GLOBAL CCS INSTITUTE

DRAFT DISCUSSION PAPER

POLICY, REGULATORY AND LEGISLATIVE WORKSTREAM

GLOBAL CCS INSTITUTE

CONTENTS

EXECUTIVE SUMMARY

The Global CCS Institute is seeking to build on its existing policy, regulatory and legal work to become a global leader in influencing carbon capture and storage (CCS) policy and program development. In this area, the Institute's activities are aimed at ensuring that global CCS deployment is based on well-developed policy approaches that reflect the wider public benefit worldwide as well as the interests of the CCS industry.

While nations have yet to agree on individual greenhouse gas (GHG) emission reduction targets (or any target for the period 2012) a number of countries did agree (in the Copenhagen Accord) to an ambitious objective of limiting the future increase in average global temperatures to two degrees Celsius. Achieving this would require very substantial reductions in GHG emissions, of between 25 and 40 per cent by 2020 and 70 to 80 per cent by 2050. This must occur in a framework where energy demand in 2050 is projected to be double the current level. A large percentage of the additional demand will come from developing countries, which are currently building coal-fired power stations at a rapid rate while being reluctant to be bound by emissions reductions targets.

The task ahead is a substantial one, and will require a huge change in the world's industrial processes, particularly as regards the unconstrained combustion of coal.

CCS technologies have the potential to play a substantial role in this transformation. The International Energy Agency (IEA) has suggested that if CCS does not achieve the level of commerciality required for it to play such a role, the cost of mitigation would be 70 per cent higher than otherwise. The IEA's blueprint also underlines the scale and urgency of the task, with its estimate that if CCS is to achieve a position where it accounts for 19 per cent of global GHG abatement in 2050, 3,400 CCS plants will need to be operating worldwide by that date.

If CCS is to play the role the IEA has projected, there are a great number of barriers to be overcome before the necessary investment of US$2.5–3 trillion will be forthcoming. The purpose of this paper is to explore how:

- policy and regulatory actions by governments can help to overcome these barriers; and
- the work of the Institute can be of benefit in influencing the outcomes.

This paper proposes three key areas of potential future activity for the Institute. They are:

- global climate change policy;
- policy action needed for rapid development of CCS; and
- specific regulatory issues.

To date, world leaders have failed to match their ambition in terms of addressing climate change with a strong global policy regime that imposes, explicitly or implicitly, a price on carbon emissions. Different and not necessarily mutually exclusive, avenues are available for achieving this, including a market-based approach (emissions trading or a carbon tax) and direct regulation (for example, restricting the combustion of fossil fuels). In the absence of a carbon price, investment in CCS technologies cannot provide a commercial return. This uncertainty about future policy imposes a high level of risk on potential investors in low emissions technologies such as CCS. There is an urgent need for governments to introduce carbon pricing consistent with achieving the objective endorsed in the Copenhagen Accord of limiting global warming to two degrees Celsius.

The existence of a widespread carbon pricing mechanism, however, is a necessary but not sufficient condition for substantial investment in CCS technologies. In some applications, such as electricity generation, other low emissions processes may be available at lower cost so that a rational investor will choose these technologies in preference to CCS. In other applications the carbon price may be insufficient to induce investment in CCS or the necessary infrastructure may not be in place. In these cases the option of paying the penalty for continuing to emit may be more commercially attractive.

Even with a widespread adoption of carbon pricing mechanisms, further policy actions by governments will be required to help overcome some of the barriers to widespread investment in CCS technologies and to reduce the risk for potential investors. These actions include providing strategic support for:

- the further innovation required to make CCS commercially viable;
- projects that demonstrate CCS technologies at scale; and
- investment in the essential enabling infrastructure required for achieving CCS.

In addition to these areas where substantial public funding may be required, governments will also need to play a major role in providing an appropriate regulatory framework for the industry.

The key question for the Institute is how it can add value by becoming involved in these four policy areas internationally, and specifically, how it can best incorporate a strategic policy initiative into its work program.

First, while the Institute has decided not to engage in funding innovation in CCS, it can still play an important role as a repository of knowledge regarding CCS innovation policies around the world.

Secondly, the funding of demonstration projects is a part of the Institute's charter, although one that would be difficult to discharge with its present level of funding. Under current circumstances, there is little incentive for the private sector to invest in risky demonstration plants, particularly in the absence of any certainty about the level of a carbon price going forward. Yet it is important that as many demonstration projects as possible can be commissioned by 2020 and in order to achieve this significant government funding will be required. As far as possible the pattern of government investment in these projects should emulate a balanced portfolio, both in terms of technologies and industries and geographical distribution. Because of the rapid growth and associated enormous investment in coal-fired power generation, it is of vital importance that a number of demonstration plants are constructed in developing economies. The Institute can play a significant catalytic role in identifying possible funding sources for these projects and helping to ensure that the required investment takes place.

Thirdly, if CCS is to play a major role in GHG mitigation by the middle of the century, the requirement for enabling infrastructure is very substantial. For example, to meet the IEA's projections to 2050, the construction of over 200,000 kilometers of pipeline for transportation will be required together with storage facilities for over 144Gt of carbon dioxide (CO_2). The private sector is very unlikely to invest in these facilities until it is confident that there will be sufficient commercial interest to justify the considerable capital expenditure. In view of the relatively short timeframe and the urgency and magnitude of the task, it seems inevitable that governments will need to be heavily involved, at least in the early years, both in the planning phases and in helping to fund the investments. The Institute must develop a policy approach so as to help play a role in working with governments to secure the necessary outcomes.

Finally, CO_2 can be hazardous, and industry generally has little direct experience of the risks and contingent liabilities in this area.[1] Capturing, transporting and storing CO_2 must occur within a comprehensive regulatory framework. It should be noted that the demonstration projects currently underway are generally governed by regulatory arrangements for the petroleum industry, where the underground storage of CO_2 is a mature technology. When CCS moves beyond the demonstration phase, an acceptable and secure regulatory framework will be essential to provide potential investors with the necessary confidence. The major issues are related particularly to storage of CO_2 and the resultant contingent liabilities, including in the indefinite future after a plant has ceased to operate. The IEA has made progress on designing a model regulatory framework for CCS. To avoid duplication, the Institute should work in close collaboration with the IEA in finalising this framework and then be available to assist governments in implementing it as required.

