The Future of Coal-Based Power Generation

James R. Katzer, MIT

The landscape for coal-based power generation is changing rapidly. Coal power-plant construction is on a sharp upturn globally but is facing increasingly stiff opposition because of concern over emissions, particularly carbon dioxide emissions. Pulverized-coal (PC) generation technology has advanced to meet increasing emissions regulations, and CO_2 can be captured from PC flue gas for geologic sequestration. Integrated Gasification Combined Cycle (IGCC) offers the potential to reduce emissions significantly further and to also capture CO_2 at lower cost. Oxy-fuel combustion offers similar potential for commercial CO_2 capture but is not well developed. There is no clear winner today for power generation with CO_2 capture. The coal-based technology with CO_2 capture appears to be a competitive economic candidate for base-load generation of low-CO_2 electricity. Captured, supercritical CO_2 can be injected into geologic formations where it will remain safely stored for many centuries. There do not appear to be any irresolvable scientific or technical issues to geologic sequestration of CO_2 with safety and efficacy. There also do not appear to be any economic show-stoppers associated with CO_2 sequestration.

However, there is still a lot that needs to be done to allow these potentials to become commercial reality at the scale needed. Key issues will be explored.

Carbon Capture and Storage – A Legal Perspective

Ian Havercroft, Research Fellow, University College London

This presentation seeks to highlight a number of key areas of legal concern, with regard to Carbon Capture and Storage (CCS) technologies; then in turn consider the mechanisms and regulatory options, which it is hoped, will eventually resolve these issues.

International regulatory system for the disposal of wastes at sea

The presentation shall consider, initially, the international regulatory system with regard to the disposal of waste in the marine environment. The United Nations Convention on the Law of the Sea 1982, the London Convention 1972, its later 1996 Protocol and the 1992 OSPAR Convention, have all come under close scrutiny in recent years and initially proved to be considerable obstacles to CCS. The entry into force of the London Protocol in 2006 and recent amendments to that Protocol and the OSPAR Convention; provide an interesting example of how the international marine community is addressing the issue.

Climate change legislation

An analysis of the international climate change regime will allow for a demonstration of how both international and regional agreements may be adapted to incorporate CCS. The United Nations Framework Convention on Climate Change and the Kyoto Protocol contain no explicit reference to the use of CCS, but proposed new accounting and inventory methodologies have gone some way toward its inclusion in the portfolio of climate change mitigation mechanisms.

The proposals to include CCS in the flexible mechanisms created by the Kyoto will also be significant for industrialised Parties to the Protocol and allow them to make cost-effective and flexible emissions reductions. Consideration of the interaction between the Protocol's flexible mechanisms and the European Union's Emission Trading Scheme (EU ETS) will also highlight gaps in the current legal regime and proposals for its amendment.

The development of EC and national legal and regulatory frameworks

There currently exists no national or European regulatory framework regulating CCS projects, although there are laws of relevance. The presentation shall analyse the European Commission's proposals for the development of an enabling legal framework for CCS in the European Union. The Commission's proposals are significant, not only because they intend to provide a single coherent piece of legislation for all members of the EU, but they may also prove to be a blueprint for future dedicated CCS legislation.

CCS: Development and Prospects in Norway

Mr. Odd Magne Mathiassen
Norwegian Petroleum Directorate

The Norwegian government has set an ambitious goal to reduce greenhouse gases by 30% within 2020. The present government, a merge of three political parties has majority in the parliament. However, disagreement about the size of cuts to take at home leads to different views on goals and measures. A white paper has been expected for some time. It may be delays until the fall of 2007.

Norway has more then 10 years of experience on CO_2 injection in geological formations, the Sleipner field (1 mill tonnes/year). Another storage operation, the Snøhvit field (0.7 mill tonnes/year) in the Barents Sea, should start later this year. Both fields have about 8 % CO_2 in the gas. This has to be separated from the produced gas due to sales gas specification and LNG processing. The Norwegian policy and CO_2 tax has made these CCS projects possible.

Currently two new major CCS project are being evaluated in Norway. One is a commercial project organised by Statoil and Shell. The plan is to build a 650 MW gas fired power plant at the Tjeldbergodden Methanol plant and deliver CO_2 (2.3 mill tonnes/year) to the Draugen and Heidrun field for enhanced oil recovery. Power to the platforms with electricity from shore is also a part of the project. The other project is CCS from two large gas fired power plants (up to 3.3 mill tonnes/year) at the Kårstø gas terminal and the Mongstad refinery. These are politically driven projects, and the government has promised to cover most of the costs. The technical challenge is to qualify more cost effective capture technologies and a joint geological storage site that is safe for leakage, not in conflict with the oil and gas production, and as close to shore as possible. In the presentation, the Draugen and Heidrun project will be briefly mentioned, but the presentation will mainly be focused on the joint Kårstø and Mongstad project. Any new information on policy or new project in Norway will also be included.

