GHGT9

Conference Summary

9th International Conference on Greenhouse Gas Control Technologies

Washington, D.C.
16–20 November 2008


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The Greenhouse Gas Control Technologies (GHGT) conference aims to provide a forum for discussing advances in the field of greenhouse gas control technologies. The GHGT conference series is the foremost technical conference of its kind. The conference series strives to promote collaboration on international research and development and to encourage an exchange of ideas for future directions.

GHGT-9, the latest conference in the series, was held from November 16–20, 2008 in Washington D.C. The conference was organized by MIT in collaboration with the IEA Greenhouse Gas R&D Programme (IEA GHG), and US Department of Energy (USDOE). The GHGT series has grown rapidly since its inception in 1991. The 2008 conference was the largest, with over 1460 attendees.

The four day conference considered every aspect of CO_2 Capture and Storage (CCS). The technical sessions covered recent developments on: capture systems, geological storage, integrated systems design, other storage options and policy related developments. In addition, the conference provided the opportunity for new pilot and demonstration projects, to be previewed and the results from existing projects were presented and evaluated. Over 600 technical papers were presented by delegates from research organizations, industry, public sector organizations, academia and non-governmental organizations.

This report summarizes the main points that arose from GHGT-9. It highlights the progress made in CCS technologies, and the evolving policy and regulatory environment in which these technologies operate.

Summary of Key Messages from GHGT-9

Policy, Regulatory, and Overall

- There is a growing recognition of the need for CCS as a key climate change mitigation technology in the work of the IPCC and IEA. Overall, the main policy driver for all mitigation measures, not just CCS, will be national greenhouse gas (GHG) emissions policy.
- Demonstration projects are urgently needed to enable the world to 'learn by doing' in all aspects, both technical and regulatory. It is hoped that discussion at GHGT-10 will center on progress made regarding the G8 leaders endorsement in 2008 in Japan to implement 20 demonstration scale CCS projects. Even though the development of these large scale demonstration projects has been slower than what many would like to have seen, it is important to acknowledge that significant progress has been made in a number of key areas through laboratory scale work, modelling, and small field projects.
- Engagement with major developing countries such as China, India, and others has been growing but is still insufficient given the growth of electricity generation capacity in those countries.
- Regulatory developments for CCS have been rapid and positive in many regions since the last conference in 2006.
- A key characteristic of all the regulatory developments is the need for flexibility within them, particularly for issues such CO_2 purity and monitoring technique requirements. Flexibility allows learning from the early projects to be incorporated in the regulations as they are developed.
- From a business perspective, there is a need to improve collaboration among various CCS industry stakeholders. This would enable enhanced leverage of funding for various projects. Governments should assist with this process.
- The potential of CCS and biomass as an effective greenhouse gas mitigation technology should be realized, and recognized in emissions trading schemes.
- Public awareness is very important, and more work is required in this area. Public awareness will become more focused on projects and local issues rather than on the abstract concept of CCS in the future. The association between CCS and coal should also be deemphasized, as CCS also applies to other fuels and sectors.
- The insurance and finance industries have a growing interest in CCS, which is welcomed.

Capture of CO_2

Costs: Rather than coming down as expected, the cost of capture is now estimated to be 10–20% higher than it was five years ago, primarily because of escalating material costs in the period up to early 2008. The degree to which basic material costs will come down as a result of the current global economic crisis is yet to be known. However, the only way to confirm cost estimates is to actually start building demonstration plants and commercial CCS facilities. Over the long term there are several promising technologies, which are expected to significantly reduce capture costs.

Scale: New capture pilot plants have been and are being built around the world, particularly for post-combustion capture, and this represents real progress. However, we also need demonstration plants at a commercial scale for coal-based power plants (eg., capturing 2-4MtCO_2/year).

Energy penalty: There are some promising new solvents such as advanced amines and ammonia that offer the potential to significantly reduce energy requirements compared to conventional amines. Further testing and scale up is needed to rigorously quantify these benefits.

