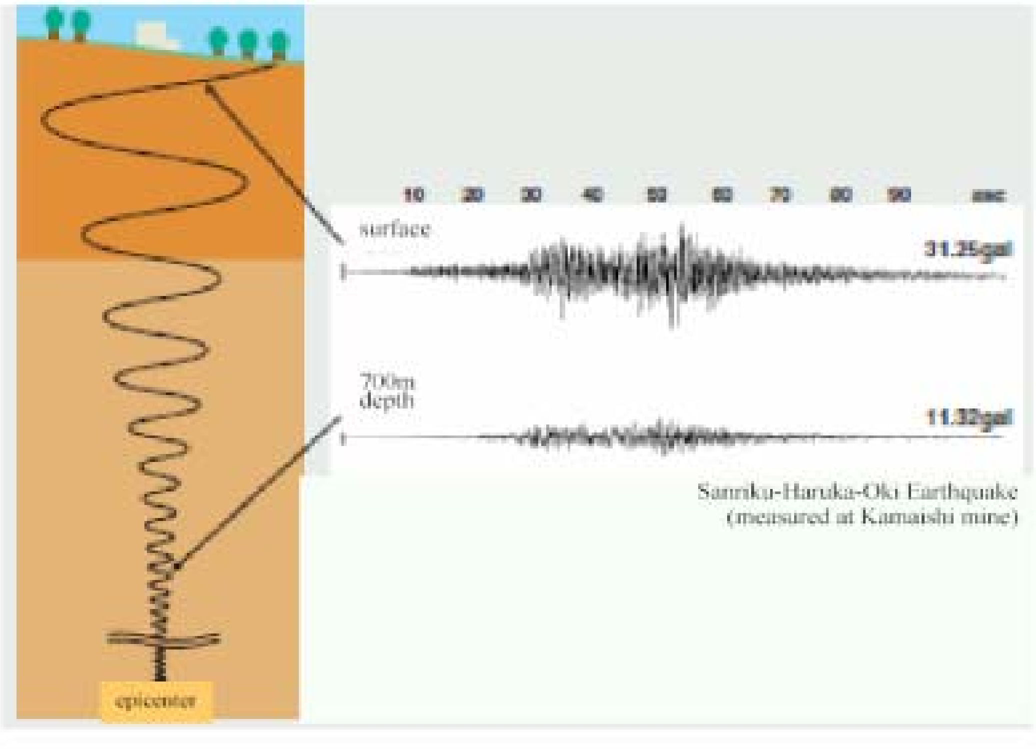

Figure 2-3 : Shaking of earthquake in the deep underground formation and the surface

(Source) JAEA

2.6. Permanence

According to the IPCC SRCCS, "The fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1000 years."

At the Weyburn EOR Project an integrated 3D geological model serving as a basis for a more comprehensive system model that includes anthropogenic attributes (well bores, production parameters,…) is constructed and used for risk assessment which shows at 95% probability that 98.7% to 99.5% of the initial CO_2 in place after the EOR period will remain stored in the geosphere for 5,000 years.

2.7. Accounting

According to the "IPCC 2006 Guidelines for National Greenhouse Gas Inventories, capture of CO_2", geologically stored CO_2 could be accounted for as emission reduction, which is to say that it could be considered to have never been emitted.

The only emissions pathways that need to be considered in the accounting are CO_2 seepage to the ground surface or seabed from the geological storage reservoir.

This guidance does not include a Tier 1 or Tier 2 methodology. There are, however, Tier 3 monitoring technologies available, which have been developed and refined over the past 30 years in the oil and gas, groundwater and environmental monitoring industries.

The inventory agency may obtain emissions information from the appropriate governing body (bodies) that regulates carbon dioxide capture and storage if it exists. If no such agency exists, then it would be good practice for the inventory agency to follow the methodology presented below.

1) Identify and document all geological storage operations in the jurisdiction.

2) Determine whether an adequate geological site characterization report has been produced for each storage site.

3) Determine whether the operator has assessed the potential for seepage at the storage site.

4) Determine whether each site has a suitable monitoring plan.

5) Collect and verify annual emissions from each site : The emissions recorded from the site and any leaks that may occur inside or outside the site in any year will be the emissions as estimated from the modeling (which may be zero), adjusted if needed to take account of the annual monitoring results. If a sudden release occurs, e.g. from a well blowout, the amount of CO_2 emitted should be estimated in the inventory.