CARBON CAPTURE AND STORAGE: SOUTH AFRICAN ACTIVITIES AND PLANS

Dr A D Surridge, Senior Manager: Advanced Fossil Fuel Use, South African National Energy Research Institute

South Africa's energy economy is dominated by coal, that commodity accounting for approximately 75% of primary energy production. In accordance with policy to address climate change, carbon capture and storage is being investigated as one of the tools to limit greenhouse gas emissions.

A first step investigation established that there were sources and possible sinks that could be pressed into service. One prominent source was the ~25 Mt/y of ~95% carbon dioxide emissions from synthetic fuel plants. With the potential established, participation in the Carbon Sequestration Leadership Forum activities continued

During mid-2006, a workshop of stakeholders was held as an outreach activity and to solicit recommendations regarding the way forward. The three outcomes were: carbon capture and storage should be one of the tools to mitigate greenhouse gas emissions; ocean storage should not be considered at this stage; and a study should be done to identify and characterise potential storage sites.

The establishment of the South African National Energy Research Institute during 2006 has brought about an interest in participating in the International Energy Agency's Greenhouse Gas Programme. Current activities include:

1. Sasol is currently investigating the feasibility of utilising carbon dioxide for enhanced coal-bed methane production.
2. A Terms of Reference for the detailed identification and characterisation of potential carbon dioxide storage sites has been drafted. This process is calling on international expertise. The results of this investigation are a 'make-or-break' for carbon capture and storage in South Africa.
3. Country Readiness is being addressed by giving attention to the following;

(a) Identification and characterisation of storage sites,
(b) Human capacity building,
(c) Enabling regulatory system,
(d) Monitoring carbon capture and storage technology development.

Possibilities to use carbon capture and storage technology in CIS countries with Kazakhstan as an example

Mr. Sergey Katyshev, KEGOC (Kazak Electricity Grid Operating Company)

According to the results of the inventory of greenhouse gases in Kazakhstan, the total emissions of gases with direct greenhouse effect in 2005 amounted to 240.7 mln. t of ? O_2-equivalent, including 187.7 mln. t of the emissions from all energy activity, 16.1 mln. t from industrial processes, 20.2 mln. t from agriculture and 16.6 mln. t from wastes. The absorption of CO_2 by forests in 2005 amounted to 5.9 mln. t. Thus, net emissions taking into account the absorption (sequestration) of CO_2 by forests amounted to 234.8 mln. t of ? O_2-equivalent. Total specific GHG emissions amounted to more than 15.2 t. per capita in 2005, and about 12.3 t of it fall to CO_2 only, being one of the highest indicators among CIS countries. Total emissions of ? ? $_2$ come to 186.3 mln. t; the increase, as compared to 2000, is 49 mln. t or 35%, that is 78% of 1990 level (238.3 mln. t). This is the general trend for CIS countries.

91.4% of total ? ? $_2$ emissions account for energy sector activity. Substantial part of energy sector activity is the country's electric power industry, with thermal power plants as major portion (88% of generated thermal power plants, and 12% are generated by hydropower plants). 90% of thermal power plants are coal-fired power plants. Capacity of a one generating unit can reach 500 MW and capacity of some power plants is as great as 4000 MW. As is known, it is coal-fired power plants that are considered the first to implement carbon capture and storage (CCS) technology in electricity sector. Only till 2015 up to 30% of installed capacities of coal-fired power plants in Kazakhstan need upgrading and rehabilitation. In addition, it is planned to extend existing coal-fired power plants and construct the new ones (2500 – 3000 MW).

There are plans to develop application of energy-efficient technologies both by electricity consumers and electricity generators, to involve renewable energy sources and nuclear power in the energy balance, and to extend use of "clean" coal technologies at power plants.

It is evident that CCS technologies may also find its place in the overall pattern of the country's energy sector. All the more, it will be due to the fact that Kazakhstan is rich not only in coal resources, but also in oil and gas with great deal of deposits, and continuous build-up of production and import of energy resources goes on. From 2000 to 2005 oil and condensate production increased from 35.32 mln. t to 61.5 mln. t. Thus, there is a number of potential geological formations in the country that can be used to store captured CO2, including:

- depleted and disused oil and gas fields
- deep saline aquifers
- deep unmineable coal seams.

