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Carbon Capture and Sequestration

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Report Abstract
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INTRODUCTION

Carbon dioxide (CO_2) is a colourless, normally odourless, non-toxic, non-flammable gas. It is released into the atmosphere and within the oceans naturally as part of the Earth's carbon cycle by a range of mechanisms including plant and animal respiration, organic matter decay, and volcanic activity. The atmospheric volumetric concentration of CO_2 is now approaching 0.04 percent or 400 ppm. The gas is also emitted through human activities such as the burning of fossil fuels.

CO_2 emissions from the combustion of fossil fuels reached a record 31.2 billion tons in 2011 according to estimates of the International Energy Agency (IEA). Large point sources of carbon dioxide include large fossil fuel or biomass energy facilities, major CO_2-emitting industries (such as cement production), natural gas production, synthetic fuel plants and fossil fuel-based hydrogen production plants. Power plants, heavy industries and refineries are the largest emitters of CO_2, accounting for approximately half of global anthropogenic emissions, (i.e., approximately 15 billion tons of CO_2 per year).

CO_2 capture and sequestration (CCS) is an essential part of the global efforts to regulate GHG emissions and avoid dangerous shifts in climate change. CCS is defined as an integrated system of technologies comprising three key stages:

1. **Capture:** the separation of CO_2 from the mixture of gases generated at (typically large) fixed point sources, such as power and industrial plants.
2. **Transport:** Once separated, CO_2 is compressed and transported in a liquefied state typically by pipeline to the site where it will be stored.
3. **Storage:** At its storage place, CO_2 is injected into deep underground reservoirs that contain fluids for long period of time.

According to the IEA, 50 percent of the long-term potential for CO_2 emissions reduction with CCS lies in the power generation, 30 percent in hydrogen production, 15 percent in heavy industries and five percent in natural gas processing.

CO_2 CAPTURE

There are four main capture routes: three for power and industrial plants (post-, pre- and oxy-combustion), and one for natural gas processing (gas sweetening). Natural gas sweetening is a mature, commercialized technology which has been already integrated into large-scale CCS projects. The main commercial available technologies employ physical solvents (e.g., methanol) and/or chemical solvents (mainly amines such as MEA) to remove CO_2 from gaseous mixtures.

A number of other novel removal technologies have been or are currently being considered for commercial carbon dioxide removal. These include improved solvent formulations, solid sorbents, membranes, and cryogenic technologies. Each of these technologies holds promise to reduce the capital and operating cost of current CO_2 removal systems.

Main CO_2 Capture Concepts and Corresponding Separation Technologies

Capture Concept	Post-combustion	Pre-combustion	Oxyfuel Combustion	Gas sweetening
Separation Task	CO_2/N_2	CO_2/H_2	O_2/N_2	CO_2/CH_4
Application	Power, Cement	Power Industrial hydrogen	Power, steel	Natural gas processing
Separation Process	Amine solvents	Solvents Adsorbents	Cryogenic air separation	Solvents Membranes
Level of Development	Pilot	Pilot for power Commercial for industry	Pilot	Commercial
Emerging Technologies/ RD& D Trends	Advanced solvents Adsorbents Calcium looping Membranes Process integration	Advanced solvents New adsorbents Membranes Cryogenic separ Process integration	Cryogenic separation Chemical looping Membranes Adsorbents Retrofit	Advanced solvents New membranes

- A detailed overview of the commercial and emerging CO_2 capture technologies is provided in this report.

CO_2 SEQUESTRATION

Capture and sequestration of CO_2 from large point sources such as power plants (over one million tons per year) will require the use of pipelines to move the CO_2 to proper geologic sequestration sites. CO_2 transport is already carried out by pipelines, mainly to recover more oil (and/or gas) from nearly depleted oil and gas fields. Significant CO_2 pipeline infrastructure has been developed in North America and Norway. However the length of pipeline needed for widespread deployment of CCS will necessitate extensive infrastructure development.

The final stage of the CCS process involves the injection of CO_2 into deep underground rock formations. Appropriate storage sites include depleted oil and gas fields, as well as geologic formations that contain water with high levels of salinity (saline aquifers). Depleted oil and gas reservoirs have a high potential for meeting CO_2 storage criteria because they securely held crude oil and natural gas in them over long geologic timeframes. Saline formations are very widely distributed globally and represent by far the largest potential for CO_2 storage capacity.

- The major technical requirements and related costs for CO_2 pipeline transport and CO_2 storage are covered in this report.

COST OF CCS

It is generally accepted that separation and capture of CO_2 is the largest cost component, possibly as much as 80 or 90 percent of the total CCS costs. Nexant has evaluated costs of capturing CO_2 at world scale, state-of-the-art plants. Estimates have been made on Western Europe and United States bases. The processes evaluated include:

- Monoethanolamine (MEA) process
- Hindered Amines process
- Ammonia-based process

A speculative assessment for a hypothetical case based on a potentially improved amine-based solvent is also given.

CCS PROJECTS

At present, there are more than 70 large-scale CCS projects globally at various stages of development. Large projects are defined as projects integrating the capture, transport and storage of at least 500 000 tons CO_2 per year from emission-intensive facilities (e.g., natural gas processing, hydrogen production, power generation). Nine of these large projects are actually in operation and eight further are under construction. North America has the most advanced portfolio of large CCS projects in the world, while CCS activity in Europe is fairly dynamic. Several large projects have been proposed in China, but it is uncertain whether they will actually materialize.

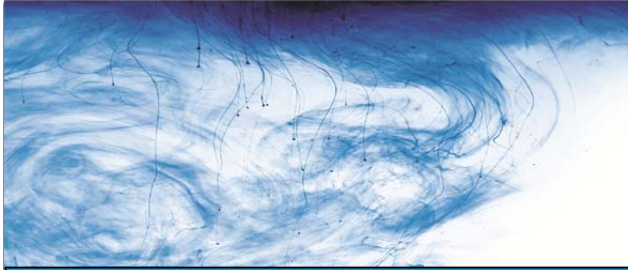
- An outlook of CCS activities on a global basis is provided in this report.

REGULATION AND LEGAL FRAMEWORK

Policies for reducing GHG emissions, primarily CO_2, have been instituted in industrialized countries since the 1990s. These policies have been strengthened and expanded in recent years due to a greater awareness of the negative impacts of climate change. Some of the policies remain voluntary, while others have specific costs and enforcement measures associated with them. There are market-based approaches that have been developed to lower greenhouse gas emissions, such as the trading of emission credits under the European Union Emissions Trading Scheme (EU ETS). Other initiatives for controlling GHG emissions include voluntary and mandated reduction targets established by state and local governments, taxes imposed on emissions, and renewable portfolio standards for electric utilities.

Insight into the policies considered for enactment provides an understanding for just when the appropriate drivers may be in place to promote CCS technology. The timeline varies from country to country.

- The latest updates concerning CO_2 emission policies in major developed countries and developing countries are profiled and compared in the report.



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