

The IEA Greenhouse Gas R&D Programme (IEA GHG)

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1. Abstract

Carbon Dioxide Capture and Storage (CCS) technology has progressed significantly towards commercialisation since the IEA Greenhouse Gas R&D Programme started in 1991. However, there is still much to do to enable its world-wide application. This paper describes the work of the IEA GHG programme and, in particular, its activities aimed at driving down the cost of CO₂ capture and the development of confidence in underground storage.

IEA GHG's members come from a wide range of countries and industrial entities. Their varied perspectives and drivers ensure the Programmes' activities are widely relevant. As CCS moves towards adoption by policymakers as a major CO₂ mitigation option, IEA GHG will be working on the many issues to ensure that CCS can be economically, safely, and environmentally adopted in a range of applications.

2. IEA Implementing Agreements

IEAGHG is a cost-sharing Implementing Agreement operating under the aegis of the International Energy Agency (IEA). Members contribute annually to a common fund.

The IEA provides the Implementing Agreements (IA) structure as a route to international co-operation on energy issues. There are currently some 40 active programmes. The IA framework is a legal mechanism for establishing the participants' commitments and a management structure.

There are 2 categories of participant in an IA:

- *Contracting Parties* can be governments or entities nominated by them. They can also be international organisations in which governments participate.
- *Sponsors* are private sector entities which have not been designated by a government.

3. IEA GHG Membership and Organisation

IEA GHG has an Executive Committee (ExCo) of representatives nominated by the Contracting Parties and Sponsors. The ExCo acts as a management board to decide on the work programme and supervise the use of the common funds. The programme works in phases to an agreed strategy and workplan. However, members recognise the need for flexible responses to fast-moving events.

Operational management of IEA GHG is assigned to an Operating Agent who is accountable to the ExCo. The Operating Agent is IEA Environmental Projects Ltd., a UK registered company.

Further general information on IEA GHG can be found on its website at: www.ieagreen.org.uk and for the IEA at: www.iea.org

Over its 14 year life IEA GHG has built up a reputation as the premier source of unbiased information on the options available to reduce emissions of greenhouse gases to atmosphere. The programme aims to produce policy relevant information but is not policy prescriptive - Members are from a wide range of countries and industrial entities each with its own policy drivers.

The main benefits of participation include:

- Members contribute to the development of the work programme and by doing so include perspectives from an international range of national and industry sources.
- Members have access to unbiased information, obtained from international experts, presented in consistent and transparent evaluations.
- Members get the benefit of significant leverage on their contributions.
- Members can reduce the need for having to duplicate the efforts of others.
- Operation under the aegis of the IEA gives members the assurance of, and a route to participate in, the IEA's comprehensive international programmes of energy co-operation.

It is a key strength of the IEAGHG Programme that it has participants from both governments and private sector entities. This provides a forum for perspectives from an international range of national and energy industry sources. Because of this range of views the activities of the programme are seen to be widely relevant and acceptable.

Membership of the IEA Greenhouse Gas R&D Programme is, at present, as follows:

(i) Intergovernmental Organisations (IGOs) - European Commission, Organisation of Petroleum Exporting Countries (legal formalities not complete.)

(ii) Countries - Australia, Austria (formalities just started), Canada, Denmark, Finland, France, Germany, India (some formalities remain), Japan, Korea, The Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States of America, Venezuela (intends to withdraw.)

(iii) Sponsors - Alstom, BG group (formalities not complete), BP, Babcock & Wilcox (formalities not complete), Chevron, EniTechnologie, E.ON, EPRI, ExxonMobil, RepsolYPF, RWE AG, Schlumberger (formalities not complete), Shell, Statoil, Total, Vattenfall

The advent of the Kyoto Agreement in February 2005 renewed world-wide activities on the climate change problem. Despite the reservations that some have about the Agreement, it is clear that one result is to focus policymakers' attention on the next generation of energy technologies. Signatories to the Agreement have agreed to:

“Research on, and promotion, development and increased use of, new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies”.

If, as expected, this encourages the search for and development of new CO₂ mitigation opportunities the role of IEA GHG in ensuring that financial and technical resources are used effectively will be of increasing importance.

4. Achievements

The Members of the IEA GHG Programme have been active for 14 years in assessing and encouraging the development of CO₂ mitigation technology. Over that period, they have succeeded in achieving widespread acceptance that CCS is one of the key options needed to obtain deep reductions in the emission of CO₂. CCS was merely a technical possibility when IEAGHG started in 1991 (see Figure1); it is now firmly on policymakers' agendas.

IEAGHG members recognise the major role that fossil fuels play in underpinning world economic development. Through the Programme's work they have demonstrated the opportunity for the continued use of fossil fuels - even under emission scenarios involving deep reductions in the emission of greenhouse gases.