Technology: There are still three general capture options on the table (post-combustion, pre-combustion and oxyfuel) with activities in all areas being pursued. This conference, however, had a heavier focus on post-combustion systems than past conferences.

Integrated systems: Flexibility of CCS operations is important, particularly within liberalized electricity markets. New work streams on flexibility of capture systems, poly-generation and matching peak demand are making good progress, but need to move beyond just the capture system.

Storage of CO_2

Much work has been done on improving storage capacity assessments, which are moving from theoretical capacity estimates to more realistic understanding on the useable capacity. Knowledge has developed considerably in this area since GHGT-8 and this remains an area of rapid progress.

- As more knowledge and experience is acquired, there is a specific need for greater understanding of saline water displacement and pressurization in saline aquifer formations.
- Considerable progress had been made in understanding the trapping mechanisms that 'lock up' CO_2 and reduce the potential for leakage over time. In conjunction with rigorous site selection and characterization procedures and improved engineering design of storage projects, this will allow continued downward re-assessment of potential storage security risks.
- A variety of monitoring techniques continue to be improved and proven. An example is the demonstration of satellite monitoring at In Salah, Algeria showing that this technology can be included in the portfolio of standard monitoring techniques.
- Work in the area of geological storage is evolving from a technology perspective to an assurance based perspective.

"Preparations for the IPCC 5th Assessment Report have indicated that meeting low carbon stabilization limits is only possible with CCS"

Jae Edmonds
Joint Global Change Research Institute

Why do we need CCS?

Jae Edmonds, Chief Scientist at the Pacific Northwest National Laboratory's Joint Global Change Research Institute, set the context for the conference by looking at climate change and the role of CCS in climate stabilization. Over the period of 1750–2005 a total of 1100GtCO2 were emitted into the atmosphere globally. On current trends we are projected to emit a further 5240GtCO2 between 2005 and 2100. This means atmospheric CO_2 concentrations will rise steeply and will still be rising in 2100. These "business as usual" emissions must be significantly reduced to stabilize atmospheric concentrations. Stabilizing CO_2 concentrations at any level means that global CO_2 emissions must peak and then decline forever. However, the scale of the problem should not be underestimated. The graphs below put in context the amount of CCS that is currently occurring relative to the amount that will be required by 2100 to keep atmospheric CO_2 concentrations below 550ppm. Edmonds also pointed out that CCS is not limited to use with fossil fuel combustion. It can be applied to a wide array of large stationary CO_2 point sources including refineries, cement plants, and chemical production facilities. Beyond that, CO_2 can also be captured from the oxidation of bio energy-derived hydrocarbons. This combination of bio energy and CCS opens the door to actually reducing atmospheric concentrations of CO_2. Several recent studies have explored the potential for extensive deployment of bio-CCS to reduce global net CO_2 emissions below zero thereby enabling stabilization at CO_2 equivalent concentration limits of 450 ppm or even lower by the end of the 21st century.

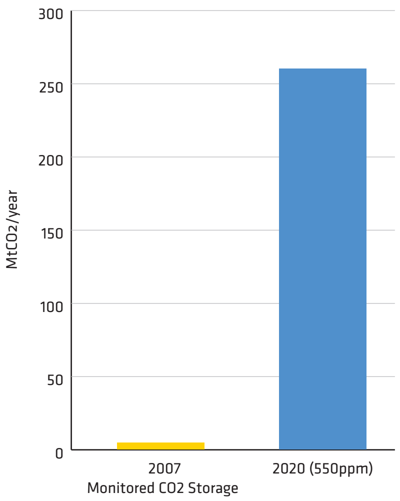
A price must be placed on CO_2 to stabilize CO_2 emissions. This price will have to increase over time as emissions need to be reduced. The price will be provided by some tax or market based mechanism such as the EU emissions trading scheme. Eventually all nations and economic sectors need to be covered as the atmosphere is indifferent as to the source of CO_2 emissions. If all sectors and countries are not included then the price for CO_2 will be higher.