1 Industry has used carbon dioxide in food processes and food production for many decades and transfer of knowledge is therefore something that could be usefully pursued.

Figure 1 below, provides an overview of the proposed approach, to the Institute's work in this area and a high level timeframe.

FIGURE 1: GLOBAL CCS INSTITUTE HIGH LEVEL ROLES IN POLICY, REGULATORY, AND LEGAL ENABLER

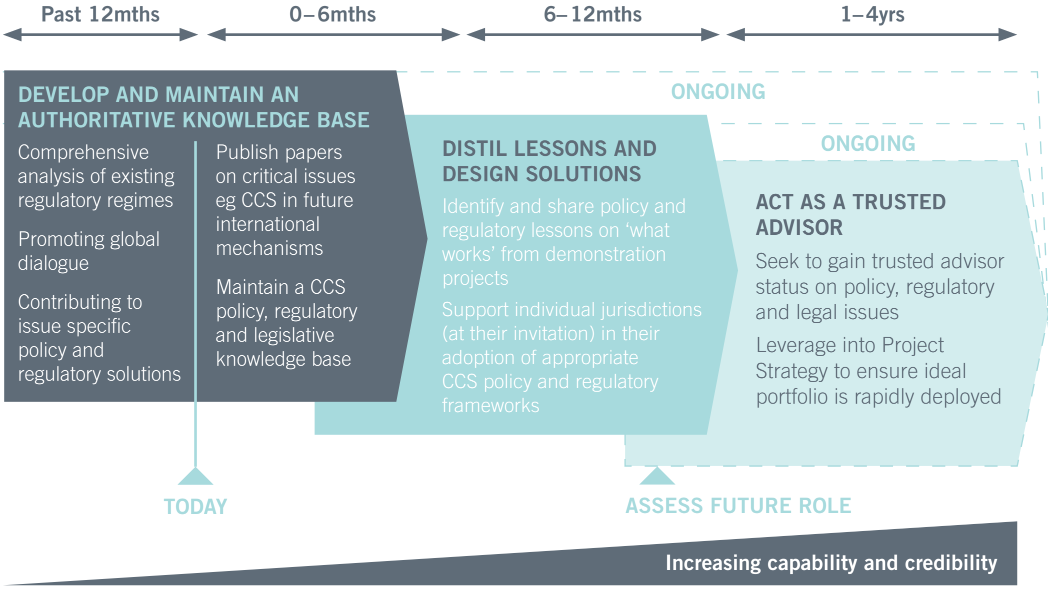


Table 1 below, sets out the proposed approach, including areas of focus and action. Attachment 1 contains more detail.

TABLE 1: GLOBAL CCS INSTITUTE: PROPOSED AREAS OF POLICY, REGULATORY AND LEGAL WORK

AREAS OF FOCUS	ACTIONS
GLOBAL POLICY APPROACH TO CLIMATE CHANGE	
Supporting a global policy approach to climate change	Maintain information on the global state of CCS including policy, regulatory and legislative development.
	Develop papers that support the case that technologies such as CCS are to be deployed to reduce GHG emissions in a substantial way.
	Provide regular reports on global policy innovations and emerging issues.
Supporting CCS in developing nations	Identify international funding options to accelerate CCS project deployment in developing nations.
	At the invitation of governments in developing nations develop a role in identifying promising CCS demonstration projects.
	Make the case that the CDM or something similar needs to continue after 2012 and ensure that CCS projects are included in future mechanisms.
ADDITIONAL POLICY ACTION TO SUPPORT RAPID DEPLOYMENT OF CCS	
Innovation, demonstration projects and infrastructure investment	The Institute will respond to requests from national governments and other stakeholders for policy, regulatory and legal policy and program advice.
	At the invitations of governments work with them as they develop policy frameworks in innovation, demonstration projects and infrastructure investment. Develop a series of papers that summarise policy experience in innovation, demonstration and infrastructure investment.
Demonstration projects	At the invitation of governments identify promising demonstration projects, particularly in developing countries, and helping individual governments to leverage the international funds required to develop them.
Infrastructure investment	Develop an understanding of the global infrastructure requirements of CCS and begin a conversation with governments in this regard.
REGULATORY ISSUES	
Supporting global development of effective regulatory and legal frameworks	Identify experience of legal and regulatory barriers and solutions. Work to address key priority legislative and regulatory issues including: • long-term liability issues; • permitting arrangements; and • technical and offset issues with CO_2 leakage. Assist individual nations, on their request, as they develop CCS regulatory frameworks based on the IEA model regulatory and legislative framework.

In order to become a credible player in above areas, the Institute must continue to develop its expertise so as to become the key 'go to' agency when governments require information or advice on CCS technologies and associated policy and regulatory issues. The Institute is already working in individual countries to provide a stronger understanding of CCS. The Institute is also acting to increase the understanding of project issues, financing options available for CCS projects and has signalled its intention to develop regional profiles to establish the status of CCS efforts and opportunities. This work needs to continue to be developed so that the Institute can work more closely and effectively with governments to accelerate the deployment of CCS.

Further opportunities would involve the Institute working with governments, collectively or individually, to develop a policy framework to support the faster development and deployment of CCS technologies.

The next phase in this process is to test the proposed areas of policy, regulatory and legal work for the Institute through discussion with Members and to develop a detailed work program.

1. CONTEXT

The development of CCS technologies and the associated establishment of the Institute represent only one element in what is intended to be a transformation in the way in energy is produced and used. It is driven by the realisation that continuing to emit large and increasing quantities of carbon into the atmosphere, primarily from the combustion of fossil fuels, could eventually have severe environmental consequences.