Figure 1: Table showing the initial scope of IEAGHG technical assessments

<i>TIMESCALE</i>	<i>BASIC TECHNOLOGY</i>	<i>CO₂ CAPTURE</i>	<i>CO₂ UTILISATION & STORAGE</i>
<i>NEAR-TERM</i>	<i>Pf coal, Natural Gas Combined Cycle</i>	<i>Absorption, adsorption, indirect biofixation</i>	<i>Enhanced oil recovery, Exhausted oil and gas wells, Chemical feedstock</i>
<i>MEDIUM-TERM</i>	<i>Integrated Gasification Combined Cycles</i>	<i>Cryogenics, membranes</i>	<i>Aquifers and salt domes New chemicals/fuels</i>
<i>LONG-TERM</i>	<i>Oxyfuel, fuel cells, topping cycles,</i>	<i>Advanced systems</i>	<i>Direct biofixation Solid disposal</i>

By the end of 2005, IEAGHG had done over 100 studies on behalf of its members. The core of the study work has focused on carbon capture and storage (CCS), but many other areas are covered; for example, comparisons with other emission reduction options, and alternative energy carriers.

Work by IEAGHG rapidly established that CO₂ could be captured from major emission sources such as power stations. However, the solution to the question of secure long-term stores was far from clear. IEAGHG's first conference was held in Oxford, in 1993 its main objective was to identify the prospects for credible CO₂ stores. At this conference the emphasis was on ocean storage but a few visionary papers described how CO₂ could be stored deep underground. The successors to this conference have now grown to be major biannual events: The GHGT series of International Conferences on Greenhouse Gas Control Technologies.

The major achievement for CCS technology over the last few years has been to demonstrate, on a large scale, that CO₂ can be stored underground and its storage monitored. Major projects, initially at Sleipner in the North Sea, and subsequently, at Weyburn, Canada have demonstrated that CO₂ can be stored underground safely. With the commencement of the In Salah CO₂ storage project in 2005 something of the order

of 3 million tones per year of CO₂ is being stored underground and its location monitored.

Phase 4 of the Programme finished at the end of 2004. During this phase IEAGHG was heavily involved in moving CCS from the realms of being a technical possibility firmly onto policy-makers' agendas. IEAGHG activities expanded to include research facilitation, research networks, and enhanced communications initiatives. These activities were all aimed at confirming the credentials of CCS as a major option for climate change mitigation.

Studies continued to be the foundation-stone of the Programme's activities.

Amongst recent key studies was one on opportunities for early application of CO₂ sequestration technology (PH4/10, September 2002). 'Early opportunities' is a theme that has subsequently been widely picked-up and developed by others. Similarly, the ground-breaking work on cost curves for CO₂ storage (PH4/9, July 2002, and subsequent reports) has had a great deal of influence, e.g. in the preparation of the IPCC's 'Special Report on CO₂ Capture and Storage'. Other key studies assessed potential improvements in both pre- and post- combustion CO₂ capture technology (PH4/19, May 2003; PH4/33, November 2004). These studies set the standard for the assessment of leading technologies for CO₂ capture and the work is to be developed further to compare their relative merits by taking into account issues likely to be of interest to power generators.

The first research network established by IEAGHG was initiated at a workshop in October 2000 in conjunction with the US Department of Energy and ABB Lummus Global. The focus of the co-operative network is on capture of CO₂ using solvents. This initiative by IEAGHG - to establish networks that provide an international forum for researchers in key areas of CCS - has proved a great success. At the time of writing the meetings of CO₂ capture network are still attracting up to 40 participants and the number of research networks has expanded to 5. The latest research networks in the series are one on International Monitoring Network started in 2004 and one on oxyfuel combustion started in 2005. The initial objective of the monitoring network was to use the results available from projects monitoring injected CO₂ to understand the current state-of-the-art and its limitations. The aim is to develop confidence that injected CO₂ can be monitored and verified and any leakage quickly detected.

IEA GHG's members are interested in promoting practical research, design, and development (R,D,&D) but the programme is not a major source of funds. The programme has assisted in several R,D,&D projects. For example, two CO₂ capture projects in Canada; one on oxyfuel combustion at CANMET, and the other at the University of Regina's International Test Centre. Both were assisted by providing the means for international cooperation in the projects and dissemination of information. Another project in which the programme participated was an industry-led design of a pre-combustion decarbonisation (PCD) power plant; the second stage of this project identified prospects for cost reduction. BP have subsequently announced that they intended to proceed with a large-scale demonstration using PCD technology at a power station in Scotland linked to an oil field in the North Sea.

The initial practical R,D,&D project facilitated by IEAGHG was the Saline Aquifer CO₂ Storage research and monitoring project (SACS). This was initiated in 1997 by Statoil in

conjunction with IEAGHG. Its objective was to monitor and learn from the world's first commercial-scale saline aquifer storage project. As a result of this project IEAGHG published the 'Saline Aquifer CO₂ Storage (SACS) Best Practice Manual. IEAGHG remains active in this area through participation in the European Commission's CO2STORE project that builds on the earlier work and adds information from new storage prospects.

