CARBON DIOXIDE GEOLOGIC SEQUESTRATION – A SAFE AND ECONOMICALLY EMERGING TECHNOLOGY FOR SUSTAINABLE ENVIRONMENT

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ABSTRACT: Fossil fuel is main source of energy and responsible for one third of the total carbon dioxide (CO_2) emissions. Global energy demand has been raised significantly due to increase in population, rapid growth of economies, emerging technologies and industrial revolution. This increase shows no signs of slowing. Now, pressure has been raised on the developed nations to reduce the CO_2 emissions because the consequences of global climate change are potentially severe. Atmospheric CO_2 can be reduced by capturing emissions from power plants or chemical units and storing them into the underground rocks and aquifers. CO_2 separation, appropriate site selection, transportation, secure storage and afterward monitoring are the core processes in sequestration technology. Economy is one of the biggest challenges for deploying this technology whereas captured CO_2 can be utilized for Enhanced Oil Recovery (EOR), Enhanced Coal Bed Methane Recovery (ECBM) and Enhanced Gas Recovery (EGR) etc to overcome on this problem. Underground uncertainty related risk assessment and management can control the major considerations for CO_2 sequestration technology.

Key words: CO_2 Sequestration, Sustainable Development, Carbon Dioxide Emission, Climate Change.

INTRODUCTION

The effects of greenhouse gasses and global warming are a matter of real public concern (Nguyen, 2003). The concentration of carbon dioxide has increased since industrialization age and consensus shows that humanity has visible impact on the world's climate. In general, burning of fossil fuels accumulates greenhouse gases and trap more heat which eventually cause global warming. The extensive research shows that the global average temperatures have been increased at unprecedented rate since last three decades.

Carbon dioxide is the major contributor to global warming in the past century by mostly from deforestation and the burning of fossil fuels. Methane arises from coal deposits, leaks from natural gas pipelines and livestock rising is the second while Nitrous oxide is at third place as shown in (Modified from Sengul, 2006) Fig.1.

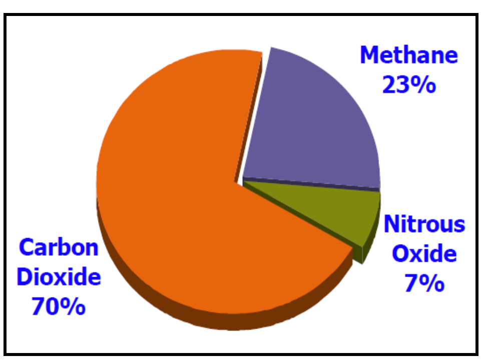

Figure 1: Three major contributor greenhouse gasses

Carbon dioxide (CO_2) sequestration is a process consisting of the separation of CO_2 from the emissions stream of fossil-fuel combustion, transporting it to a storage location and injecting it into the subsurface for its long-term isolation from the atmosphere. The developed economies and industrialized nations are critically dependent on fossil fuels which release carbon dioxide.

Impacts of Green House Gasses (GHG's) on Climate Change: Climate change can be beneficial as well as very dangerous for human health and socioeconomic systems. The extreme emissions scenarios have very harmful effects. The threats are particularly acute for poor and vulnerable communities in tropical and subtropical countries (IPCC, 2001).

Various major effects of climate change include:

a. More hot climatic conditions
b. Wider geographical range of tropical / subtropical diseases
c. Crop zones migration possibility for more volatile weather, e.g. increased flooding
d. Sea-level rise
e. Species extinction
f. Potential for the ocean's thermo-haline circulation belt to slow or shut down

While, few scientists claim that the climate change process is not the result of CO_2 emission. Further researches and discussions should be there to verify the validation of this postulation.

Purpose of Geologic Sequestration: The purpose of geologic sequestration is to develop practical considerations for reducing the magnitude of CO_2

emissions required to stabilize and reduce atmospheric concentrations of greenhouse gases (GHGs). It also provide enormous amount of potential storage capacity around the world. Following are the main purposes for geologic sequestration.

a. To protect human health and safety
b. To protect ecosystems
c. To protect underground portable water and other natural resources
d. To ensure public confidence through regulation clarity and proper GHG accounting.
e. To enhance the recovery of oil and gas.