In principle, capturing and storing carbon emissions, rather than releasing them into the atmosphere, is one of the more obvious means of reducing greenhouse gas emissions. There are three broad applications for CCS. It is already being used to sequester CO_2 emissions from the production of oil and gas, where it has an associated application in enhanced oil recovery (EOR). This technology is now relatively mature and the extent of its use in the future will depend, in the absence of its value in EOR, on the level of a carbon price. The second area of application is to capture and sequester emissions from industrial processes. Since there are usually no competing processes in this application, the decision on whether to use CCS for this purpose or alternatively to purchase emissions permits (or pay a carbon tax or charge) will depend on the level of any carbon price at the time and the availability of the necessary infrastructure (pipeline and storage reservoirs). The application of CCS to electricity generation based on coal or natural gas is the third potential area of use. This application, which is a major focus of this paper, is the area where the possibilities in terms of reducing global carbon emissions are the greatest but where very substantial challenges exist. It is also an area where other low emissions technologies are available and so, in order to succeed, CCS needs to come to market at a competitive cost.

The continuing absence of widespread carbon pricing mechanism is an obvious barrier to the success of CCS. Even with a carbon price, one of the major barriers to the early deployment of CCS is its current cost, particularly in electricity generation application. Unless this is overcome, it can only make a very limited future contribution to reducing emissions from generating electricity. Other barriers include the lack of a comprehensive regulatory framework for the sequestration of CO_2 and a lack of clarity over which parties should bear the risks and contingent liabilities arising from the long term storage of CO_2.

These barriers are all, to a greater or lesser extent, susceptible to remedial policy action. Some positive outcomes from the 2009 Copenhagen Summit included the engagement of the world's two largest emitters, China and the United States, while the failure to reach an agreement on global policy action can be turned around, either this year or next. Financial support by government for further innovation in CCS technologies could help to make the process more cost competitive. Appropriate policies can be designed to support CCS deployment while regulatory frameworks are already being developed to determine an appropriate allocation of risk and liability. Alongside existing international organisations such as the Carbon Sequestration Leadership Forum (CSLF) and the IEA, the Institute can make an important contribution to this endeavor.

Role of the Global CCS Institute

The Institute aims to accelerate the commercial deployment of carbon capture and storage technologies. There are two preconditions for commercial CCS deployment. First, a portfolio of full-scale integrated carbon capture projects must be constructed to demonstrate CCS technology is cost effective at scale. Secondly, the policy, technical, financial and other enablers for CCS must be put in place to support both the demonstration projects and the broader commercial deployment to follow.

The Institute's work towards achieving these preconditions is undertaken as a set of work streams under a Strategic Framework (Figure 2). The framework includes four broad 'pillars' of Institute activity (areas where the Institute will interact with the global CCS stakeholder community). One of these is a set of 'enablers' (areas where significant work remains to be undertaken by the global CCS community). As set out in Figure 2, the six 'enablers' are: Policy and Regulatory; Financial and Commercial; Public Awareness; Technical; Capacity Building; and Knowledge Sharing.

FIGURE 2: GLOBAL CCS INSTITUTE STRATEGIC FRAMEWORK

OVERARCHING OBJECTIVE: "To accelerate the broad deployment of commercial CCS, ensuring that it plays a role in responding to the world's need for a low carbon energy future"

3 REGIONAL PROFILES AND GLOBAL SERVICES

1 ENABLING STRATEGIES

- Policy/Regulatory
- Financial/Commercial
- Public Awareness
- Technical
- Capacity Building
- Knowledge Sharing

2 PROJECTS STRATEGY

- Strategic Analysis of Projects
- Project Support Program
- Thematic Focus Groups

4 MEMBERS

Services Model
Member Charter

The Institute promotes progress on each enabling strategy by gathering information, developing a high quality knowledge base, codifying findings, undertaking analysis of priority areas for attention by decision makers, advocating for action on priority areas, and working closely with public and private sector stakeholders as they review options and make decisions.

Given the Institute's present funding base, it is not in a position to make a material contribution to directly addressing funding constraints at the project level. However, much essential information can only be gathered, and progress made, 'on the ground'. There is much more to be done than just the setting out of an objective fact base drawn from desk research. The Institute needs to undertake an active program of collaboration with decision makers in national CCS programs and proposed CCS projects, with tight integration between the Institute's 'enabler' work streams and the 'pillars' of activity. In some cases, direct financial support for project proponents may be appropriate in order to support proponents in sharing information, building networks, or undertaking other activities with significant benefit beyond the individual projects.

For each enabler, the Institute is in the process of developing its strategy and work plan. Having identified the major issues in the policy, regulatory and legislative space, the Institute is working to understand the most important areas where further work is required. Given its resources, capabilities and existing activities, the Institute can then assess how it can best promote progress in these areas and develop the appropriate work plan accordingly.

The present paper sets out a draft of the Institute's Policy, Regulatory and Legal Strategy and a preliminary high level work plan. The paper:

- provides a scene setting issues paper for the Members' Meeting in Pittsburgh in May 2010; and
- describes at a high level how and in what areas the Institute should act to promote policies and programs that would address some of the barriers to the success of CCS technologies.

Further development of the document is expected to include:

- substantiating early views about areas where progress is most critical;
- testing with CCS industry stakeholders the potential roles of the Institute canvassed in the high-level work plans; and
- converting the high-level work plans to more detailed and concrete actions with appropriate timelines.

2. THE NEED FOR URGENT ACTION TO DEVELOP CCS

Over the last two centuries, the world has experienced an extraordinary period of technological advancement, industrial development, productivity growth and improved standards. The most important enabling factor underpinning this story was the availability of low cost energy derived from the combustion of fossil fuels. In particular, the use of coal for electricity generation has provided the basis for growing industrial production, while oil has underpinned the global transport revolution and natural gas has increasingly offered an inexpensive source of heat.

It is only recently that a scientific consensus has developed to the effect that these economic benefits have come at a substantial cost to the global community. Carbon emissions from the combustion of fossil fuel are associated with a significant negative externality or spillover. High and increasing emissions have led to a build-up of carbon concentrations in the Earth's atmosphere and thereby to the enhanced greenhouse effect. While the world passes naturally through periods of increased warming and cooling, the greenhouse effect has overlaid these natural cycles with anthropogenic global warming. The scientific consensus suggests that this human-induced effect has been a major contributor to an increase in the Earth's average temperature over the last century. Although average global temperatures fluctuate from year to year, they do so around a longer term upward trend, with the ten warmest years on record having occurred since 1990.