Total national emissions for geological carbon dioxide storage will be the sum of the site-specific emission estimates.

3. Project boundary and Leakage

Only methodologies for geological storage are considered in this summary, because ocean storage is in the research phase according to IPCC SRCCS. To be specific, EOR, storage in abandoned oil/gas reservoirs and storage in aquifers are considered based on the submitted methodologies.

3.1 Geological storage is defined as *“emission reduction”* not as *“sink”*

Geological storage of captured CO_2 is considered as a reduction of CO_2 by source, not as a CO_2 sink. According to Article 1, para 8 of UNFCCC, "Sink" means any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere. Also in IPCC 2006 Guidelines for National Greenhouse Gas Inventories, capture of CO_2 is considered as emission reduction.

3.2 Project boundary

It is clear that a project whose all activities are conducted within one Non Annex I country has no problem of eligibility.

A project whose activities are across more than one Non Annex I countries needs approval of all related countries. The allocation of credits and liabilities should be determined upon a consultation among the countries.

The inclusion of CO_2 source in the project boundary will be determined case by case.

According to the Marrakesh Accords, the project boundary shall encompass all anthropogenic emissions by sources under the control of the project participants that are significant and reasonably attributable to the project activity.

There was a discussion whether a power plant which is a CO_2 source should be included in the project boundary or not. However, in the case where emissions are measured *ex post* at the sources outlet (stack), it makes no difference to baseline or emission reduction determination.

3.3 Leakage

The increased oil production by EOR will not be considered as leakage.

According to the Marrakesh Accords, Leakage is defined as the net change of anthropogenic emissions by sources of greenhouse gases which occurs outside the project boundary, and which is measurable and attributable to the CDM project activity. The term “leakage” above is different from physical “leakage” in the CCS field which is “seepage.”

There are some precedents to the argument on the increased oil production by EOR.

The methodology on recovery and utilization of gas from oil wells that would otherwise be flared (AM0009) describes that “substitution of fuels due to the project activity is unlikely to lead to an increase of fuel consumption in the respective market.”

According to the methodology on renewable energy project activities (AM0019), “No significant sources of leakage are to be expected for renewable energy projects. The energy prices will not decline due to the addition of a renewable energy project and thus there is no risk that it will result in a higher consumption of electricity by the end-users.”

Even though the production of oil increases due to EOR, the consumption of oil would not change unless lower price of oil is introduced to the market by EOR to the extent to alter the supply curve of oil. It should be reminded “oil is not CO_2.” As is the case with the above precedents, the increased oil production by EOR will not be considered as leakage.

4. Permanence

4.1 Seepage during project period

The amount of seepage (escape) of each crediting period will be accumulated and will be adjusted at the end of the last crediting period.

A Flow chart of the monitoring is described in the Figure 4-1. In this flowchart, no escape by an unrecognised route is expected. The dotted part is replaced with Figure 4-2 if any escape should occur.

Monitoring - mainly monitoring of injected wells and 3D seismic survey - will be conducted during a project period to detect the presence of seepage. Also simulations will be run in conjunction with monitoring to conduct monitoring where seepage is predicted to occur.

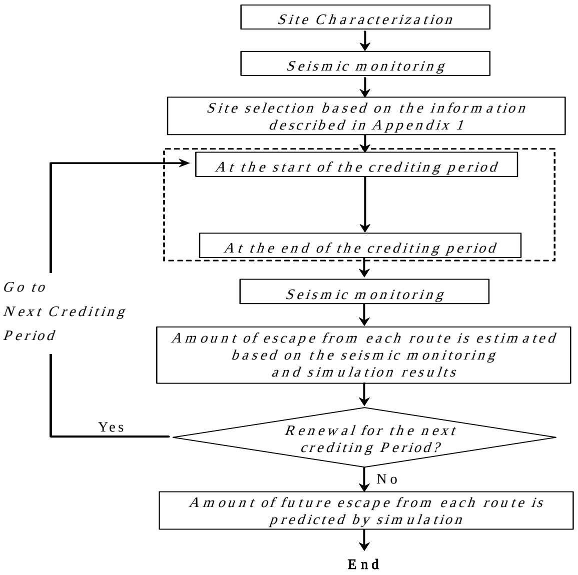

Figure 4-1 :Flow Chart of Monitoring

(Source) Proposed NMM for CCS in aquifers

4.2 Seepage after project period

At the end of a CDM project, future CO_2 seepages after the project ends will be deducted from the emission reduction.