The legislation of Kazakhstan related to attraction of investments and new technologies to the country has been developed in recent years (more than 50 billion dollars of direct

foreign investments have been attracted during the last 10 years. Kazakhstan is a leader among CIS countries with regard to this index per capita). Provision is made for further development of legal framework of the country in this direction; the country's industrial development program has been approved and is now effective. It enables Kazakhstan to keep and further develop the available research base and increase the number of scientific manpower. It shall be noted here that the Environmental Code was adopted last year, and Kazakhstan is an active participant in the activity related to UN FCCC.

Thus, in Kazakhstan as in most CIS countries there are conditions favourable for implementation of CCS technologies, with its application extended to the developed countries and increase of commercial attractiveness. No doubt that international cooperation is required to distribute the information on CO2 capture and storage research, development and demonstration, stimulate discussions of technical, economic and regulatory aspects of CCS technology. It will contribute to extension of CCS technology application possibilities around the world.

Assessing and Monitoring the Security of Geological Storage of Carbon Dioxide

Sally M. Benson
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Professor (Research) Energy Resources Engineering Department
Stanford University

Geological storage of CO_2 captured from large point sources can be used to reduce emissions while continuing to use fossil fuels, particularly in coal-fired electricity generating stations. The security or retention of stored CO_2 will determine the effectiveness of CCS (Carbon Capture and Storage) as a greenhouse gas mitigation technique. This presentation will review the lines of evidence used to support the conclusion in the IPCC Special Report on Carbon Dioxide Capture and Storage that retention rate of 99% over 1000 years or greater is achievable and sufficient. A framework for monitoring and assuring long-term performance will be presented. Specific approaches for and examples of monitoring storage reservoirs will be presented, along with conclusions regarding the sensitivity and sufficiency of the current state of the art.

CCS: Public perception and environmental issues
Dr. Gabriela von Goerne, Greenpeace (Germany)

Carbon dioxide capture and storage (CCS) has been raising more and more attention in the past years – an option that would allow the continued or new use of fossil fuels, esp. coal, by storing the carbon dioxide permanently underground. Industrialised countries spread the impression that CCS will become an important mitigation option in the near future. CCS has not yet reached the public debate. Carbon dioxide capture and storage is almost unknown and not well understood. If faced by the prospect of millions of tonnes of carbon dioxide to be stored underground, people might feel like being overrun by this technology resulting in a „NIMBY" position. Studies show that if CCS is explained public accepts CCS as a necessary evil until renewable energy gains ground to substitute fossil fuels. CCS however raises a number of environmental concerns and questions about e.g. leakage – what happens if a storage site leaks?, liability - who is responsible, can leakage be remediated?, or costs – who is going to pay? CCS is not an easy and cheap technology and its contribution to sustainable development is under critical discussion. CCS obliges future generations to monitor stored CO2 for safety and climate protection reasons, and to remedy potential leakage. Focus should therefore be put on real clean renewable solutions that are already available, and not CCS.

Potential of CO2 storage in underground structures in Poland.
Pawel Krzystolik

The biggest source of CO2 emissions are the power plants, producing 95% of electric energy from coal. Aquifers constitute majority of country storage capacity, with huge potential counted in G-tones CO2. Hydrocarbon fields are of local importance. Gassy coal seams located in the Silesian Coal Basin have potential to store CO2 emissions of many power, CHP and other industrial plants. In Europe the first sequestration of CO2 into coal seams (ECBM) was realized in Poland (EU RECOPOL project). Two power plants blocks with CCS are in project stage.

Introduction to Carbon Dioxide Capture and Storage in China

Ms. Li Xuefing, Deputy Director, Strategy and Policy Department, PetroChina

China's National Climate Change Programme was published by the Chinese government in June, 2007. The technologies of CCS were stressed to improve the capacity to address climate change, including international technology cooperation and transfer. China has been in the membership of the Asia-Pacific Partnership on Clean Development and Climate, and China-Europe Memorandum of Understanding on CCS to Achieve the Goal of Zero Emission. A program between China and Europe aiming at carbon dioxide capture and storage cooperation was launched in November, 2006.

In recent years, the scientific researches, including the carbon dioxide storage in coalbeds, injecting flue gas from boiler into oil field to improve the recovery and recycling of oil, are being carried out.

PetroChina has paid more attention to the R&D of CCS technologies; some technologies have been tested in Daqing oil field to improve the oil recovery efficiency. Preliminary projects have been put into motion. Furthermore, with the development of high carbon dioxide natural gas, carbon dioxide sequestration and comprehensive utilization of resources in Jilin oil field, as a key R&D project of PetroChina, has been started up.