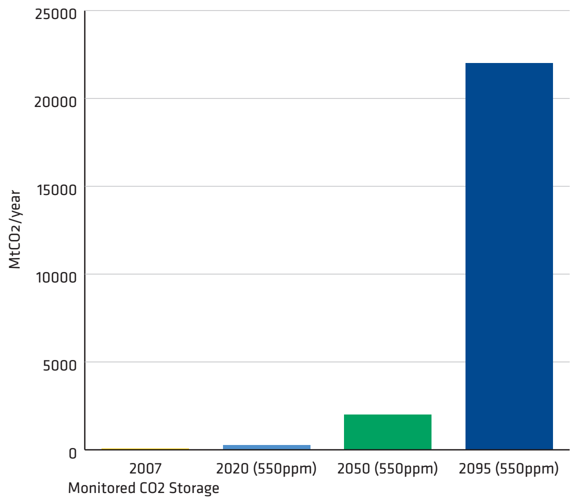
Stabilization of atmospheric CO_2 emissions requires a fundamental change to the global energy system. New technologies such as CCS will contribute significantly but there is no 'silver bullet' solution. The role of CCS depends on its location, technology and the price of CO_2 but it will not be constrained by the global storage capacity. Published estimates place the potential theoretical global geologic CO_2 storage capacity at approximately 11,000GtCO2. For stabilization scenarios of 450–750 ppm, most models show a cumulative demand of no more than 2,200GtCO2 of storage during the 21st century.

CCS capture technologies and overall CCS costs are heterogeneous with multiple capture and storage methods involved. The cost of capture of CO_2, ready to store, can range anywhere from US$9–80/t. The impact of CCS is very hard to predict when combined with cost variations in different markets. The role of technology in general and CCS in particular is to help society control the cost of limiting carbon emissions. Depending on the target stabilization level, CCS can reduce the cost of achieving the target by up to US $5 trillion between now and 2100.

Annual Rate of Deep Geologic CO2 Storage

Source: Pacific North West National Laboratory





What is the status of CCS?

Kelly Thambimuthu, Chief Executive Officer of the Centre for Low Emission Technology and Chairman of the IEA Greenhouse Gas R&D Programme (IEA GHG), gave an overview of the status of CCS technology and the challenges ahead. In 2006, at GHGT-8, international acceptance of CCS was seen as a major barrier to its deployment. By GHGT-9 in 2008, CCS has been accepted as a mitigation option under the Kyoto Protocol, is now legal under the London Convention and OSPAR Marine Treaties which regulate disposal at sea and is now included in the EU Emissions Trading Scheme.

The oil and gas sector has led the field on CCS deployment. For example, the Sleipner project, located offshore Norway, started injection in 1996. The Sleipner project captures 1MtCO_2/year from natural gas treatment for storage in a saline reservoir beneath the North Sea. Other commercial projects include Weyburn (Canada), In Salah (Algeria), Snøhvit (Norway) and Rangeley (USA) which capture, transport and store CO_2 in geological formations. The total annual storage of anthropogenic CO_2 from these 4 projects is now over 7Mt/year. Snøhvit also adds 160km of CO_2 pipelines to the global experience on CO_2 transport. There are over 4000km of CO_2 pipelines in operation globally. There are also a number of projects that will commence shortly. These include the US Regional Carbon Sequestration Partnerships Phase III projects and the Canadian Aquifer projects. These projects are expected to raise the total amount of CO_2 stored to over 24Mt/y by 2012. There is considerable activity in the developing world as well. Brazil is actively researching CO_2-EOR at the pilot scale and China has recently built its first CO_2 capture pilot plant.

