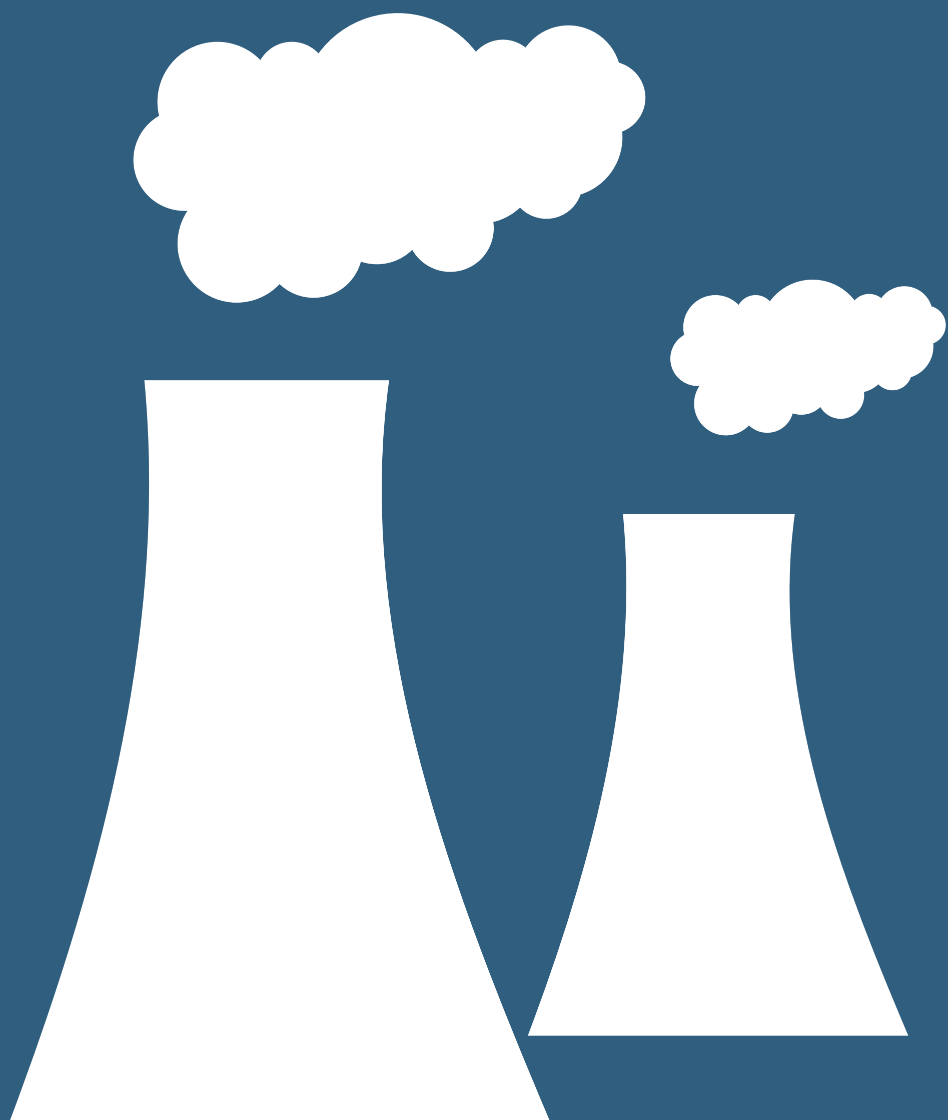
Comprehensive Report on CCS at Power plants



POWER PLANT CCS

The comprehensive report on Carbon Capture and Storage (CCS) at Power plants is a detailed report on various aspects of carbon capture and its sequestration. This preview provides inputs on focus areas of the report, the complete list of contents and a brief on sample topic from each chapter of the report.

The comprehensive report on Carbon Capture and Storage (CCS) was last updated in the 2nd week of December 2010 and has 340 pages.

Main List of Contents

Chapter wise list of contents and sample data

Chapter 1: Introduction to CCS

This chapter provides a detailed description about the basic concepts on carbon capture and sequestration, the importance of CCS in the context of climate change and emission reduction goals. The section on “The Future of Coal” provides a detailed description on how coal is inevitable to achieve energy security and address the problem of energy demands arising in the future.

