CARBON CAPTURE AND STORAGE

Full-scale demonstration progress update

INTERNATIONAL ENERGY AGENCY

Background

Secure, reliable and affordable energy supplies are needed for sustainable economic growth, but increases in associated carbon dioxide (CO_2) emissions, and the associated risk of climate change, are a cause of major concern. The IEA analysis in *Energy Technology Perspectives 2008* (ETP) projects that the CO_2 emissions attributable to the energy sector will increase by 130% by 2050 in the absence of new policies or supply constraints as a result of increased fossil fuel usage (IEA, 2008a). To address this increase will require an energy technology revolution involving greater energy efficiency, increased renewable energies and nuclear power, and the near-decarbonisation of fossil fuel-based power generation.

Nonetheless, fossil fuel usage is expected to continue to play a major role in delivering global energy supply, with the latest IEA projections showing a global increase in fossil fuel usage through 2030 (IEA, 2008b). The only technology available to mitigate greenhouse gas (GHG) emissions from large-scale fossil fuel usage is carbon dioxide capture and storage (CCS). The ETP BLUE scenario, which assessed strategies for reducing GHG emissions by one-half in 2050, concluded that CCS will need to contribute one-fifth of the necessary emissions reductions to achieve stabilisation in the most cost-effective manner. CCS is therefore an essential part of the portfolio of technologies that is needed to achieve deep global emission reductions.

However, CCS technology faces many challenges to successful, full-scale demonstration and commercial deployment including issues such as: financing large-scale demonstration projects and integration of CCS into GHG policies; the higher cost and efficiency penalty of CCS technologies; development and financing of adequate CO_2 transport infrastructure; development of legal and regulatory frameworks to ensure safe, permanent CO_2 storage; adequate public consultation; and developing capacity and awareness in rapidly growing fossil-based economies. There is a large and growing body of work underway to address these issues at the international and national levels; however, the critical next step is to verify the performance of CCS at scale, with capture from a variety of different industries and storage in a variety of geologic settings. To date, only a few large-scale CCS projects are in operation.

At the Hokkaido Toyako Summit in 2008, G8 leaders committed to undertake the following CCS-related actions to address this gap:

- Announce 20 large-scale CCS demonstration projects globally by 2010, taking into account various national circumstances, with a view to beginning broad deployment of CCS by 2020.
- Establish an international initiative with the support of the IEA to develop CCS technology roadmaps and enhance global co-operation through existing and new partnerships.
- Take various policy and regulatory measures to provide incentives for commercialising CCS technologies.

This report will provide an update on global CCS development, and discuss the path forward on tracking the G8 recommendations for reporting at the Canada G8 Summit in 2010.

What is CCS?

CCS is a system of technologies that integrates three stages: **CO_2 capture**, **CO_2 transport** and **geologic CO_2 storage**. Various technologies with different degrees of maturity are competing to be the low-cost solution for each stage of the CCS value chain. However, each of the stages of CCS is technically available and has been used commercially for many years. For example, **CO_2 capture** technologies

have long been used for high-concentration, high-pressure CO_2 sources. **CO_2 transport** has been used safely for the past 30 years – the United States has several thousands of miles of CO_2 pipelines that transport CO_2 captured from industrial plants for enhanced oil recovery (EOR). **Geologic CO_2 storage** has been operating for more than a decade at a growing number of sites worldwide. Early projects have injected CO_2 into a variety of geologic formations, including depleted oil and gas fields and saline formations, with all available evidence showing the CO_2 has performed as anticipated after injection. However, as each site will have unique circumstances, more experience is needed to improve predictions of CO_2 behaviour and to identify suitable storage sites, particularly deep saline formations, which hold the most promise for long-term CO_2 storage potential. To date, none of the existing large-scale projects involve the capture and storage of CO_2 from dilute sources; *e.g.* coal-fired power plants or industrial plants in key sectors such as cement, chemicals, metals, and pulp and paper.

Current status of global CCS development

At present, there are four fully-integrated, commercial-scale CCS projects in operation (see box). Sleipner, Snøhvit and In Salah are all projects in which the CO_2 content of the extracted natural gas is too high. To achieve commercial-grade quality natural gas, the CO_2 is stripped, collected and stored securely in underground geological formations. At Weyburn-Midale, compressed CO_2 is captured from a coal-based synfuels plant and piped to an oil field, where it is injected to increase the recovery yield from the oil field. In total, these plants store more than 5 million tonnes (Mt)of CO_2 per year.