At an appropriately selected and managed reservoir seepage would hardly ever occur, hence monitoring will not be conducted after the project has ended. Instead, seepage after the project has ended is considered. Table 4-1 shows ideas on how to manage seepage after the project has ended.

Mitsubishi Research Institute, in their CDM methodology submission suggests the following method: First - at the end of the last crediting period - estimate the amount of seepage for 1,000 years after the project has ended by running simulations. Secondly, compare the above estimated amount of seepage with the amount equivalent to 1 % of the stored CO_2. Assume the bigger amount among those two as the amount of seepage for 1,000 years after the project has ended and

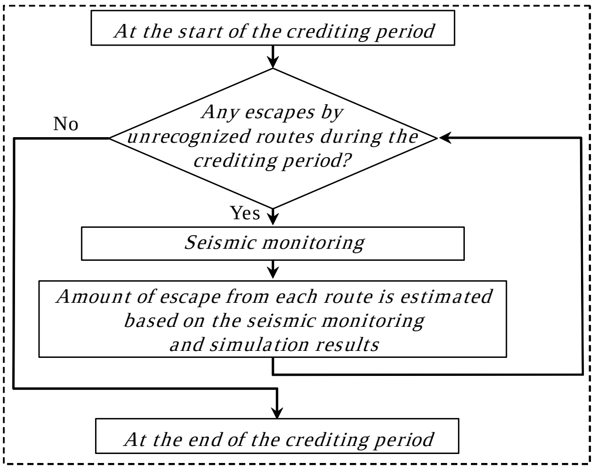

Figure 4-2 :Flow Chart to consider Escape

(Source) Proposed NMM for CCS in aquifers

Table 4-1 : Possible methodology to account long-term seepage

Option	Treatment of liability for non-permanency	Transferability	Disadvantage
Full crediting with one time insurance payment	Ignore long-term seepage risk.	High	Not conservative for accounting emission reduction. Acceptability of Climate community?
Discount	Future seepage is reflected to discount	High	Difficult to find appropriate discount rate (time frame is needed)
	Seepage is compensated at certain interval. A part of amount is permanent.	Possible	Period for verification is needed (a few centuries)

(Source)Introduction of accounting approaches for CDM, ARCS

deduct such amount from the emission reduction (from the amount of crediting that would be issued in the last crediting period). The 1 % may seem ad-hoc and controversial. However, it would be conservative value in well-selected sites. Apart from determination of this kind of number, which may need further discussion, this kind of approach that could be called discounting or set-side has an advantage to produce conservative estimation of emission reduction, which leads to extra emission reduction and would promote acceptability of climate mitigation community.

5. Others

Environmental impact assessment (EIA) is not included in the methodologies but included in PDD. EIA is based on regulations of the host country and outside the category of the Kyoto Protocol.

It is proposed that a new UN fund should be established, accumulate one part of credit of a CCS-CDM project, and prepare for the risk of climate change by future seepage of CO_2 from a reservoir. In general, an insurance system is appropriate to achieve a lower risk of each project.

6. Conclusion

As described in the IPCC SRCCS, CCS is extremely important as one of the probable options for global warming countermeasures. Especially, CDM which is carried forward together with the host country will be increasingly important from now on. At this workshop Experts from both CCS and CDM fields assembled to exchange opinions. It is important to develop mutual understanding through suchlike opportunities and to proceed with the implementation of CCS projects as CDM, using a bottom-up approach. We consider that such a process could solve various issues on proceeding with the implementation of CCS projects as CDM.

Annex: Submitted Methodologies

1. New Methodology CCS project activities which involve the storage of CO_2 in oil reservoirs

"Recovery of anthropogenic CO_2 from large industrial GHG emission sources and its storage in an oil reservoir"

(1) Baseline scenario

Continuation of current practices – CO_2 from the source is emitted/vented uncontrollably into the atmosphere

In the absence of the CDM registered CCS project, CO_2 generated by a source plant/factory is emitted/vented into the atmosphere. The total amount of CO_2 emitted by the source represents the anthropogenic baseline emissions for the project.