Coal alone accounts for 40% of the total electricity generated in the world and combustion of fossil fuels like coal, oil and natural gas releases CO_2 in the atmosphere that is contributing to the climate change. It is now generally accepted that there needs to be some cap on the amount of CO_2, in general greenhouse gases, emitted to prevent any further damage to the environment. Scientists, researchers and industrialists rely largely on the carbon capture and storage techniques to prevent the building up of CO_2 in the atmosphere. CCS is a strategy that can be used to buy time until CO_2-free energy solution is developed.

World's Total Electricity Generation (in Billion kilowatthours)		
Country	**Total Generation (in Billion kilowatthours)**	**Coal Fired Generation (in Billion kilowatthours)**
USA	4139	2017
China	3041	2422
Japan	1063	328
Russia	959	221
India	762	542
Canada	621	115
Brazil	439	6
South Korea	402	173
Australia/New Zealand	282	199
Mexico	244	45
World	**18783**	**7923**

Source: EIA, International Energy Statistics database

CCS techniques consists of series of steps involved in capturing, transporting and storing CO_2 with the main aim of limiting greenhouse gases emissions in the atmosphere. CCS has gained importance in recent times due to the efforts of world community to make the world greener by making fossil fuels sustainable, in addition to moving to renewable energy space. CCS is the means of mitigating the contribution of fossil fuels to global warming, based on capturing CO_2 from major sources like large power plants and storing it in such a way that is environment friendly. According to International Energy Agency, the crucial part to reduce greenhouse gas emissions in the atmosphere is to use CCS technologies in industries. CCS is a promising emission reduction option with environmental, economic and energy security benefits.

This chapter comprises the following sections and sub-sections:

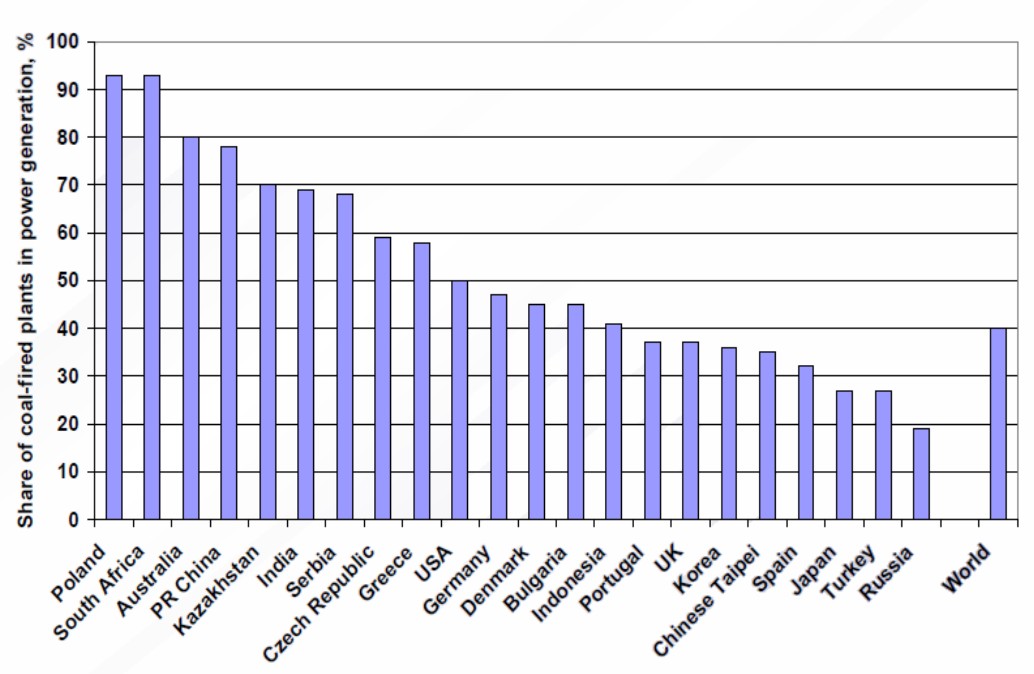
Sample Topic

The Role of Coal in Electricity Generation and Carbon Emissions

On an average, coal-fired power plants currently contribute to 40% of world's electricity generation and this varies from one country to another. In countries like Poland and South Africa, coal is the only source of electricity generation, where coal alone contributes to over 90% of electricity generated. While in developed countries like USA, UK and Germany, around half of the electricity generated is from coal.