The next big step globally needs to be the development and deployment of CCS in the power sector and in manufacturing industries such as cement and steel production. In the power sector, deployment of CCS must go hand in hand with increases in plant efficiency. Power plant efficiency is increasing steadily. State of the art hard coal plants currently operate at 47% LHV efficiency and gas plants at 55% LHV efficiency. These figures are expected to increase to 50% and 60% respectively, with the use of nickel based alloys in the heat recovery sections in power plants and new turbine designs.

For power generation, supercritical (SC) and ultra supercritical (USC) coal-fired plants and natural gas combined cycle plants are now proven and reliable technology. Post-combustion solvent capture processes still require scaling up and have not yet been integrated with the power cycle, so they are currently unproven at scale. For pre-combustion capture, coal based integrated gasification combined cycle (IGCC) is nearly commercial and is improving in reliability. There is also considerable experience with oil and pet coke fed IGCC. IGCC solvent capture units for CO_2 are available at scale but there are still issues concerning integration and power block hydrogen utilization. As far as oxyfuel combustion is concerned, currently there is no proven experience of operation of pulverised coal power plants in oxyfuel combustion mode. There are a number of pilot plants under construction that should demonstrate

“The momentum is building to demonstrate this technology but the real challenge we face is going from 10’s to 1000’s of plants by the middle of this century”

Kelly Thambimuthu
Centre for Low Emission Technology (cLET)

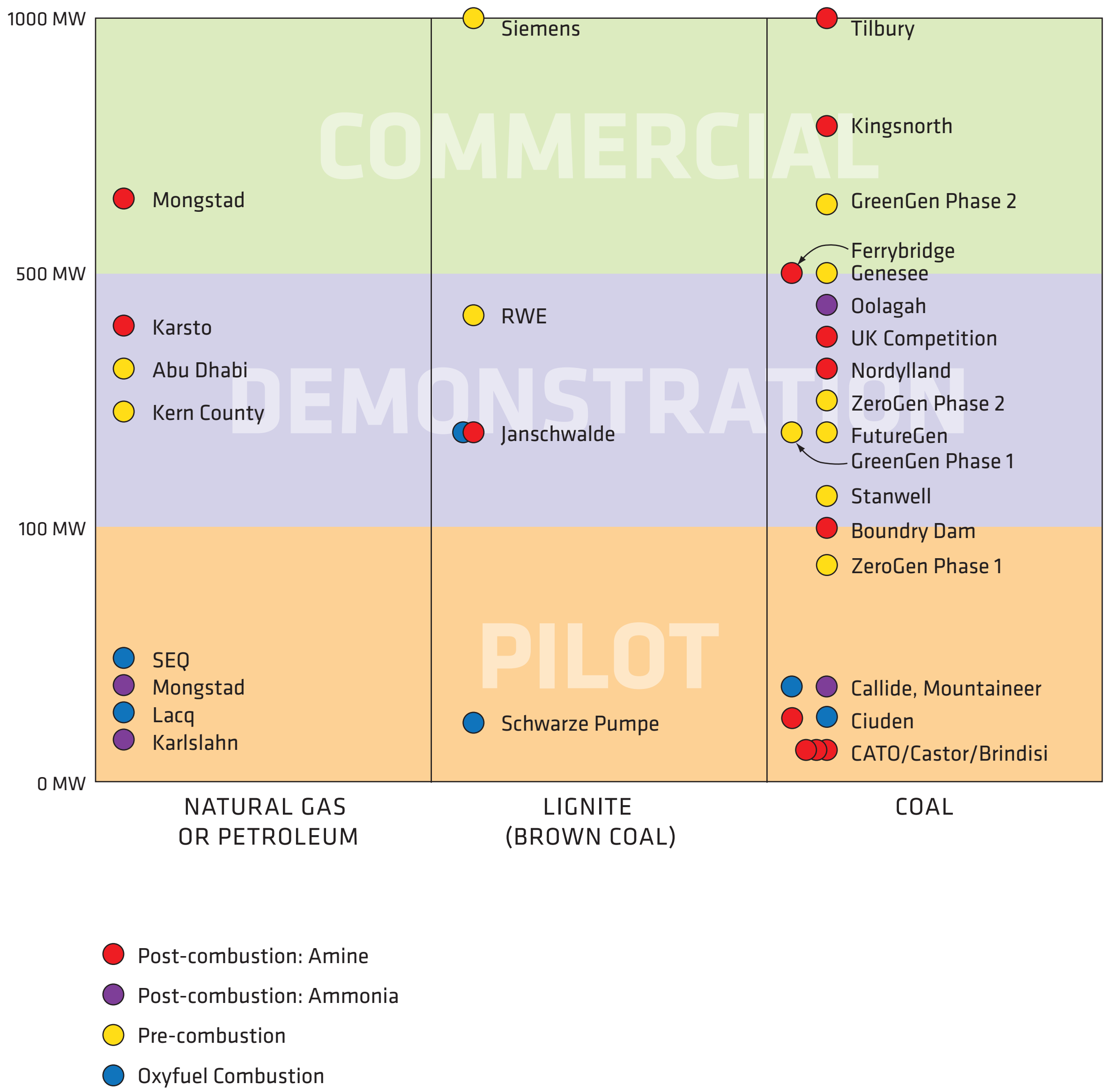
this technology in the next year. The next issue will then become one of scale-up. The components of the oxyfuel system differ in readiness. For example, large scale air separation units for O2 production are proven and reliable, while some development is required for tail end CO_2 purification, and CO_2 or hybrid turbines do not exist for oxy-fuel combined cycles.