(2) Baseline emissions

Baseline emissions are equivalent to the amount of CO_2 gas emitted from the source. This is determined using the following formula:

$$G_A = G_1 \times G_2 \times R$$

Where:

G_A = Amount of CO_2 measured at monitoring point A [tCO_2/yr] (point A : refer to (3) project boundary)

G_1 = Amount of gas emissions [W gas] measured at monitoring point A [m^3Wgas/yr]

G_2 = Fraction of CO_2 in gas [m^3CO_2/m^3Wgas]

R = Density of CO_2 gas [tCO_2/m^3CO_2]

(3) Project boundary

Figure A-1 shows the physical delineation of the project boundary (area inside the double lined box):

The letters A - E represent major monitoring points.

A: CO_2 measured (metered) at a point soon after the stack

B: CO_2 measured (metered) after the compression and dehydration process

C: CO_2 measured (metered) at the injection well

D: CO_2 measured (metered) after separation from oil

E: The final amount of recycled CO_2 measured (metered) before reintroduction to the main CO_2 injection line

Those projects which do not have a production well (projects utilizing a spent oil reservoir as the storage structure), will only require equipment/machinery for CO_2 capture, compression, dehydration and injection. In this case, monitoring points D and E will not be applicable.

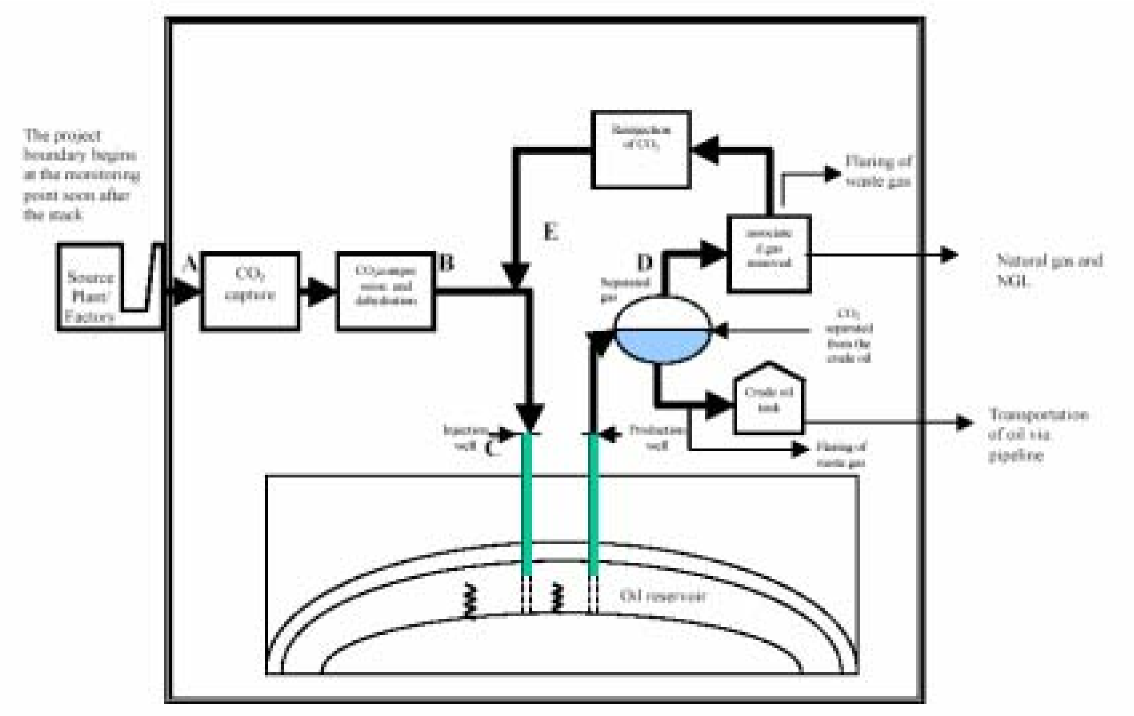

Figure A-1 : Physical delineation of the project boundary

(Source) Proposed NBM for EOR

(4) Project emissions

Project emissions will be determined to address the following:

a) CO_2 from the source which was lost (as fugitive emissions) during the capture, transfer or recycling processes

b) GHG from energy used by the project (both associated with fossil fuel and electricity)

c) Flaring/venting of CH_4 contained in waste gas derived from the CO_2 recycle plant

d) Seepage of the CO_2 during the project's lifetime after being stored (if required)