CO_2 emissions come from majorly three sources. Thermal power plants using coal as the raw material is by far the largest emitter of CO_2. Coal's share of world carbon dioxide emissions grew from 39 percent in 1990 to 42 percent in 2006 and is projected to increase to 45 percent in 2030. Coal is the most carbon-intensive of the fossil fuels, and it is the fastest-growing carbon-emitting energy source in the *IEO2009* reference case projection, reflecting its important role in the energy mix of non-OECD countries—especially, China and India. In 1990, China and India together accounted for 13 percent of world carbon dioxide emissions; in 2006 their combined share had risen to 25 percent, largely because of strong economic growth and increasing use of coal to provide energy for that growth. In 2030, carbon dioxide emissions from China and India combined are projected to account for 34 percent of total world emissions, with China alone responsible for 29 percent of the world total.

Percentage share of coal in electricity generation across countries, 2007



Source: IEA statistics

Chapter 2: Conventional CCS technologies

This chapter provides a detailed description of the existing technologies or practices that is currently in use related to carbon capture and storage. The advantages and disadvantages of each of the conventional carbon capture technologies are discussed in detail. A sub-section on the case studies focuses on the companies that are using each of the conventional CCS technologies for capturing carbon. The cost involved in capturing, transporting and storing CO_2 is discussed under relevant sections.

Carbon capture and storage technologies can be classified into conventional and emerging based on the stage of development of each of these technologies. The three types of conventional carbon capturing technologies are pre-combustion, post-combustion and oxyfuel method. In the pre-combustion method, the carbon content in the fossil fuel is removed even before the combustion process starts, while in the post combustion method, the CO_2 is separated from the flue gas stream post the combustion process. The captured CO_2 is transported to the specific storage sites through ships, pipelines or tankers. The prominent modes of transporting CO_2 which are in use currently are pipeline based and ship based transportation. The captured CO_2 is stored in geological formations like deep saline formations, underground rocks, depleted oil and gas fields which are currently in practice.

HIGHLIGHTS

According to a recent estimate of US department of energy, the storage potential for CO_2 in the whole of USA and parts of Canada is anywhere between 1,800 to 20,000 billion metric tons, and in terms of time period it translates into 5,700 years of storage potential in the geological formations of these regions. Given this, the potential for CO_2 storage in geological formations worldwide is enormous.

This chapter comprises the following sections and sub-sections:

Sample Topic

Conventional CO_2 Storage

If our energy system is to continue to rely on fossil fuels, almost all the carbon captured from combustion of fossil fuels has to be stored to prevent it from entering the atmosphere again. This means that we could conceivably require permanent storage capacity for the over 6,000 GtC (Giga tonne of Carbon) in the estimated fossil fuel resource base. A carbon sink is a term used for a medium in which carbon is currently stored or potentially can be stored. The three major sinks identified for carbon sequestration are surface storage, ocean storage and geological storage. Geological storage is the only implementable option right now. Mineral sequestration and ocean sequestration are also being considered for possible future storage of CO_2. Another possible method of storage being researched today involves making products from CO_2 that can store the captured carbon for long periods of time.

Potentially, huge quantities of CO_2 could be stored in several types of formation. The most important of these and their estimated storage potential are:

Global Capacity of Sequestration Sites

Sequestration Sites	Capacity (in Giga tonnes of CO_2)
Oil and Gas Reservoirs	100-1000 Gt
Deep saline aquifers	100s-10000 Gt
Coal seams	10-100 Gt