IEAGHG was also active in the Weyburn EOR project in Canada. This project has produced extensive information about the behavior of CO₂ in this type of oil reservoir. In 2003 IEAGHG led experts from around the world in an external review of the project. Agreement has been reached that IEAGHG will continue to assist the partners in the second phase of the Weyburn EOR project.

The IEAGHG runs a major conference every two years that is seen as being the premier communication event for workers in the area of greenhouse gas control technologies. GHGT-8 will be in Trondheim, Norway, 19th -23rd June 2006. GHGT-7 was held in Vancouver, Canada, in 2004. This was the largest conference in the GHGT series to date, attracting nearly 670 delegates from 35 different countries. In total some 230 technical papers and 200 posters were presented. In keeping with the progress made in gaining acceptance of the feasibility of CCS as a major option for the reduction of CO₂ emissions there was an increased emphasis on addressing wider issues. Topics such as risk assessment and legal aspects were allocated sessions and there was a significant number of papers dealing with national action plans to implement CCS. On the final day, there was a special panel session on public perception of CCS at which the results from studies undertaken in the USA, Japan, and the UK were presented. None of the studies suggested fundamental public opposition to CCS.

5. Present and future activities

In the current 5-year phase of the programme members have agreed to 3 strategic themes:

- Continued generation of technology and market information that is widely accepted as reliable and unbiased
- Increased focus on activities aimed at building confidence in mitigation technology. For example, the Research Networks.
- Improved communications to ensure that information reaches decision and policy makers.

Studies

IEAGHG continues to generate information in the following areas:

- Capture and transmission of CO₂
- Safe secure storage of CO₂
- Comparison of mitigation options
- Near zero-carbon energy carriers
- Implementation routes and barriers
- Major energy-using industries

An indication of the depth of activity covered by these brief bullet-points can be gained from table 2 which highlights some of the implementation issues.

Routes	Barriers
Early opportunities	Acceptance
Implementation scenarios	Commercial/Financial
Scale and timing	Legal
Demonstrations required	Locational restrictions
Best practice and standards	Regulatory
	Safety

Table 2: Implementation routes and barriers

This work is, in the main commissioned from external experts, but in some cases is done in-house. Each report is subject to peer review by experts nominated by the members of the programme. This ensures the quality of the work and that it reflects the wide-range of members' perspectives.

Confidence building

The programme engages in confidence building by promotion of technology development. Amongst these activities are support for R,D&D programmes by facilitation of and provision of advice, and organization of research networks as forums for themed R&D activities. The networks are a means for researchers in specific fields to meet and work on topics of common interest. Each one has goals which are determined by the participants – these may involve, for example, comparing and contrasting test methods for CO₂ capture, and preparing guidelines on risk assessment approaches to CO₂ storage.

Practical activities are more varied in their style and content than the networks. In some of these, IEA GHG is instrumental in identifying the gaps, working with others to develop a programme of work, and participating in the subsequent project in an advisory capacity and to handle dissemination. In others, a project leader or funder has approached IEA GHG because of its reputation and invited it to participate; perhaps to contribute in evaluating technology, in providing the international perspective, as a user of the results, or for dissemination (e.g. Weyburn, Recopol, ITC¹, CO₂NET2). In other cases, IEA GHG may have been asked to provide specific help and to provide international publicity. In none of these projects can IEA GHG make a significant financial contribution to the project because the Programme does not have sufficient funds for this.

Communications

IEAGHG aims at information dissemination to governmental and other policy makers, industry leaders, and public audiences such as environmental NGO's. Deliverables in this area include: Public summary reports, the bi-annual international GHGT conference, a quarterly newsletter, 2 websites, and maintenance of information databases. The programme maintains a database of practical R&D projects that has proved to be a popular reference source. See www.co2captureandstorage.info

6. The Challenges

CO₂ mitigation technology has come a long way down the road to commercial application since the IEAGHG programme started in 1991. However, there is still much to do to enable its commercial take-up on a world-wide scale.

¹ International Test Centre

The members of IEAGHG come from a wide range of countries and industrial entities and, despite their varied perspectives and drivers, co-operate very effectively. This spirit of cooperation is in keeping with seeking solutions to a global problem and it is hoped it can be retained as the programme develops.

The adoption of CO₂ capture and storage will always cost money, but there are real hopes that the penalties can be significantly reduced. Ultimately, this reduction will depend on demonstrating the technology in real applications.

Storage of CO₂ and monitoring the stored CO₂ has been shown to be technically feasible. However, there are many outstanding issues to be resolved, amongst them, a key challenge is to gain and retain public acceptance.

The IEA GHG programme has the goal of attracting and maintaining participation by a broad range of countries and industrial participants. Input from these participants is important to identify key issues that need to be addressed and ensure the results of IEAGHG's work are widely applicable and realistic. Accordingly, the programme encourages additional participants; further information for prospective members is given on the main website:

www.ieagreen.org.uk

Our other website containing information on CCS is well frequented:

www.co2captureandstorage.info