The scientific evidence suggests that global warming is leading to a significant change in the Earth's climate. Much of this climate change is already in train. The challenge for national governments is to take coordinated, cost effective and urgent action to limit global warming to a level that would not be associated with catastrophic climate change. Measures taken to date, including those under the auspices of the Kyoto Protocol, have not succeeded in reducing the build-up of carbon concentrations in the atmosphere. Indeed, a recent acceleration of the rate of industrialisation in countries such as China and India and the associated greater investment in coal-fired electricity generation has led to an even faster rate of growth of carbon emissions into the atmosphere.

Responding to climate change

In the face of this threat, a collaborative concerted policy response to climate change is under development. This is necessarily a tortuous exercise because of a number of factors, including:

- uncertainties over some elements of the science and therefore the extent of the threat;
- different priorities between a number of countries (for many developing countries, climate change is a less pressing issue than addressing poverty);
- a view on the part of developing countries that their growth should not be constrained when the problem was 'caused' by the prior economic growth of developed economies;
- the cost of taking action, in terms of living standards being lower than otherwise; and
- the fact that the costs of taking action will be visible in the short term while any benefits will be gained only in the longer term, well after any current government has left office.

Over the last year, other concerns of a temporary nature have hindered progress towards a global agreement on measures to address climate change. Ameliorating the impact of the global financial crisis has been the main priority for governments, while publicity around some errors and omissions by eminent climate change scientists may have had some negative effects in public confidence in the integrity of the science. On the other hand, countries like China and India have become much more engaged in the process.

An important initiative taken in 2009, initially by the G20 countries and then by the nations represented at the Copenhagen summit, was to agree on an objective of restricting the average global temperature rise to two degrees Celsius. This would require the stabilisation of carbon concentrations in the atmosphere (CO_2-e) at a level of around 450 parts per million by volume (ppmv). To achieve this, with a current level of just under 430 ppmv, very substantial and rapid reductions in GHG emissions would be required of the order of:

- global emissions would need to peak by around 2016;
- emissions reductions of between 25 and 40 per cent from year 2000 levels would be required, at least by developed countries, by 2020; and
- global emissions reductions of 70 to 80 per cent from year 2000 levels would be required by 2050.

This represents a very high level of ambition, particularly when it is understood that the global economy is expected to be around three times larger by 2050 and world energy demand is projected to more than double over that period. The magnitude of the task is made substantially greater when it is understood that the growth in energy demand growth is heavily weighted towards non-OECD and developing nations, where the preparedness to take action to reduce GHG emissions tends to be lower than in developed economies. The IEA has estimated that, because of rapid economic and population growth, over 90 per cent of the increase in world primary energy demand between 2007 and 2030 will come from non-OECD countries. China and India are expected to account for 39 per cent and 15 per cent respectively of the global increase in primary energy use between 2007 and 2030. The bulk of this increase in demand will be met by coal-fired generation.[2]

One major implication of the global emissions reduction target of 70–80 per cent is that virtually no unconstrained combustion of fossil fuels—including natural gas, with its relatively low carbon footprint—will be possible by 2050. Traditional energy production will need to give way to very low and zero emissions technologies, such as CCS, nuclear power and a range of renewables. For the combustion of fossil fuels to continue to provide a significant source of energy, the associated emissions of carbon cannot be allowed to pollute the Earth's atmosphere. If they cannot be eliminated, they will need to be captured and stored in perpetuity. Clearly, as well as representing a substantial challenge, this situation offers significant opportunities to investors in alternative energy technologies, including CCS.

The urgency and scale of the task

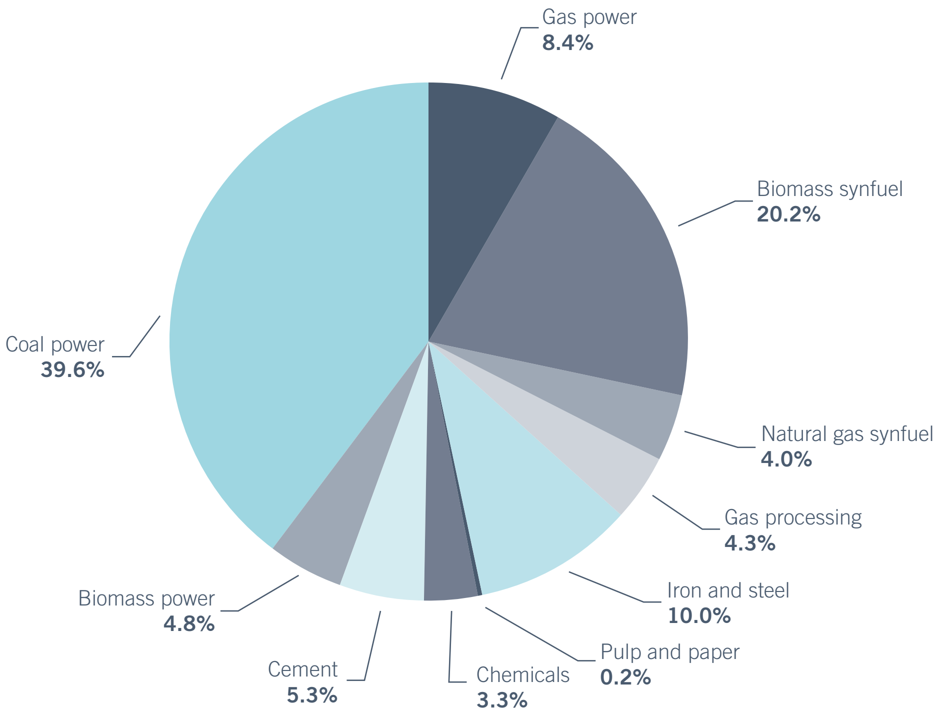
The challenge for the Global CCS Institute and the industry is to develop CCS technologies to the point of technical and commercial viability in time to make a significant contribution to meeting the 2050 emissions reduction target.