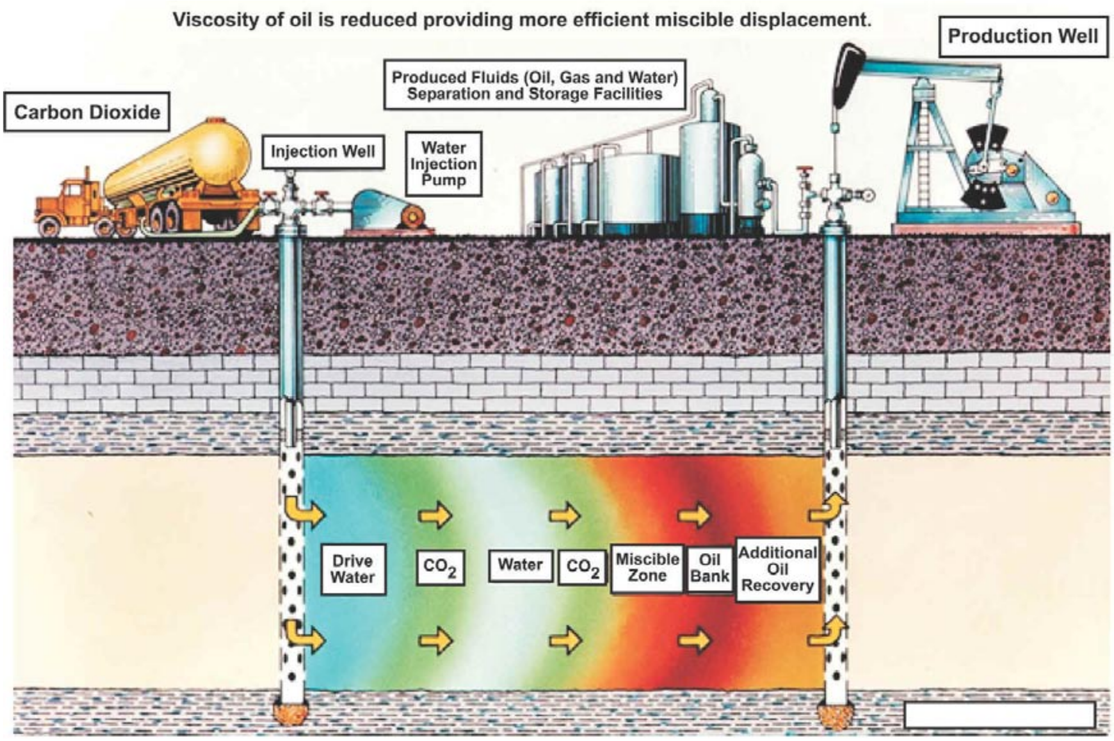
Source: IEA report on"The Prospects for CO2 Capture and Storage"

Geological storage has emerged as a leading candidate because of the potential widespread availability of these storage sites and their ability to handle large quantities of CO_2. Currently, three geologic storage options emerge as most feasible: enhanced oil recovery (EOR) in depleted oil & gas fields, deep saline formations, and un-minable coal seams. Other promising candidates may exist onshore or offshore, but in every case CO_2 is injected into deep subsurface geologic formations.

HIGHLIGHTS

In a recent development, as a boost to geological storage practices, Washington State's department of energy (DOE) has granted a permit for the world's first pilot study of carbon capture and sequestration in basaltic rocks. This initiative is one of several CCS projects partly funded by the DOE with a grant from the Obama administration under the Recovery Act.

A schematic representation of enhanced oil recovery operations through injection of CO_2



Source: National Energy Technology Laboratory, Department of Energy, USA

Chapter 3: Emerging CCS Technologies

In the quest for more energy efficient and cost effective methods for sequestering CO_2, new technologies are being investigated. Though the conventional carbon capture and storage technologies are in practice today, these methods have its own disadvantages in terms of more fuel consumption and less energy efficient. This chapter starts with the current status of emerging technologies related to CCS and provides a detailed description of the various emerging carbon capture and storage technologies that are in different stages of development. Among the emerging CCS technologies that are gaining the attention of researchers and scientists worldwide is 'Algae based CO_2 capture'. A section on 'CCS using Algae' provides a detailed description of the process, its advantages and disadvantages and the cost analysis along with the current status of algae based CO_2 capture projects across the globe.

Some of the CO_2 storing technologies which are in various stages of development are mineral and ocean sequestration. Another promising CCS technology is using algae for capturing and storing CO_2. Physical and chemical absorption are considered to be emerging carbon capturing technique apart from membrane and enzyme based systems which are in their early stages of development. Apart from storing CO_2 in geological sites, the CO_2 captured can be used for manufacturing useful products like urea, methanol, ethanol, biochar and industrial chemicals like acetic and formic acid.

HIGHLIGHTS

In a recent development, a California-based company Calera has got a patent for a technology that claims to manufacture cement from CO_2. They claim 1 ton of cement captures ½ ton of CO_2. Calera's process is versatile and can be economically employed to capture CO_2 from power plants across the globe and convert it into cement, which can meet the demands of construction industry apart from removing CO_2 from the atmosphere.

This chapter consists of the following sections and sub-sections:

Sample Topic

Emerging Technologies in CO_2 Storage

The world community is looking for new options to store the CO_2 captured from various industrial sources as an effective way to prevent the accumulation of CO_2 in the atmosphere. The two of the emerging technologies that are in various stages of its development are mineral sequestration and ocean storage.