(5) Leakage

Some projects with a production well may recover a small amount of natural gas which is separated from the crude oil and waste gas. Although most projects will utilize this internally (as an energy source), some may choose to transport it to market. In such a case, emissions due to CH_4 (natural gas) escaping from the pipeline shall be calculated using data from regional estimates. If this data is not available, IPCC estimates of fugitive emissions from oil and natural gas activities can be used.

$$E_{pipe} = L_{pipe} \times F_{pipe}$$

Where:

E_{pipe}=Emissions from the natural gas pipeline [tCO_2/yr]

L_{pipe}=Length of natural gas pipeline [km]

F_{pipe}=Pipeline emission factor [tCO_2e/km]

(6) Emission reduction

Emission reductions

= baseline emissions

– {total emissions from the project activity

+ emissions due to leakage}

[tCO_2e/yr]

(7) Monitoring

The Monitoring Methodology requires the monitoring of the following items to determine whether significant release of stored CO_2 has occurred during the crediting period(s):

a) Time lapse 3D seismic data for updating the reservoir model

b) Vertical seismic profile of injection well(s) and (production well if applicable)

c) Amount of stored CO_2 is double checked by monitoring gas "bubble" using repeat seismic surveys (4D seismic)

d) Soil gas analysis or direct water analysis

Items a), b), c) and d) above are monitored to help determine whether seepage exceeds 0.7% of the total stored amount of CO_2, in a 7-year crediting period (1.0%/10-year crediting period).

The Monitoring Methodology also requires the monitoring of the following items to determine whether the project is still in accordance to applicability conditions and minimum standards (M.S.) stipulated in this new methodology:

1) Compliance to host country regulations for design, construction and maintenance of the well as well as to underground Injection Control regulation CFR 146.67(a).
2) Actual well (head) injection pressure to ensure that the maximum injection pressure is not exceeded
3) Temperature and pressure of the reservoir
4) Annular pressure
5) Tubing pressure
6) Map the location of sample points, location/number, etc.
7) Well abandonment carried out in strict compliance to regulations outlined in Appendix 1 of the Baseline Methodology.

The Monitoring Methodology requires the monitoring of the following items to determine baseline emissions:

The total amount of CO_2 measured at point A (see Figure A-1)

The Monitoring Methodology requires the monitoring of the following items to determine leakage:

Emission factor in regards to CH_4 escaping from the pipeline

2. New Methodology for the aquifers storage type project

"The capture of CO_2 from natural gas processing plants and liquefied natural gas (LNG) plants and its storage in underground aquifers or abandoned oil/gas reservoirs"

(1) Baseline scenario

The acid gas containing CO_2 is separated from the natural gas at the acid gas removal facilities of a natural gas processing plant or a LNG plant, and is emitted directly to the atmosphere or through the acid gas incinerators. CO_2 generated due to the operation of the acid gas incinerators is also emitted to the atmosphere. In case the regulations do not require any incinerator in the baseline scenario, the CO_2 associated with the operation of the incinerator is set as zero.

(2) Baseline emissions

The baseline emissions in a year "y" (CO_2_BASE y) are expressed as the summation of the direct emission of CO_2 contained in the acid gas separated in the acid gas removal facility (CO_2_EMIy) and the emission of CO_2 from combustion of the fuel gas in the operation of the acid gas incinerators (CO_2_INCy), if required by the regulation.