Full-scale CCS demonstrations are costly – up to USD 1 billion incremental funding per project – but the challenges of integration and scale can only be met through the experience of building and operating commercial-scale CCS facilities in a variety of settings. Governments are beginning to address this funding gap; there has been a dramatic increase in government and industry demonstration activities in the past year. Most of the major economies have announced ambitious plans (and associated funding) for large-scale CCS demonstration projects. For example:

- **Australia** launched in April 2009 the **Global CCS Institute** (GCCSI) to foster international collaboration, particularly around near-term, large-scale demonstration projects; in addition, domestically, the government has announced **AUD 2 billion for large-scale demonstration.**
- In **Brazil,** oil company **Petrobras** is investing in **two to four large-scale demonstration projects** as part of its sustainability and climate change plan.
- **Canada** has allocated **CAD 3.5 billion for large-scale CCS project demonstration.**
- A consortium of companies in **China** is moving forward with the **GreenGen project**; which has received support and approval from the government;
- The **European Union** (EU) financial stimulus package includes **EUR 1 billion** for CCS demonstration; this complements the early 2009 EU decision to set aside **EUR 300 million allowance revenues for CCS funding.**
- **France** is developing smaller-scale demonstration projects as part of a **EUR 1 billion** funding package for research and development; these projects will be expanded after their performance is assessed.
- **Italy's Enel**, the national electricity company, is developing **one pilot plant.**
- **Norway** is continuing its leadership by developing the **Mongstad and Karstø projects.**
- **South Africa** will launch a **CCS Centre** in September 2009, and plans to rapidly build capacity with the aim of having **at least one full-scale project operational by 2020.**
- **The United Arab Emirates** has **three large-scale CCS projects** under development, building on the region's expertise in enhanced oil recovery.

Current Commercial CCS Projects

Four fully-integrated, large scale CCS projects are in commercial operation today. Three—Sleipner, In Salah and Snøhvit—inject CO_2 from a natural gas production facility where it is separated from the natural gas sent to market. The fourth project captures CO_2 at the Great Plains Synfuels Plant and transports it to the Weyburn-Midale project. All four are contributing to the knowledge base needed for widespread CCS use.

Sleipner. The world's first commercial CCS project started in 1996 when Norway's state-owned oil company, Statoil, began injecting more than 1 million tonnes a year of CO_2 under the North Sea. This CO_2 was extracted with natural gas from the offshore Sleipner gas field. In order to avoid a government-imposed carbon tax equivalent to about US$50/tonne, Statoil built a special offshore platform to separate CO_2 from other gases. The CO_2 is re-injected about 1,000 meters below the sea floor into the Utsira saline formation located near the natural gas field. The formation is estimated to have a capacity of about 600 billion tonnes of CO_2, and is expected to continue receiving CO_2 long after natural gas extraction at Sleipner has ended.

In Salah. In August 2004, Sonatrach, the Algerian national oil and gas company, with partners BP and Statoil, began injecting about 1 million tonnes per year of CO_2 into the Krechba geologic formation near their natural gas extraction site in the Sahara desert. The Krechba formation lies 1,800 meters below ground and is expected to receive 17 million tonnes of CO_2 over the life of the project.

Snøhvit. Europe's first liquefied natural gas (LNG) plant also captures CO_2 for injection and storage. Statoil extracts natural gas and CO_2 from the offshore Snøhvit gas field in the Barents Sea. It pipes the mixture 160 kilometers to shore for processing at its LNG plant near Hammerfest, Europe's northernmost town. Separating the CO_2 is necessary to produce LNG and the Snøhvit project captures about 700,000 tonnes a year of CO_2. Starting in 2008, the captured CO_2 is piped back to the offshore platform and injected in the Tubåsen sandstone formation 2,600 meters under the seabed and below the geologic formation from which natural gas is produced.

Weyburn-Midale. About 2.8 million tonnes per year of CO_2 is captured at the Great Plains Synfuels Plant in the U.S. State of North Dakota, a coal gasification plant that produces synthetic natural gas and various chemicals. The CO_2 is transported by pipeline 320 km (200 miles) across the international border into Saskatchewan, Canada and injected into depleting oil fields where it is used for EOR. Although it is a commercial project, researchers from around the world have been monitoring the injected CO_2. The IEA Greenhouse Gas R&D Programme's Weyburn-Midale CO_2 Monitoring and Storage Project was the first project to scientifically study and monitor the underground behavior of CO_2. Canada's Petroleum Technologies Research Centre manages the monitoring effort. This effort is now in the second and final phase (2007-2011), to build the necessary framework to encourage global implementation of CO_2 geological storage. The project will produce a best-practices manual for carbon injection and storage.

Source: IEA Greenhouse Gas R&D Programme (2008).

- The **United Kingdom** is advancing CCS via its **large-scale demonstration competition**, which will announce **one major project to be operational by 2014**; in addition, in April 2009 the government announced proposals to establish a mechanism to support **up to four large-scale CCS demonstrations** and to require **any new coal-fired power plant over 300 mW capacity to demonstrate CCS on a proportion of its capacity.**
- The **United States** announced (in May 2009) **USD 3.4 billion** in new funding for CCS projects.