Mineral sequestration aims to trap carbon in the form of carbonate salts. The basic idea of carbon dioxide mineral sequestration is to transform minerals (mostly calcium or magnesium silicates) with CO_2 to (Ca or Mg) carbonates. Mineral sequestration involves reaction of CO_2 with common mineral silicates to form geologically stable carbonates like magnesite or calcite is known as mineral carbonation. This reaction that converts naturally occurring minerals to geologically stable minerals and silica is exothermic and hence thermodynamically favoured. The most promising feedstock minerals are olivine, serpentine and wollastonite. The overall reactions for these minerals are shown below:

Olivine: $Mg_2SiO_4 + CO_2 \rightarrow MgCO_3 + SiO_2$ $\Delta H = -89$ kJ/mol (Eq. 1)

Serpentine: $Mg_3Si_2O_5(OH)_4 + 3CO_2 \rightarrow 3MgCO_3 + 2SiO_2 + 2H_2O$ $\Delta H = -64$ kJ/mol (Eq. 2)

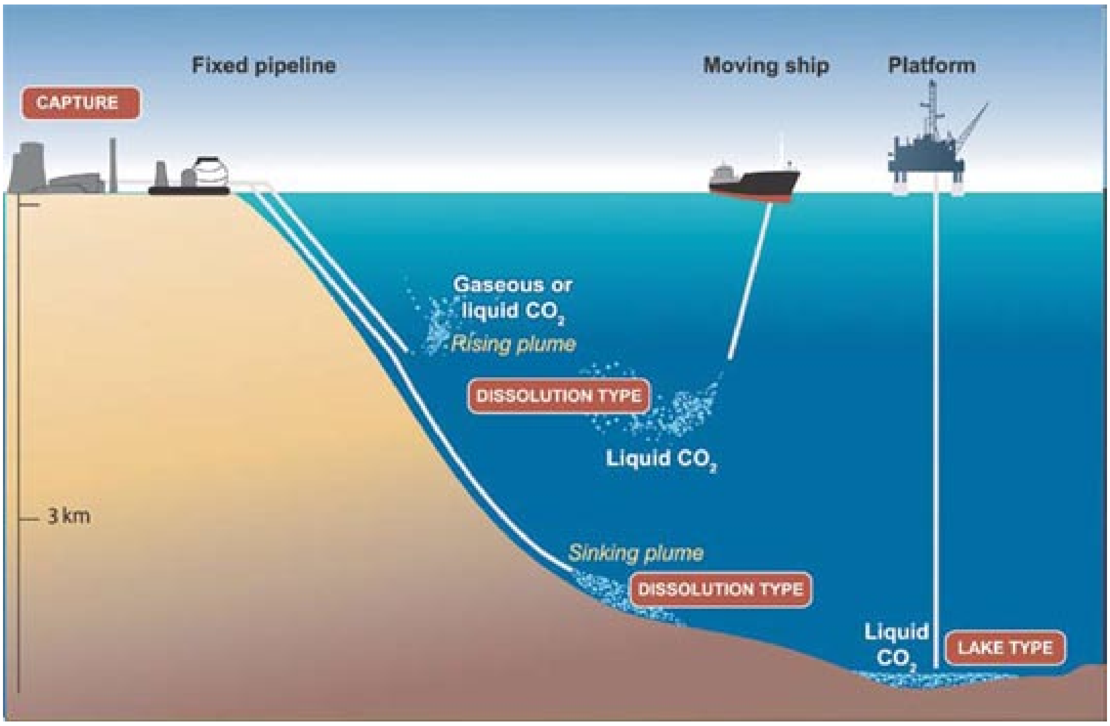
Wollastonite: $CaSiO_3 + CO_2 \rightarrow CaCO_3 + SiO_2$ (Eq. 3)

Eq. 1 illustrates the conversion of naturally occurring mineral olivine to magnesium carbonate and silica. In this case, one ton of olivine can dispose of approximately two-third a ton of CO_2. Eq. 2 shows how serpentine is transformed to magnesium carbonate along with water and silica on reacting with CO_2. Here, one ton of serpentine can dispose of ½ ton of CO_2.

Some of the advantages of mineral sequestration are:

1. Raw materials like magnesium based minerals are in abundant,
2. The overall reaction is exothermic and hence economically viable
3. Possibility of re-release of CO_2 is minimal.