There are two aspects inherent to this goal. First, in the anticipation of the introduction of a significant carbon price, the potential of CCS technologies in reducing industrial emissions needs to be demonstrated at scale and the appropriate policy and regulatory framework for the supporting infrastructure established. Secondly, 'commercial viability' means that CCS will need to be able to compete in the electricity generation role with technologies such as nuclear power and renewables by around 2030 at the latest to provide time for large-scale deployment by 2050. Ultimately, investors in energy production will choose between various competing technologies on the basis of a trade-off between their cost and carbon footprint. For any application, no matter how technically efficient a particular solution may be, if it is not cost-effective it will not succeed in the market place where lower cost alternatives are available.

In this context, the IEA has produced a CCS Roadmap which tracks the required deployment of CCS. The Roadmap is based on an assumed global objective of reducing CO_2 emissions by 50 per cent from current levels by 2050, with CCS accounting for 19 per cent of global emission reductions by mid-century. The projected sector shares of CCS in 2050 are shown in Figure 3.

2 IEA (2009), *World Energy Outlook 2009*, p.76.

FIGURE 3: PROJECTED CCS SECTOR CONTRIBUTIONS TO GLOBAL MITIGATION IN 2050 (MTCO$_2$)



Source: IEA, *CCS Roadmap*

The immense scale of this task should not be underestimated. Under this scenario, which is based on an emissions reduction target substantially less ambitious than the one required to limit temperature rising by two degrees Celsius, the IEA considers that 100 industrial-scale CCS projects will need to be operational by 2020, with 3,400 in place by 2050. This would require an enormous undertaking in terms of infrastructure and storage capacity, requiring the construction of over 200,000 kilometers of pipeline for transportation together with storage of over 144Gt of CO_2 from 2010 to 2050. This is a significant increase from the current status of CCS and would equate to an investment of US$2.5–3 trillion.[3] It would require the commissioning of over 100 new projects, on average, per year between 2020 and 2050.

The IEA's work involves a number of assumptions regarding costs and technological change going forward. In terms of costs, for example, it is notable that in the IEA's projections the application of CCS to power generation accounts for over 50 per cent of the technology's contribution to CO_2 mitigation by 2050. This is clearly based on an assumption that CCS will become cost competitive in the electricity generation application, which at present it is not. As a recent joint Organisation for Economic Coordination and Development (OECD) and IEA report shows, nuclear power is setting the benchmark, in terms of cost, for generating base load electricity with low to zero carbon emissions in many developed economies.[4] While nuclear power will not be appropriate for every nation, if CCS is to succeed it will need to be reasonably competitive with nuclear energy and other low emissions base load technologies by 2030.This will require a very substantial reduction in the costs of CCS in the electricity generation application and one that will only be achieved by significant further innovation in the current demonstration phase of the technology.

3 IEA (2009), *Technology Roadmap—Carbon Capture and Storage.* The roadmap is based on the IEA's BLUE Map scenario, contained in the IEA's 2008 Energy Technology Perspectives. The outcomes in the BLUE scenarios rely on a number of assumptions, particularly concerning technological advances, and are not possible with the technologies available today. The roadmap was developed by the IEA on the basis of available information at the time, and is intended to be a 'living document'.

4 OECD (2010), *Projected Costs of Generating Electricity, 2010*, Paris, March.

Another assumption is that there will be little technological development in mature technologies going forward. While this might appear to be reasonable, recent developments in the gas industry demonstrate that such assumptions may not always accord with reality and how the situation can change very rapidly. In the last few years, the development of the process to extract coal seam gas (CSG) and the use of hydraulic fracturing ('fracking') to release so-called tight gas have the potential to add enormously to the world's reserves of natural gas. Already the development of an export liquefied natural gas (LNG) industry based on reserves of CSG is being seen. These technological developments have the potential not only to increase the availability of gas in many countries, but also to reduce its cost. With fuel accounting for around 30 per cent of the costs of combined cycle gas turbine (CCGT) power generation, this in turn implies that gas will become much more competitive with coal and renewables in producing electricity. In particular, by 2050 the relative shares of coal and gas-based generation may look very different from that shown in Figure 3. This suggests that there is a need for the CCS industry to increase its focus on carbon capture technologies related to CCGT generation.

The critical importance of CCS being cost competitive is illustrated by global economic modelling undertaken by the Australian Treasury (using the computable general equilibrium GTEM model) and published by the Australian Government in 2008. The modelling suggests that if CCS is to succeed as a viable electricity generation technology, by around 2050 it will need to capture and store up to 100 per cent of emissions at a competitive cost. If it is able to accomplish this, the modelling projects that CCS technologies will account for a little over 50 per cent of the global electricity generation market by 2100, with the remainder shared approximately equally by renewables and nuclear power. In the event that CCS is unable to achieve commercial viability at this level of mitigation, renewables will account for approximately 52 per cent of global electricity generation in 2100 and nuclear power for the remainder.

The Australian modelling finds that if CCS fails to achieve commercial viability, global mitigation costs will be around 10 per cent higher in 2050 than they otherwise would be.[5] The IEA has estimated that without CCS, the cost of halving emissions in 2050 would be 71 per cent higher per year.[6]

This shows the importance of the current demonstration phase in establishing technical and commercial viability for CCS technologies in the electricity generation role. It also provides a guide to the magnitude of the Institute's task.

The current state of play: CCS projects around the world

The CCS industry is operating in its demonstration phase, whereby it is important that investment occurs in a diverse portfolio of different CCS processes and technologies in order to derive the greatest possible benefit. In 2009, the Institute commissioned L.E.K. Consulting (L.E.K.) to develop an 'Ideal Portfolio' of CCS project types for prioritising the development of CCS projects in the demonstration phase. The Ideal Portfolio is defined by industry, technology and geography, and provides a framework to ensure that the different hurdles (technology-related, regulatory, political, financial) to global deployment of CCS are addressed. It also provides the means to increase our understanding of CCS technologies, to help to bring down the costs and to build public confidence in the technology as a viable carbon abatement strategy.