(3) Project boundary

Figure A-2 shows the project boundary (area inside the dot-lined box):

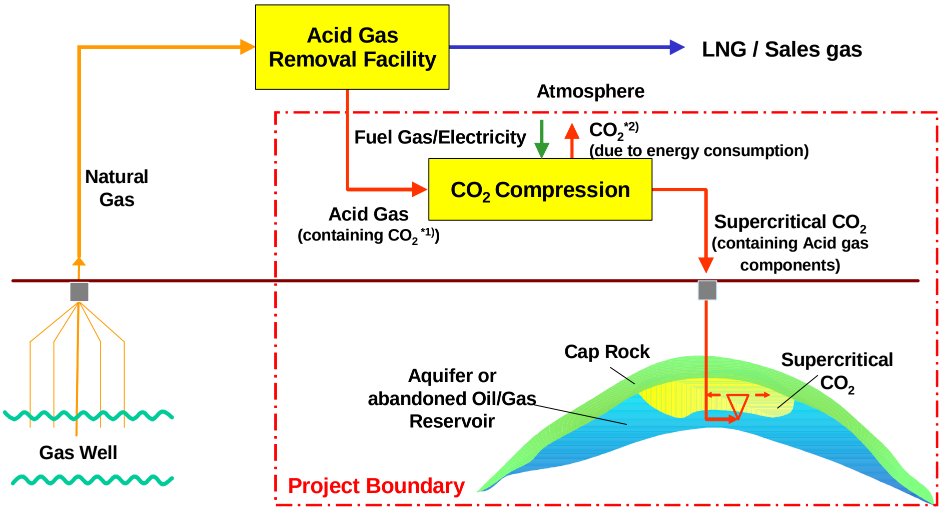

Figure A-2 : Diagram of the project boundary

(Source) Proposed NBM for CCS in aquifers

(4) Project emissions

a) CO_2 emissions from energy consumption:

CO_2 emissions from the project derive from the energy consumption required for the operation of related equipment during the compression, transport and injection of CO_2.

b) CO_2 escape from the pipelines and the injection wells:

Pressure changes will be monitored to detect any CO_2 escape from the pipelines and the injection wells. The possibility of escape from the pipelines and the injection wells can be reduced to substantially negligible levels by applying proper programs for quality assurance and quality control (QA/QC).

c) CO_2 escape from the reservoir:

Periodic 3D seismic surveys and other appropriate monitoring measures will be taken to monitor any escape from the reservoir. CO_2 injected into a well selected reservoir is expected to be retained safely and the possibility of escape is extremely small.

(5) Leakage

There is no leakage involved in this methodology.

(6) Emission reduction

1) The baseline emissions in a year "y" (CO_2_BASE y) are expressed as below.

$$CO_2\_BASE\ y = CO_2\_EMI\ y + CO_2\_INC\ y \quad [t\text{-}CO_2/y]$$

2) The project emissions in a year "y" (CO_2_PRJ y) are expressed as below.

$$CO_2\_PRJ\ y = CO_2\_PF\ y + CO_2\_PE\ y + CO_2\_ESCPI\ y + CO_2\_ESCRES\ y \quad [t\text{-}CO2/y]$$

Where:

CO_2_PF y = CO_2 emissions from fuel consumption

CO_2_PE y = CO_2 emissions from electricity consumption

CO_2_ESCPI y = CO_2 escape from the pipeline and injection well

CO_2_ESCRES y = CO_2 escape from the reservoir

3) The emission reductions ER "y" are calculated as below.

$$ER\ y = CO_2\_BASE\ y - CO_2\_PRJ\ y \quad [t\text{-}CO_2/y]$$

(7) Monitoring

The Monitoring Methodology requires the monitoring of the following items to determine emissions in the baseline scenario and the project scenario:

a) Injected CO_2

- The total amount of injected acid gas measured at the inlet of the pipeline.
- The concentration of CO_2 in the acid gas is measured at the inlet of the pipeline.

b) CO_2 emission from fuel/electricity consumption

- Fuel consumption due to the equipment installed for the project activity.
- Carbon number and molecular weight of the fuel gas.
- Electricity consumption by the equipment

installed for the project activity.

- Carbon emission factor of the electricity.

c) CO_2 escapes from the pipeline and the injection wells

- Pipeline pressure (both of the flow pressure and the static pressure at the inlet of the pipeline)
- Wellhead pressure (both of the flow pressure and the shut in pressure at the head of the wells)
- Annular pressure between the casing and the tubing of the injection wells
- Emission factor in regards to CO_2 escaping from the pipeline
- Emission in regards to CO_2 escaping from the injection wells

d) CO_2 escapes from the reservoir

- Three dimensional (3D) seismic survey
- Downhole monitoring (input data for the simulations)