A schematic diagram of ocean storage of CO_2



Chapter 4: Legal Aspects of CCS

The other chapters of this report deal with the technical aspects of CCS technologies. The study on CCS is not complete without understanding the legal and regulatory framework surrounding the carbon capture and storage activities. The legal issues affecting the CCS development at international level are United Nations Framework Convention on Climate Change (UNFCCC) and International maritime environment protection instruments such as UNCLOS, the London convention followed by London protocol and the OSPAR convention. This chapter discusses about the key aspects of various international legal and regulatory frameworks to protect the environment and its relevance to carbon capture and storage activities. The onshore storage activities are governed by the concerned countries local laws which may vary from one country to another. A separate section on 'Domestic Legal Framework' deals with this aspect.

The international legal framework is relevant only to offshore storage while the national/local legal framework covers the onshore storage aspects. Having said this, any activity by one state that has an adverse impact on other territory will be governed by international laws. The onshore CCS activities are governed by domestic legal framework and vary from one country to another which has been discussed for few countries like USA, UK, Canada and Japan. This chapter also talks about the status of CCS inclusion in clean development mechanism (CDM). Under CDM, a country with emission reduction commitment shall implement emission reduction projects in developing countries. Thereby, they are entitled to certified emission reduction (CER) credits, each equivalent to one tonne of CO_2, which can be counted under Kyoto protocol as emission reduction target. The question of including CCS related activities under CDM was first raised in the Conference of Parties (COP) to the UNFCCC held in Montreal, Canada and discussions are still on whether to make CCS a part of CDM.

HIGHLIGHTS

In the recently concluded UN climate conference in Cancun, an agreement has been reached to set up a $100 billion "Green Fund" to fight global warming. According to the deal, every year $100 billion are expected to be mobilised until 2020 to fund the projects in developing nations for adaptation and mitigation purposes. In this background the inclusion of CCS activities in CDM has gained importance.

This chapter consists of the following sections and sub-sections:

Sample Topic

London convention and protocol

The international legal framework is relevant to offshore carbon storage activities. The main international frameworks relevant to storage of CO_2 are laws of the sea (UNCLOS), the marine environment protection framework and the climate change framework. Some of the legal instruments relevant to marine environment protection are London convention, London protocol followed by its amendment and the convention for the protection of the marine environment of the north-east Atlantic, which is widely known as OSPAR convention that covers a specific area of the ocean.

The London convention framework comprises of London convention itself and its 1996 protocol (known as London Protocol). The London convention is the oldest convention to protect the marine environment from human activities. The relevance of London convention to CO_2 storage is limited to storage from aircrafts and vessels and platforms. Hence, it doesn't apply to storage in ocean seabed or its sub-soil or from a land based pipeline. On the contrary, the London protocol of 1996 is more relevant to CO_2 storage and this protocol came into effect in 2006. The objective of London protocol is to protect and preserve the marine environment from all sources of pollution. In addition, it demands to take effective measures to prevent pollution caused by dumping or incineration of wastes or other matters at sea.

The amendment to the London protocol in 2006 allows the storage of CO_2 in the rocks below the sea. This removes the legal hurdle for many large scale CCS projects that aim at storing GHG in geological formations under the ocean. The 1996 protocol prohibits the dumping of wastes in the ocean, except for material listed under the "reverse list" in the annex 1 of the protocol. CO_2 was not included in the reserve list. Subsequently, the London protocol was amended in 2006 and CO_2 was added to the annex 1, thereby allowing the storage of CO_2 in ocean geological formations.

The UNFCCC creates a structure for intergovernmental efforts to tackle the challenge posed by climate change. The main objective of this convention is to stabilise the concentrations of GHG in the atmosphere at a level that would negate anthropogenic interference with the climate system that is contributing to the climate change. This would definitely require a drastic reduction in GHG emissions.

Chapter 5: Key Industry Players

This chapter talks about the key industry players who are involved in the development of CCS technologies. The companies dealt in this section are classified under four heads-energy companies, technology developers, engineering & manufacturing firms and Oilfield services companies. RTI international, Siemens Power Generation, Praxair Inc, Air products and chemicals are few companies that are discussed in this section. The technologies related to carbon capture that are discussed in this chapter are in various stages of development and the feasibility of adopting these in commercial scale are yet to be gauged.

A brief about the company and their activities are discussed. Recent projects undertaken by each of the companies relevant to carbon capture and storage activities have been elaborated in detail in this section.

This chapter has the following sections and sub-sections:

Sample Topic

Company Profile

Schlumberger Limited (Schlumberger) is a supplier of technology, integrated project management and information solutions to customers working in the oil and gas industry. The Company operates in two business segments: Schlumberger Oilfield Services and WesternGeco. The Schlumberger Oilfield Services provides range of products and services from exploration to production. WesternGeco is an advanced surface seismic acquisition and processing company. In March 2010, the Company acquired Geoservices, a French oilfield services company.