L.E.K. proposed that the Ideal Portfolio should comprise projects in:

- the largest CO_2 emitting industries (power generation, iron and steel, and cement) and industry sectors that already carry out CO_2 separation (gas extraction and processing, industries with H_2 production and other gasification processes);
- specific capture technologies, transport solutions and storage configurations with the greatest potential to significantly contribute to large-scale commercial CCS deployment in the target time frame. This would include a variety of capture technologies in each industry (for example, pre-combustion, oxy-combustion and post-combustion in the power industry), five different transport solutions (on-shore, off-shore back-bone and cross border pipelines, and a ship-based solution), and six different storage solutions including deep saline aquifers (structured and unstructured), gas fields and oil fields (both depleted and enhanced recovery); and

5 Australian Government (2008), *Australia's Low Pollution Future: The Economics of Climate Change Mitigation*, Canberra, page 127.
6 International Energy Agency 2008, *Energy Technology Perspectives 2008—Scenarios and Strategies to 2050*, July 2008.

- a variety of geographic locations, determined by the level of CO_2 emissions, the availability of suitable storage sites and the attractiveness of the policy and regulatory environment.[7]

In 2009, the Institute commissioned WorleyParsons to undertake the *Strategic Analysis of the Global Status of Carbon Capture and Storage*.[8] That report identified the level of CCS activity as including:

- 213 demonstration scale or larger CCS projects at various points in their project life cycle—140 projects were in the planning phase and 73 projects are active;
- 101 of these projects are at commercial scale; and
- 62 were fully integrated carbon-capture-storage projects—53 projects in the planning stage and nine projects are active.

When considering the location of CCS projects, 63 per cent of all projects and 70 per cent of integrated projects were in the United States and Europe. In addition, Australia, Canada and China each had a significant number of projects, including integrated projects. Very few integrated projects are in developing countries. There are seven planned or active integrated projects in just four developing countries: China, Algeria, Malaysia and the United Arab Emirates (see Figure 4A).

FIGURE 4: CCS PROJECTS BY COUNTRY AND INDUSTRIAL PROCESS, 2009

Figure 4A: CCS projects by location (demonstration and integrated)

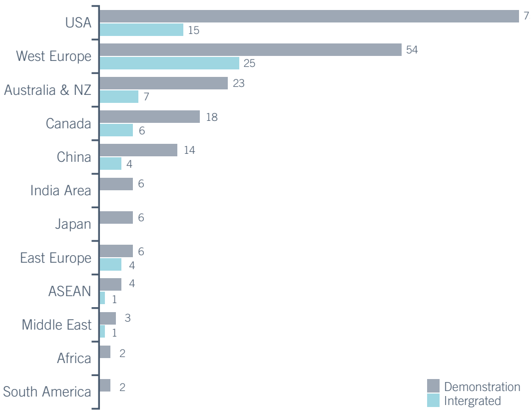
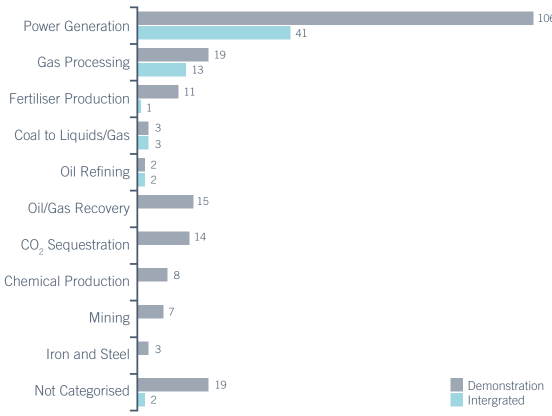


Figure 4B: CCS projects by industry (demonstration and integrated)



Source: WorleyParsons 2009, *Strategic Analysis of the Global Status of Carbon Capture and Storage, Report 5: Synthesis Report, Final Report* available at http://www.globalccsinstitute.com/

The distribution of CCS projects will need to be determined to a certain extent by where growth in energy demand occurs, and particularly where that demand is to be met by coal and gas-fired generation. As noted above, India and China are likely to account for a substantial proportion of the growth in fossil fuel-based energy generation. In the immediate future, developed countries will need to lead global deployment efforts for CCS. However, by 2050, the IEA has proposed that around 65 per cent of the targeted 3,400 projects should be situated in non-OECD countries. For example, in relation to CCS deployment in the power sector, almost one third of total projects will need to be located in China and India.[9]

CCS projects are active or planned in a wide range of industrial applications. Power generation accounts for around half of all demonstration projects, but this share increases to be 66 per cent of all integrated projects (see Figure 4B). Note that all of the 41 integrated power projects are still in the planning stages, meaning no

7 LEK (2009), *An Ideal Portfolio of CCS Projects and Rationale for Supporting Projects*, pp. 4–9
8 WorleyParsons 2009, *Strategic Analysis of the Global Status of Carbon Capture and Storage, Report 5: Synthesis Report, Final Report* available at http://www.globalccsinstitute.com
9 IEA (2009), *Technology Roadmap—Carbon Capture and Storage*, pp.16–17

active or planned, commercial scale, integrated CCS projects in the power generation sector have advanced beyond project sanction. Of these power generation projects, 38 use coal as a feedstock.[10]

With regard to carbon capture technologies, transport solutions and storage configurations, of the 62 active or planned, commercial scale integrated CCS projects:

- the majority identified the method as being either pre or post-combustion (with a broadly equal share between the two, and mainly related to coal-fired power), 13 of these were based on natural gas processing, and four oil refining. Only two projects indicated that oxyfiring would be used;
- in regard to transport modes, only three projects indicated that ship-based transport was an option. The remaining projects indicated that either pipelines would be used (ranging from on-site storage to over 300 km pipelines), or that the method of transport was as yet undecided; and
- storage methods are dominated by geological storage (39 in total, of which just over half are saline aquifers, and the remaining depleted oil or gas fields or unspecified), with enhanced oil recovery accounting for 16 projects, and one project involving enhanced gas recovery.[11]

The Institute's Project Strategy identifies that an Ideal Portfolio of CCS projects is dynamic in nature and will evolve over time in line with industrial, technological and geographical developments. By comparing the Institute's Ideal Portfolio with ongoing updates to current projects, the Institute will be able to identify gaps in the global portfolio of projects, allowing it to take action through strategic enablers and the program support facilities.