However, there are planned and proposed demonstrations for all these technologies, as shown in the table below.

If all these projects proceed, then a range of technical combinations of fuels, capture technologies, and storage options will have been tested. This will build confidence in the future potential for wide scale deployment of CCS.

Planned and Proposed CCS Projects [Illustrative– June 2008]

Source: IEA Greenhouse Gas R&D Programme



What are the issues we need to consider?

“When should we start building commercial CCS projects? Five years ago.”

David Hawkins
National Resources Defense Council

The issues that need to be considered for CCS were addressed in a series of technical sessions at the start of the conference. These sessions were organized by the technical leads from the Programme Committee (Sally Benson – Stanford University, Jim Dooley – Pacific Northwest National Laboratory, David Reiner – Cambridge University, and Ed Rubin – Carnegie Mellon University). The results of these deliberations are summarized below.

CO_2 Capture & Integrated Systems

The key issues we need to address for CO_2 capture are:

How to reduce the cost of capture and the associated energy penalty These are two of the foremost issues that we need to tackle to make CCS more cost-effective.

The water usage of CO_2 capture plants This has the potential to become a significant issue as water resources become more valuable. Research is needed to assess how big an issue this might become.

Plant flexibility in integrated systems Plant flexibility is very important and is an additional challenge to the operation of the CO_2 capture plant. This is particularly so in a liberal electricity market environment where plant flexibility can dictate how the plant is used.

Defining capture readiness Questions still remain regarding the definition of what is ‘capture ready’ despite the work in this area by the IEA GHG.

Retrofit/repowering of the coal-fired power plant with CCS One of the prominent issues raised was how to adapt a CO_2 capture plant to an existing power plant and whether power plant refurbishment or rebuilding should be undertaken at the same time as retrofitting capture capability.

Regulatory assurance The power generation industry will need long term regulatory assurance to allow them to invest in capture technology.

> “There is no room for complacency in developing CO2 storage. In particular, site selection and characterization remains a key aspect in gaining public acceptance of major storage proposals.”
>
> **Trude Sundset**
> StatoilHydro

CO2 Storage

The key issues we need to address for CO2 geological storage are:

Storage capacity estimation Currently, there are two methodologies for estimating storage capacity, both of which deliver volumetric assessments that can be compared easily. However, the resulting estimates are ‘theoretical’ and do not allow for a variety of technical and economic factors that could reduce the actual capacity available.