Technology

EverCRETE CO_2-Resistant Cement

EverCRETE CO_2-resistant cement-the latest wellbore isolation technology for CO_2 geological storage—provides an enduring solution for zonal isolation during injection, storage and monitoring, and after abandonment. This technology can be applied for carbon capture and storage, as well as CO_2 enhanced oil recovery projects.

When CO_2 is stored underground, it has the potential to become highly corrosive to existing oilfield cements, compromising the integrity of the well. Such damage to the cement sheath would allow CO_2 to leak out of the reservoir and return to the atmosphere. This leads to economic loss and reduction of CO_2 injection/storage efficiency.

Based on existing CemCRETE technology, EverCRETE cement has proven highly resistant to CO_2 attack in the most extreme laboratory conditions, including wet supercritical CO_2 and water saturated with CO_2 environments under downhole conditions. The EverCRETE system reduces the risk of CO_2 induced degradation of the cement sheath that could lead to leakage. It can be incorporated into standard primary cementing operations for zonal isolation of new CO_2 injection wells. EverCRETE CO_2-resistant cement can also be used to plug and abandon existing wells drilled through the storage zone to reestablish long-term well integrity.

CCS Involvement and Projects

1. *Schlumberger will manage the storage for the Midwest Geological Sequestration Consortium, recently awarded a contract by the US DOE for the CCS project in Decatur, Illinois.*

   The project involves storing around 1 million tons of CO_2 from an ethanol plant in a saline formation. Schlumberger carbon services will manage the complete design, construction, and operation of the storage portion of this project, using its oilfield subsurface evaluation and integrated project management solutions.

   The Illinois State geological survey and Archer Daniels Midland are also major partners. The CO_2 will be captured from an Archer Daniels Midland ethanol plant and injected into the Mount Simon formation, a geological structure spanning the states of Illinois, Kentucky, Indiana, and Ohio, over a period of three years.

   The project is designed to test and demonstrate the ability of a geological formation to safely, permanently, and economically store considerable amounts of CO_2. It will help to form design and safety regulations for future CCS projects. Schlumberger carbon services were the only oil and gas related company selected as a project partner.

   Among the Schlumberger services proposed are:

   Q technology for simultaneous acquisition of surface and borehole seismic data to be used before, during, and after the injection phases to sharply image the fluid movement in the reservoir CO_2-resistant cements for long-term hydraulic wellbore isolation during the injection phase and after decommissioning of the site.

   Petrel and ECLIPSE software packages to model and simulate scenarios to understand CO_2 injection behavior, migration over time, reservoir integrity, and associated risks.

   Data & Consulting Services providing geotechnical support in the evaluation of existing data, strategies for new data acquisition, and ongoing interpretation.

2. *Alstom and Schlumberger have signed an agreement for mutual collaboration in the joint offering of CCS-ready studies.*

The studies will consist of a technical analysis of a power plant to identify how it should be adapted to accommodate an Alstom CCS system. The studies will also include an evaluation of potential CO_2 storage sites for the power plant, as well as an evaluation of required investments for future CO_2 transport and storage.

This is designed to facilitate the future conversion of power plants to CCS and the securing of environmental permits as well as optimizing time-to-market periods and associated costs.

The first wave of large-scale CCS demonstration projects, such as AEP's Mountaineer in the United States or Vattenfall's Schwarze Pumpe in Germany, also requires an integrated approach along the value chain. This agreement is designed to offer this type of comprehensive service, both for new and existing power plants.

Chapter 6: Research & Development Projects in CCS Technologies

Realising the importance of CCS in dealing with climate change, there has been a lot of interest in the subject matter of carbon capture and storage. As a result there are lot of research happening in this emerging field of study. Organizations both at national and international levels are contributing towards this study. This chapter discusses in detail about the various projects relating to CCS activities undertaken by national and international organizations. Carbon Sequestration Leadership Forum (CSLF) is one such initiative that is focused on the development of cost effective carbon capture and storage technologies to make it commercial and viable. The International Energy Agency (IEA) is an intergovernmental organization that acts as energy advisors to its member countries to ensure reliable and clean energy for their citizens. IEA GHG is the leading international collaborative programme on technologies for reducing GHG emissions from use of fossil fuels. IEA is involved in a number of collaborative efforts with industry players and governments in developing an affordable CCS technology.