3. GLOBAL POLICY APPROACH TO CLIMATE CHANGE

Imposing a carbon price: risk and uncertainty with the policy process

With few exceptions, low emissions technologies such as CCS will not be attractive to investors unless policy action is taken to address the negative externality associated with carbon emissions.[12] This will lead to the introduction of a carbon price in order to reduce the attraction of investing in technologies with a high carbon content relative to lower emissions processes. The carbon price may be explicit, as it clearly is when market mechanisms such as emissions trading are applied or where there is a straight charge on carbon, as with a carbon tax. Other policy instruments give rise to an implicit carbon price, for example regulatory measures to restrict the unconstrained combustion of fossil fuels or instruments such as a mandatory renewable energy target. Some economists suggest that both types of measures can play a complementary role, such as an emissions trading system accompanied by regulations to restrict the unconstrained combustion of coal.[13] For example, if an investor chose to build a new coal-fired power generator even in the face of a carbon price, an associated regulation could mandate that the plant was built so as to be CCS ready.

The inconclusive outcome from the Copenhagen Summit in December 2009 means that there is, as yet, no global policy agreement in place to implement the expressed intention of the nations of the world to limit further global warming to two degrees Celsius. Key aspects of the Kyoto Protocol effectively terminate in 2012.[14] It seems clear that if countries are going to take significant action to reduce greenhouse gas emissions, a global agreement is required. Without this, nations with a more ambitious approach to tackling climate change will suffer economic disadvantage if they take significant action while other countries do not.

Not only will their industries lose competitiveness to countries that do not take action, but their policy initiatives will have little effect on reducing the rate of global warming. Ideally the significant work, individually and collectively, that governments have been undertaking since Copenhagen will be reflected in a global agreement, either at Cancún this year or in 2011.

10 WorleyParsons 2009, *Strategic Analysis of the Global Status of Carbon Capture and Storage, Report 5: Synthesis Report, Final Report*, pp.17–18, available at http://www.globalccsinstitute.com
11 WorleyParsons 2009, *Strategic Analysis of the Global Status of Carbon Capture and Storage, Report 5: Synthesis Report, Final Report*, pp.7–16, available at http://www.globalccsinstitute.com
12 In some market conditions, investment in hydro, geothermal or nuclear power might be profitable in the absence of a carbon price.
13 See, for example, Paul Krugman, 'Building a Green Economy', *New York Times*, 5 April 2010.
14 Specifically the legally binding quantified emissions commitments for Annex 1 Parties inscribed in Annex B of the Kyoto Protocol ends in 2012.

Currently, the further development of low emissions technologies is being severely hampered not only by the lack of an international agreement to introduce a carbon price but by a high level of uncertainty as to future policy. This means that investors in greenhouse-friendly assets face the considerable risk that, should their expectations of a carbon price not eventuate, their assets will be stranded at the outset. Many of the industries that will need to adjust to a carbon constrained environment are highly capital intensive and their investments are subject to significant commercial risks even before the carbon price uncertainty is taken into account. Commissioning a base load power generator, for example, can take up to ten years from inception, with a pay-back period of over 20 years and an economic life of up to 60 years.

Under these circumstances, the ongoing policy risk will give rise to inevitable delays in shifting the pattern of investment to low emissions technologies. This will mean either that the objective of limiting the temperature rise to two degrees will be impossible to meet or that the cost of doing so will be significantly greater than it need be. In the recent words of the CEO of one energy company, "it is unquestionably clear that if we have set a goal [for GHG emissions], even in the long term for 2050, the longer we delay pursuing that goal the more it will cost to achieve it, because we will continue to lay down the wrong mix of assets."[15]

A necessary but not a sufficient condition for CCS success

A carbon price (implicit or explicit) is a necessary but not sufficient condition for investment in the widespread deployment of CCS technologies. Some CCS projects may occur in the absence of a carbon price. The Gorgon LNG project in Western Australia, for example, has integrated CCS into its project engineering, but in a situation where retrofitting CCS would be considerably more expensive, this is in anticipation of the eventual introduction of a carbon price. It is not impossible that governments will support the construction of individual CCS plants in the short to medium term even if this is also in anticipation of a carbon price. But a significant carbon price, or the widespread expectation of such a carbon price, is essential in order to attract large-scale commercial investment in the deployment of most low emissions technologies, including CCS. In terms of the global commitment to attempt to limit the temperature increase to two degrees Celsius, the establishment of an international carbon price regime has now become a matter of some urgency if the required investment in the appropriate timeframe is going to occur.

Proponents may then wonder why is the application of a carbon price not a sufficient condition for the success of CCS as an enabling technology in a carbon constrained world. There are two issues here.

First of all, where no competing emissions reduction options are available, such as with many industrial emissions, a sufficiently high carbon price would be a sufficient condition for the application of CCS provided the appropriate infrastructure were available. Where the industrial activity takes place a long way from a suitable CO_2 storage reservoir, however, or where a lack of potential customers means that it is uneconomic to build a pipeline to ship the CO_2, then it is likely to be more cost effective to continue to emit the GHGs.

Secondly, the existence of a carbon price is not a sufficient condition for investment in CCS in cases where alternative low emissions technologies are more cost effective. While the same consideration regarding the availability of appropriate infrastructure also applies to the electricity generation application for CCS, for example, there is another important factor at work in this case. Although the existence of a carbon price would make CCS technologies in electricity generation more competitive relative to fossil fuels, the same will be true for all low and zero emissions electricity generation technologies. The key factor determining whether investors are attracted to CCS is its cost competitiveness relative to other low emissions technologies. In the current demonstration phase, the relative cost competitiveness of CCS in electricity generation would not make it attractive to investors in low emissions technologies, irrespective of the carbon price. Under current circumstances a very high carbon price would be required to ensure the commerciality of CCS projects. The *Strategic Analysis of the Global Status of CCS* identified that the cost of CCS for power generation, based on the use of commercially available technology, ranged from US$66 to US$112 per tonne of CO_2 avoided. This is significantly greater than the carbon price required to make nuclear, hydro, wind or geothermal technologies commercially viable. The report also showed that the production of steel and cement is associated with the highest percentage cost increases with the application of CCS, in large part because the capture of CO_2 is not inherent in the design of these facilities.