Options for CO_2 Geological Storage: Terrestrial sequestration, geologic sequestration and chemical conversion are main options for CO_2 sequestration (Barne *et al*., 2009). On the other hand, following are the primary alternatives for CO_2 geological storage as shown in (Modified from Raza, 2009) Fig.2.

a. Depleted oil and gas reservoirs
b. Saline aquifers
c. Un-minable coal seams

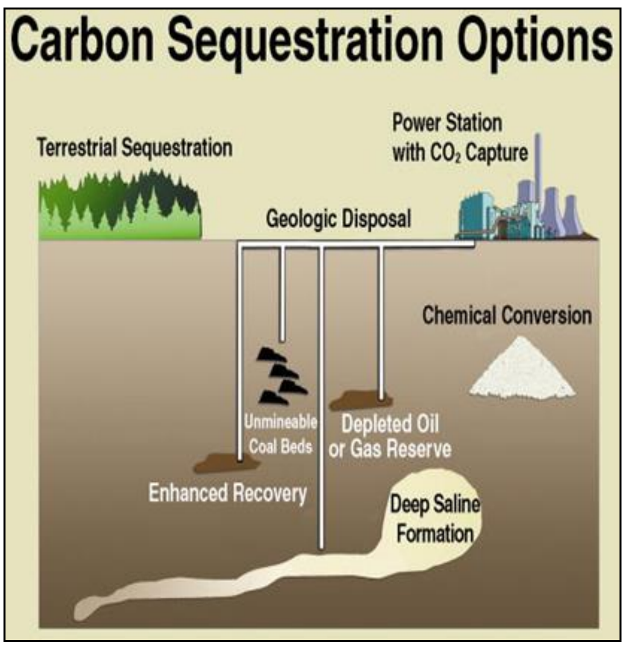

Figure 2: Main options for CO_2 Sequestration

Components of Geologic Sequestration: Although there are no specific criteria to break down the parts of this technology but the following are the main components.

Capturing of Co₂: Capture or separation of CO_2 from an emission stream requires compression to change it from gaseous to liquid or supercritical state. Mostly, 99% pure CO_2 can be captured, but lower concentrations are also acceptable. Capturing requires the specific quantity that can be transported easily (Herzog, 1999; 2001).

CO_2 can be captured by the following three methods.

a. Pre-combustion capture
b. Post-combustion capture
c. Oxy-firing capture

Transportation: It is the movement of CO_2 from its source of emission to the storage reservoir. It can be transported by truck, train and ship. Operational experience provides a base for the development of a CO_2 pipeline infrastructure (Nguyen, 2003). Global standards for CO_2 pipeline can be designed depending upon the regulatory practices.

Injection: Injection is the process of depositing CO_2 into the storage reservoir. The geological formations and aquifers are considered the main candidates for CO_2 storage. Commercial conversions of CO_2 is also possible but not on a large scale.

Monitoring: After injecting CO_2 into the subsurface reservoirs, the most crucial task is to monitor it. Although it is not toxic or flammable, it poses only a minimal health and safety risk (Heinrich *et al*., 2004). In monitoring process, many geophysical tools and techniques are used. Important among them are the time lapse 3D seismic monitoring, passive seismic monitoring, cross well imaging etc. On the other hand, simulation and modeling also guide us about the CO_2 flow in reservoir against the passage of time (Herzog, 2010).

Cost and Economics of Geologic Sequestration: CO_2 Sequestration is receiving significant attention from the universities and the media. However, the economic reality of the capital investment and commitment is necessary to move it from research to large-scale deployment. Using geologic sequestration for enhanced oil-gas recovery can be the primary driver for deployment of the projects on industrial scale.

Capturing Cost: The capturing cost is estimated from the CO_2 concentration in the fuel gas stream. The cost of CO_2 will be lower at concentrated CO_2 streams e.g., industrial plants (Dooley *et al*. 2006). The current expected cost for carbon capture at a coal-fueled power plant is approximately US dollars 25-65/t CO_2. The cost of the first project is considerably high due to equipment installation and decline thereafter as the technology advances.

Transportation and Infrastructure Cost: Natural gas pipeline is the good analogue for CO_2 transportation and analysis for transportation cost indicates that It can also be transported by truck, train and ship but cost of these transportation mode are relatively higher. That's why the existed pipeline infrastructure on depleted oil and gas reservoirs is the best suitable option for transportation (Nguyen, 2003). Moreover, geologic sequestration shows overall economic trend of storage among the other storage options as shown in (Metz *et al*., 2005) Table 1.