In addition to these major announcements, there are several dozen other smaller-scale – yet critically important – CCS research and demonstration projects around the world. The Carbon Sequestration Leadership Forum (CSLF) is currently updating its project list; preliminary indications show over 60 large projects that are planned or underway; work is underway by the GCCSI and CSLF to verify this project list. These projects will provide a wealth of critical information that will guide future CCS efforts.

Tracking the G8 large-scale projects goal

The G8 leaders have asked the IEA to track global progress toward the goals they set in 2008. To encourage the broadest possible reporting, the IEA proposes that project tracking be guided by the following criteria:

- **Scale is large enough** to demonstrate the technical and operational viability of future commercial CCS systems.[1]
- **Location of the storage site** is clearly identified.
- **Effective integration** of CO_2 capture, transport and storage.[2]
- **Scheduled to begin full-scale operation between 2015-20**.
- **Strategies to engage the public** demonstrate intent to **incorporate input into the project design**.
- **Funding commitments** demonstrate **established public and private sector support.**

[1] The size threshold will vary based on the type of CO_2 source; for example, coal-fired power plants might inject more than 1 Mt of CO_2 storage per annum whereas gas-fired power plants and some industries will have a smaller CO_2 stream.

[2] With the understanding that some CO_2 sources located at or near the storage site will involve minimal or no transport; this could also include enhanced oil recovery projects.

There is also a need to ensure widespread CCS development in a variety of settings. Thus, the following guiding principles should help to shape the global portfolio of CCS projects:

- **CCS projects** need to be…
  - demonstrated at scale in all major fossil-based economies, including emerging economies.
  - designed to maximise knowledge sharing via transparent and regular publication of results.
- **CO_2 capture** needs to be demonstrated…
  - using a variety of CO_2 capture technologies.
  - at a variety of point sources, including coal- and gas-fired power plants, refineries, chemical plants, cement plants, iron and steel manufacturing facilities, and other industrial operations.
  - through retrofitting at a coal-fired power plant (this is an urgent need).
  - using biomass input (this offers an important carbon-reduction opportunity, and should be pursued urgently).
- **CO_2 transport** needs to be enhanced…
  - through deployment of infrastructure.
  - by applying effective design and regulation of networks.
- **CO_2 storage** needs to be demonstrated…
  - in a wider set of projects with different geologic settings.
- **Enhanced oil and gas recovery** offer cost-effective opportunities for CCS demonstration, and should be pursued as an early opportunity.

Tracking other G8 recommendations

At the 2008 G8 Summit, the IEA presented 27 recommendations on near-term opportunities for CCS to the G8 leaders. These recommendations were developed in partnership with the CSLF through a series of stakeholder consultations. These recommendations highlight other critical issues that must be tackled to ensure that CCS can be safely and rapidly expanded from large-scale pilots to commercial scale in time to achieve GHG mitigation targets. The recommendations reflect critical areas that must be addressed for successful CCS development:

- Development of viable and internationally consistent legal and regulatory frameworks to ensure safe, secure CO_2 transport and storage.
- Provision of incentives via effective integration of CCS into GHG regulations and policies.
- Increased public awareness and input.
- Expansion of effective institutions and expertise, with additional research, development and training initiatives.
- Expanded international collaboration.

There has been important progress in these areas in recent years, including the development of national and regional legal and regulatory frameworks and increased co-ordination amongst the GCCSI, the CSLF, the IEA and the IEA's GHG Implementing Agreement. However, more still needs to be done, particularly in the areas of public consultation and more comprehensive recognition of CCS in GHG regulatory mechanisms. The IEA and its partners will release a global CCS Roadmap in October 2009, which will provide a number of milestones and necessary actions to guide efforts to address these issues.

Looking forward to the Canadian G8 Summit

Over the next year, the IEA will work with key partners – including the IEA Working Party on Fossil Fuels, the IEA GHG Implementing Agreement, the GCCSI and the CSLF – to conduct a thorough global overview of the status of large-scale CCS project development. Many planned CCS projects were announced prior to the financial crisis that started in the autumn of 2008 and the impact of which continues today. Therefore, it will be important to establish a proper understanding of the current status of these projects. The GCCSI is conducting a thorough review of large-scale demonstration projects as one of its first activities; results from this review will provide important information to the tracking process. The groups will also continue to track the progress toward the 27 recommendations with a variety of activities underway.

The IEA proposes the following process for tracking progress toward the G8 goal set in 2008:

July 2009	Present criteria to G8 leaders
July 2009 – September 2009	Complete GCCSI review of global CCS project portfolio
September 2009 – July 2010	Work with GCCSI and CSLF to contact government and industry project investors to develop a list of projects which meet the criteria
July 2010	Publish global project list, along with status report on 27 recommendations, at Canadian G8 Summit

References

IEA Greenhouse Gas R&D Programme (2008), "Carbon Capture and Storage: Meeting the Challenge of Climate Change", IEA/OECD, Paris.

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