The storage potential for deep saline reservoirs In 2005, the IPCC special report on CCS stated that deep saline reservoirs could be used to store up to 10,000GtCO2 worldwide, the approximate equivalent of the next 200 years of total anthropogenic emissions of CO2. The main challenge is to supplement these high level theoretical storage capacity estimates with more realistic site or region specific capacity assessment, by taking into account such factors as over-pressurization and brine displacement.

Understanding trapping mechanisms While it is widely believed that CO2 storage security increases over time, researchers need to understand better and to quantify the trapping mechanisms that determine the long-term fate of injected CO2. This would allow more accurate determination of storage capacities and better assessment of associated risks. These factors are of particular importance for saline reservoir formation projects, where greater potential storage capacity must be weighed against current greater uncertainty.

Quantifying the risks of CO2 geological storage Risks associated with potential leakage from storage formations need to be quantified for regulatory and public assurance. Such risks could include potential impacts on human health, ecosystems and shallow reservoirs suitable for potable supply. Induced seismicity constitutes another potential hazard but its potential impact needs to be assessed.

Policy and Regulation

The key issues we need to address are:

The CCS value chain To reduce the uncertainties, we need to pull together the whole value chain for CCS that connects the players from different sectors and the government.

The need to incentivize CCS The policy options that governments could use to incentivize CCS include: carbon taxes, greenhouse gas cap and trade schemes, a greenhouse gas obligation for power fleets, new plant performance standards, and direct payments for stored CO2.

The issue of liability There are a number of issues relating to the long term liability of the stored CO2 that need to be resolved. It is felt that concern about liability is often linked to lack of knowledge about key parameters such as the likely frequency and significance – if any – of long term leakage events.

CCS inclusion in the Clean Development Mechanism (CDM) This was seen as an important mechanism to enable CCS to be taken up in developing countries.

Post 2012 climate policy The international community needs to work together to develop a post Kyoto strategy encompassing both developed and developing countries.

Public awareness To gain public acceptance CCS must come to be seen as a valuable tool to fight climate change that can be used in many different economic sectors and not just a way to promote new coal-fired power plants.

> “Public opinion is an important resource, not a nuisance.”
>
> **Samuella Verceli**
> Sapienza University of Rome

What Did We Learn at GHGT-9?

“The cheapest capture options are always the ones furthest away from commercial deployment.”

Ed Rubin
Carnegie Mellon University

To understand how we addressed the issues raised during GHGT-9, a concluding panel comprising the technical leads was organized and facilitated by John Gale, General Manager of the IEA GHG. The panel members presented summaries of what they felt had been learned.

What Have We Learned about Capture?

The two key issues related to CO_2 capture are its cost and the scale of capture operations. Capture is known to be the most expensive component of the CCS process so any reductions in cost will have a significant impact on the overall commercial viability of CCS. However, because of recent escalations in plant construction costs, the estimated cost of capture is now 10-20% higher per ton of CO_2 than it was five years ago. However, there is no way of confirming these costs without building and operating the plants.

With regard to scale, many new capture pilot plants have been built in different parts of the world since the last conference, particularly for post-combustion capture systems, but also including one new oxyfuel pilot plant recently commissioned in Germany. However, we still do not have a demonstration of any capture technology at full commercial scale (2–4MtCO_2/year) on a coal-fired power plant. The demonstration plants currently planned hope to achieve this in the next 5 to 6 years through the combined efforts of government and industry working together to finance and build a number of large-scale demonstration plants.

Many new developments reported at the conference aim to reduce capture costs, such as through the use of improved modelling tools that allow the design of more compact and cost-effective plants. In regard to the energy penalty issue, there are several promising new solvents, including advanced amines and ammonia, that have potential to significantly reduce the energy requirements compared to conventional amines. This reduces both the capital and operating cost of plant capacity. There were also some concerns reported about the secondary effects of ammonia and amines leaving the stack, which need to be addressed. We expect further progress and resolution of all these issues when the results of pilot operations become available, most probably by the next conference.