Table 1: Transportation and storage costs)

Component	Cost range (US$/t$CO_2$ transported or stored)
Transportation (per 250 km)	1 – 8
Geological Storage	0.5 – 8
Ocean Storage	5 – 30
Mineral Carbonation	50 – 100

Risk Assessment for CO_2 Sequestration: Captured CO_2 is less dense than water and tends to migrate from base to the top of the storage tank due to the force of buoyancy under its supercritical nature. It is expected that the CO_2 will leak to some extent due to high pressure and permeable nature of the porous rocks. It will also cause storage uncertainties in the geologic reservoirs. The decrease of injectivity over time and the early breakthrough of CO_2 due to the heterogeneity of the formation will affect injectivity, containment and sequestration process as shown in (CO_2 NET, 2004) Fig 3.

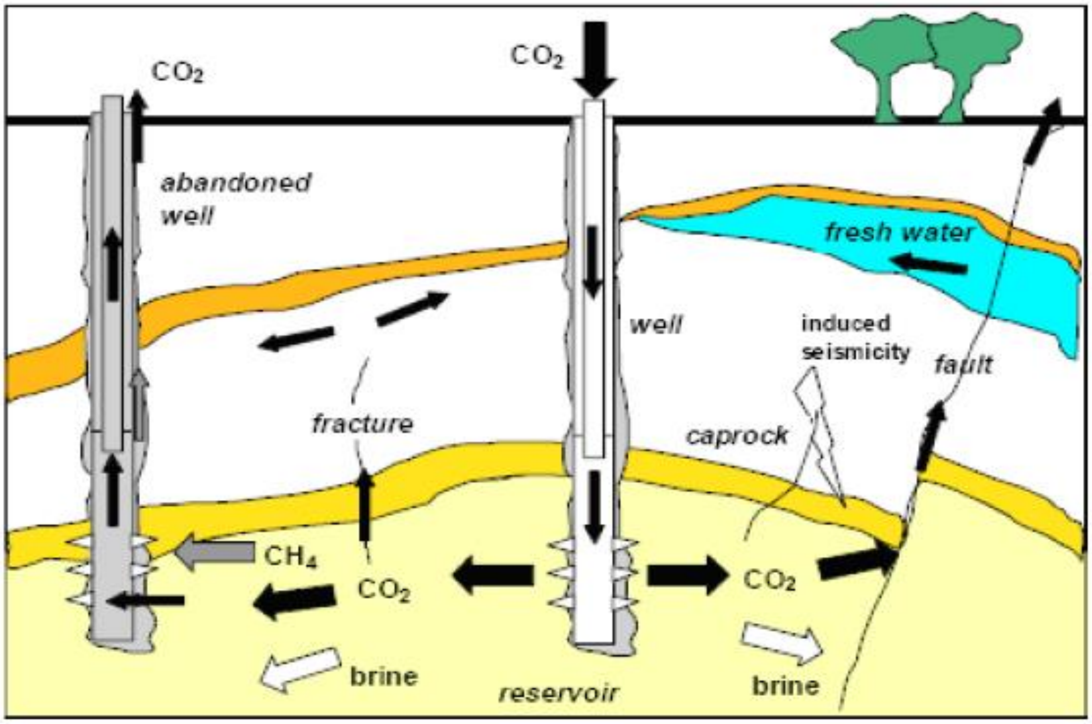

Figure 3: Risks of underground CO_2 storage

Global and Local Risks: The storage risks of CO_2 in geological reservoirs are divided into global and local categories. Global risks involve the release of CO_2 that may contribute to overall climate change and various hazards for humans, ecosystems and groundwater. Local risks are related to injection well failures and local undetected faults or fractures. Examples of local risks are as under:

a. Hydraulic fracturing
b. Capillary leakage
c. Shear deformation/fracturing
d. Fault-related flow
e. Pre-existing fissures and fractures
f. Tectonic failure
g. Corrosion
h. Wellbore Integrity

Risk Mitigation Methods: Mitigation methods of these risks include the following:

a. Proper site screening and preliminary studies
b. Geophysical monitoring from injection to post closure
c. Mechanical tools for well remediation
d. Reduce injection rate
e. Redistribute CO_2 injection in existing field
f. Use pressure relief wells
g. Develop an alternate CO_2 injection site

Performance Management and Risk Control: The ultimate goal of a performance management and risk control is to evaluate all the safety aspects for geological storage of GHGs over an extended period of time. The three main phases for performance, management and assessment are shown in (Schlumberger, 2012) Fig. 4.