This chapter has the following sections and sub-sections:

Sample Topic

6.3 Canada

There has been interest in the implementation of components of zero emissions technology (CO_2 capture, storage and utilization) for some time in Canada. At the first conference organized by the IEA greenhouse gas programme on CO_2 capture and storage in Oxford, UK in 1993, Canadians gave papers on, among other topics, amine capture, membrane separation and calcium carbonate formation. Canadian activities prior to that time included pilot projects on CO_2 enhanced oil recovery. A western Canadian information network was also in existence, bringing together interested players and exchanging information on CO_2 capture, storage and utilization technologies.

Since negotiation of the 1997 Kyoto protocol, Canada has been working towards its ratification. The target is to reduce annual greenhouse gas emissions to a level of -6% by 2008-2012 relative to the 1990 level, which is estimated to have been the equivalent of 601 Mega tonnes (Mt) of CO_2. In early 1998, the Canadian federal, provincial and territorial ministers of energy and environment initiated work on a national climate change strategy with a mandate to develop a plan to meet the Kyoto protocol target. This in turn prompted the formation of a national initiative on CO_2 capture and storage at a meeting held in Regina (Saskatchewan) in March 1998, with subsequent gatherings in 1999 in Calgary (Alberta), Halifax (Nova Scotia) and once again in Regina.

Suitability of Canada's Sedimentary Basins for CO_2 Sequestration

Sedimentary basins have various degrees of suitability for CO_2 sequestration in geological media as a result of different conditions and geological, hydro-geological and geothermal characteristics. The purpose of the project is to identify on a continental-scale the suitability of approximately 70 sedimentary basins in Canada for CO_2 sequestration in geological media. On a regional scale, the suitability for CO_2 sequestration of the Alberta basin and of the Canadian part of the Williston basin (shared with the US) is being assessed.

The study of the Alberta portion was completed in 2000 and that of Williston basin was completed in December 2002.

The Canadian government funded $270,000 for the operating expenditures and a matching amount from the Alberta province government for manpower through the Alberta Energy and Utilities Board.

Sequestration of Carbon Dioxide in Alberta's Oil and Gas Reservoirs

Alberta currently has approximately 26,000 gas pools and more than 8,500 oil pools in various stages of production and depletion. The ultimate capacity for CO_2 sequestration in these pools has been estimated using the Alberta Energy and Utilities Board reserves database. Results to date indicate that the ultimate CO_2-sequestration capacity in Alberta's gas reservoirs not associated with oil pools is 9.8 Gt (Giga tonne) CO_2. The sequestration capacity in the gas cap of approximately 5,000 oil reservoirs is 2.2 Gt CO_2. In contrast, the sequestration capacity in depleted oil pools is only 637 Mt CO_2. Of the more than 8,500 oil pools in Alberta, 4,273 reservoirs were identified as suitable for CO_2-flood EOR. Estimates of the incremental CO_2-sequestration capacity in these reservoirs at CO_2 breakthrough and at 25% and 50% hydrocarbon pore volume (HCPV) of injected CO_2 indicate that an additional 117, 360 or 673 Mt CO_2, respectively, would be sequestered through CO_2-flood EOR.

The objective of the last stage (last year) of the project is to develop and apply reservoir ranking methodology that will consider such elements as reservoir characteristics, CO_2 capacity, injectivity, depth, distance from CO_2 sources and timing, in order to identify the hydrocarbon reservoirs that should be considered first in the implementation of large-scale CO_2 sequestration in oil and gas reservoirs in Alberta.

The duration of the project was three years from April 2000 to March 2003. The project was funded by Alberta energy research institute for operating expenditures and Alberta energy and utilities board for the manpower.

Sample list of figures

Total Number of Figures and Charts in this report: 60 (approximately, subject to change due to revisions)

Sample list of tables

Total Number of Tables in this report: 35 (approximately, subject to change due to revisions)

Sample list of references

1. International Energy Agency-www.iea.org
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ABOUT US

PowerPlantCCS is a leading information and intelligence support resource for the innovations and novel ideas being attempted for CO_2 sequestration at power plants.

Within mainstream concepts, there are a number of innovations being explored. Outside of these mainstream avenues, there are novel processes and technologies being tried out. PowerPlantCCS is focussed on providing inputs and insights on these innovations - within and outside the mainstream routes.

The PowerPlantCCS team works out of Chennai, India. It is part of Clixoo (www.clixoo.com), a company with a focus on providing sustainability support.

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