"The CCS industry shouldn't limit itself just to coal. There are important opportunities to combine CCS with natural gas production in the near term and in the longer term biomass based electricity production"

Jim Dooley
Pacific Northwest National Laboratory

"We need to think about scaling up our activities, and going to 250Mt storage projects."

Sally Benson
Stanford University

The conference also affirmed that there are still three general capture options on the table – post-combustion, pre-combustion and oxyfuel – all of which are the subject of ongoing research and development. It was interesting to note however, that this conference had a heavy focus on post-combustion capture, more so than at previous ones. We saw a variety of promising new capture technologies moving from the laboratory to pilot scale and we expect to get more information and results by GHGT-10.

Finally, the conference also demonstrated that good progress has been made on technical issues related to integrated systems, with the creation of a whole new work stream on CCS flexibility, poly-generation and matching peak demand. This flexibility does, however, need to look beyond the capture systems to the whole CCS chain. Here too, we should see more results in this area by GHGT-10.

What Have We Learned about Storage of CO_2?

Many results were presented at GHGT-9 that emphasized the potential differences between theoretical storage capacities and more realistic figures. The importance of brine displacement and pressurization in saline reservoir formations was highlighted in several presentations. The effect of geological heterogeneity – natural variation in the properties of storage formations – was another factor shown to be important in determining storage capacity and efficiency. Overall, there has been continued progress on how to convert theoretical storage capacities to real, economic, and acceptable storage volumes, and the acceptance that storage is not infinite and not available everywhere.

Considerable progress had also been made in understanding the trapping mechanisms that serve to 'lock up' CO_2 and thus reduce the potential for leakage over time. The continued active research into these mechanisms, in conjunction with rigorous site selection procedures and improved engineering design of storage projects, should allow continued, downward re-assessment of risks associated with potential leakage.

There has been an 'evolving landscape' as a focus on technology that began in the 1990s has been complemented by an increasing focus on assurance issues involving the financial and business communities. In other words, key technical elements of strategy for CO_2 geological storage such as understanding storage and leakage mechanisms, site selection and characterization, storage engineering, operational safety, monitoring, remediation, and regulatory oversight, are now being joined with considerations of financial responsibility. Future focus will shift increasingly to a market-based approach to implementing CCS.

GHGT-9 highlighted some important novel concepts for geological storage including surface dissolution in saline formation brines, storage in seabed sediments, hydrate deposits, and deep sea basaltic formations. These alternative options show great early potential as future storage options and will be the focus of new research at later conferences.

What Have We Learned about CCS Policy and Regulation?

On the regulatory side, progress has been rapid and positive around the world, although there is still much to do in terms of implementation of regulation. A key characteristic of all the regulatory developments is the flexibility allowed within them, so as to allow learning from the early projects to be included later. An example of this is the non-prescriptive nature of requirements for site-specific monitoring techniques. This conference has shown the new realization for the potential for satellite monitoring to be included in the portfolio of standard monitoring techniques.

The conference has highlighted the benefits of sharing information across jurisdictions. Governments should assist industry in joining up the value chain for the CCS process, joining up different players from different industry sectors, and enabling the financial value to be identified within this chain.

One of the most significant recent developments in CCS has been the engagement of the finance and insurance industries. Their opinions were presented at 'The View from Wall Street' session where there was broad agreement that both sectors are willing to move ahead toward the goal of insuring CCS projects. For example, the insurance company Zurich said that they already have a CCS insurance policy and are in talks with project developers. Most importantly, none of the representatives in the session saw any major road blocks for CCS development aside from concerns about political risks and the direction of future climate change policy. With regards to specific CCS regulation, it is good to see the emergence of discussion on how policy can promote good behaviour and not just using taxes to protect against bad operators.