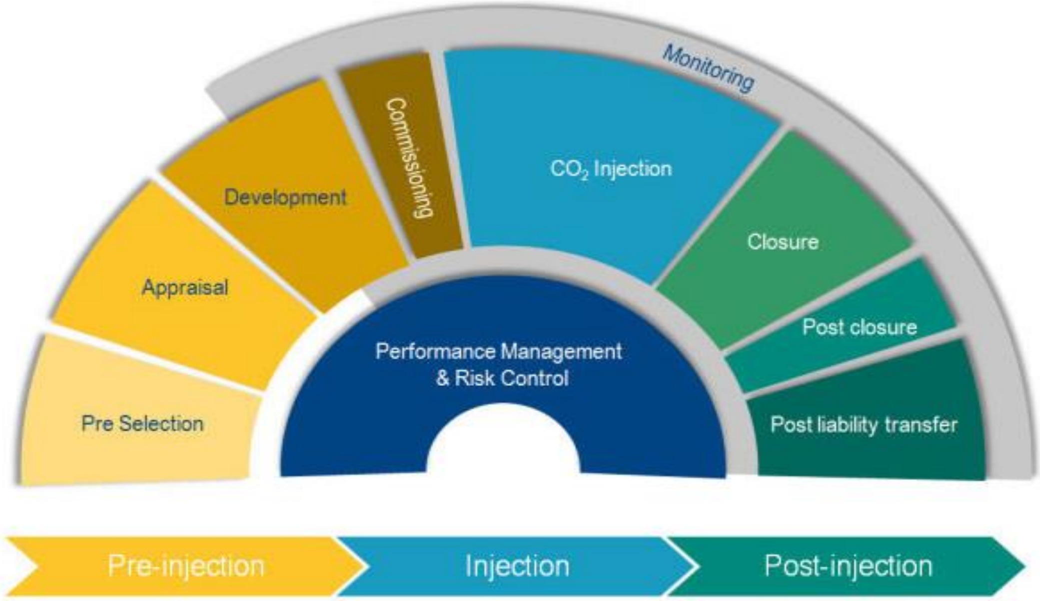

Figure 4: Work Flow for performance management and risk control in CO_2 Sequestration

Pre-Injection Phase: It includes all processes that are essential for effective storage before the CO_2 injection. Site screening, characterizations, appraisal and commissioning are the major aspects.

Injection phase: It is the second performance assessment phase in which CO_2 is injected into the underground storage reservoir. Capturing and transportation are the typical processes included in injection phase.

Post-injection phase: Several monitoring tools (especially geophysical tools) are used for assessing the performance of these sequestration projects from well plugging and abandonment to over a long period of time.

Monitoring, Measurement, and Verification (MMV): Effective MMV basically relies on initial parameters of site characterizations before injection. Monitoring also plays a key role during injection and post injection phases for safe CCS. Thus, various surveys should be conducted for each monitoring parameter. Three major approaches of MMV for CO_2 sequestration are organized into following manner.

a) Careful monitoring of surface and near-surface aquifers for leak detection and its remediation
b) Construction of dynamic reservoir simulation model
c) Measuring the CO_2 amount within the formation after specific time domain by using both direct and remote sensing methods

Conclusions

1. Global energy demand and more dependence on fossil fuel gives rise to large amount of GHG's which are the main cause of global warming
2. Global warming has severe impact on human and environments which offers obstacles in sustainable development of the environments.
3. Geologic sequestration is a promising technique that can make a large contribution for environmental CO_2 reduction.
4. Economic and security aspects of CO_2 sequestration are the two main hurdles for its operation.
5. The cost and economic problem can be solved by the cooperation of the petroleum industry. Because, it has both experience and infrastructure of CO_2 injection in reservoirs for taking enhanced oil-gas recovery.
6. MMV (Monitoring, Measurement, and Verification), site initial screening, appraisal, piloting, and modeling are important tools for controlling the risks of any sequestration project.
7. Much has been discussed but less to be practiced for CO_2 sequestration. It is the need of the time to put into practice than the discussion only.

Recommendations: The general purpose of this section is to recommend relevant actions that can contribute to cost effectiveness and safe deploying of sequestration technology. Progress will require series of demonstration projects worldwide to diminish the environmental concerns and eventually result will be in sustainable development for the coming generations. Furthermore to

1. Create awareness among the various nations of the world
2. Develop global approach and consensus
3. Reduce the global tension
4. Carry out more R&D to make it cost effective

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