A straightforward way of including CCS in the post-2012 regime is to recognize it in an emissions trading scheme. Guidelines for this are already being developed in the EU ETS, but not yet in the CDM which may mean some natural gas-based CCS projects in developing countries could be prevented from progressing. Associated with this is that CCS should be recognized as more than just for use with coal generation. A new realization at GHGT-9 was that CCS with biomass may not be recognized in these emissions trading schemes, and thus not incentivized, so work is required on this issue. Market based mechanisms such as an emission trading scheme may not be the only way forward as many stakeholders advocate using emissions performance standards to incentivize the deployment of CCS.

Regarding public awareness there has been only slow progress. Research continues but more effort needs to be put into coordination to take best advantage of scarce resources. Public awareness will become more focussed on projects as real projects develop, and some incidents of NIMBY seem inevitable. On a project basis, local social assessments should be undertaken as well as geotechnical ones to determine the best locations. In addition, the rhetorical link between CCS and coal should be broken, and the message of the potential for CCS with biomass needs to be made more broadly, especially to engage environmental NGOs on the potential for negative emissions.

"We urgently need demonstration projects to enable the world to learn by doing in all aspects, both technical and regulatory."

David Reiner
Cambridge University

Challenges for the Next Two Years

Challenges Ahead for Capture

- What more can we do to reduce capture costs?
- Can we scale-up capture processes to the size required?
- For post-combustion capture:
    - How low can we reduce the energy penalty of solvents?
    - What are the options for new solvents?
    - Are organic amines and ammonia going to deliver the benefits claimed?
    - Do hindered amines and other low energy penalty solvents have any impact on the size and capital costs of capture plants.
- We need to identify any potential environmental impacts that exist in the life-cycle of capture system.
- We need to better understand water use requirements in capture plants.
- We need to be confident that we can retrofit CCS to existing power plants and industrial sites.
- We need to be able to validate the results from pilot and demonstration plants to ensure that we know which capture technologies are the most suitable for wide scale deployment.
- We need to understand the implications of CCS plants on power plant flexibility and what we can do to improve on it.

Challenges Ahead for Storage

- What are the implications of pressure build-up in the storage formation?
- For large scale injection, we need to know where the displaced water will go and what is the risk to groundwater.
- What will be the footprint of the CO_2 plume, how big is it, and where does it migrate? How can we make more reliable predictions?
- From prospectivity to selecting real sites… how do we gain confidence?
- Monitoring strategies and detection limits… what are the cost effective approaches for assuring local environmental protection and carbon emission accounting?
- In the unlikely event that a CO_2 leak occurs, what can be done to stop it? How much will it cost and how long will it take to fix?

Challenges Ahead for Policy and Regulation

- How best to promote the deployment of large scale CCS demonstrations?
- How do we increase engagement of the finance and insurance industries?
- Post-2012 climate change policy discussions must place a high priority on CCS.
- CCS needs to be encouraged in developing countries whether through inclusion in the CDM or other means.
- CCS must be viewed as more than just a coal-related issue.
- We must place greater emphasis on the opportunities for CCS with biomass.
- Governments must provide greater regulatory and political certainty at both the national and international levels.
- We need to build the expertise and human resources in CCS so that the needs for large scale deployment can be met.
- We need to improve public awareness and engage the public at a local level to encourage acceptance.
- We need governments to assist industry in joining up the price-chain for the CCS process.
- We need to increase involvement from major developing countries such as China and India.
- We need to improve communication about CCS by gaining a better understanding of the role of information and of the source providing the information.

The Challenge for GHGT-10

GHGT-10, the next conference in the series, will be held in the Netherlands in September 2010. In the next 2 years we need to address a number of issues to maintain the momentum to move the technology forward. These issues become the challenges we must address. These challenges effectively set the technical work scope for the next two years and we hope to report back on progress at GHGT-10.

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