15 Grant King, Managing Director Origin Energy, 'Fuelling Growth: Australia's Energy Options', presentation to Committee for Economic Development of Australia, 13 April 2010.

Other policy measures, in addition to a carbon price, will be required if CCS is to become more attractive to investors. These are discussed in Section 4 of this paper.

Policy issues for developing nations

In terms of the need for early action to address global warming, the situation regarding developing countries raises some particular concerns. GHG emissions are generally increasing at a much faster rate in developing countries, particularly China and India, than in the developed world, with rapid growth in the commissioning of coal-fired power stations as well as emissions from transport and industry. According to the IEA, by 2030 deployment of CCS technologies in non-OECD countries will need to account for around 50 per cent of all CCS investments and this will grow to over 60 per cent by 2050.

A particular issue for the Institute is how to support mechanisms and approaches that will be required to fund demonstration projects for CCS technologies in developing economies. This must occur within the international financial architecture that is being developed to support both mitigation actions and the transfer of technology to developing countries. Understandably, the governments of most developing countries take the position that if they are to participate in international efforts to reduce emissions then the richer nations, which they see as being overwhelmingly responsible for causing global warming, will need to transfer to them low emissions technologies and know how as well as providing substantial financial support. Under the United Nations Framework Convention on Climate Change (UNFCCC), developed countries have a commitment to support developing countries with financing the incremental cost of mitigation measures. In the interests of supporting CCS deployment in developing countries, it is important for the Institute to identify and help leverage mechanisms that enable this transfer to occur in the most efficient, stable and predictable way.

Carbon markets, such as the offset market will play some role in delivering financing to developing countries. Under the Kyoto Protocol, Annex 1 countries can ‘offset’ their domestic emission caps by financing abatement in developing nations. The project-based Clean Development Mechanism (CDM) has been the key offset finance vehicle to date within the Kyoto Protocol. However, the CDM is limited in scope. Pending further guidance for the Conference of Parties serving as the Meetings of the Parties serving the Kyoto Protocol, CCS projects are not currently approved as CDM project activity. However CCS projects are fully eligible for Joint Implementation project activities. Nevertheless, as illustrated earlier in this paper, there has been minimal development and deployment of CCS in developing countries, whilst developed countries pursue rapid programs of development and deployment.

In the lead up to COP16, work is underway by Parties on reforming the UNFCCC financial mechanisms such as offset markets and establishing new mechanisms such as those provided in the Copenhagen Accord, Sectoral Mechanisms and Nationally Appropriate Mitigation Actions (NAMAs). It is extremely important that CCS is recognised positively and appropriately within these mechanisms if it is to play its role as a potentially significant mitigation option.

Global policy approach to climate change: How can the Global CCS Institute influence the outcome?

As the Copenhagen Summit showed, any global treaty on the future policy approach to climate change will be difficult to secure—all decisions in the UNFCCC and its Kyoto Protocol are made by consensus. Although many governments will attempt to make inputs into the process, ultimately the major emitters, that is the US, China and the European Union, are likely to be the major influences of the outcome.

Realistically, the views of agencies such as the Institute will have little direct impact on the outcome from these continuing negotiations on an international post-Kyoto agreement. What the Institute can do is to make the case, whenever and wherever possible, that a global agreement on reducing emissions in a substantial way is essential if new greenhouse-friendly technologies such as CCS are to be deployed.

In terms of developing countries, the Institute can also help make the case that the CDM, or something similar, needs to continue after 2012. The Institute could engage and influence international discussions to ensure that CCS projects can be eligible for inclusion in a future CDM-type mechanism. One way forward would be for the Institute to prepare a report for the Cancún conference later this year showing how this could be achieved.

Beyond the CDM issue, it is essential that a greater number of demonstration projects occur in developing countries, which will account for the major share of the growth in GHG emissions. The Institute needs to develop an influence strategy in this area. In addition, the Institute could play a role in identifying promising CCS demonstration projects in developing countries and in developing options to leverage the necessary funding for their deployment.

Finally, in support of achieving global outcomes, the Institute should act as a source of information on the global state of CCS including policy, regulatory and legislative development. This information should form the basis for the Institute to provide regular reports on global policy innovations and emerging issues.

4. ADDITIONAL POLICY ACTION TO SUPPORT RAPID DEVELOPMENT OF CCS

Introduction

As suggested in the previous section, the introduction of a carbon price is a necessary but not sufficient condition for the success of CCS. While a carbon price will reduce the cost disadvantage of CCS technologies (with a focus here mainly on electricity generation) it will do little to reduce the cost disadvantage of CCS relative to other low or zero emissions technologies. An important issue for governments, therefore, is the extent to which the public sector should provide financial support to assist the further (and urgent) development of the CCS industry. That issue is addressed in this Chapter. An additional and very important issue relates to the enabling regulatory and legislative framework that will be required to provide more certainty for investors in CCS technologies. This issue is addressed in Chapter 5.

One of the other Institute papers, dealing with the financial requirements of CCS development, concludes that a substantial financial contribution from government will be required if CCS is to succeed. This paper addresses the question of government financial support not from the CCS industry's viewpoint but from the perspective of government and the public interest. The key question for policy makers is not necessarily what the industry needs in order to succeed, but whether there is a net public benefits in providing the industry with the level of support that may be required to achieve this. If the response to this is in the affirmative, the subsidiary questions relate to the appropriate level of support and the form of assistance provided.

Apart from the regulatory framework for the industry, which will need to address some important issues on risk and contingent liabilities, there are three main areas where governments will evaluate the need to provide financial support to CCS development. These involve the provision of funding for:

- further *innovation*, in order to reduce the costs of CCS so as to make the technologies more attractive to commercial investors;
- building *demonstration plants* to test CCS at greater scale and reduce the perception of risk on the part of potential private investors by demonstrating the efficacy and cost effectiveness of CCS technologies; and
- developing the extensive *infrastructure* that will be required if CCS is commercially successful, including pipelines to transport liquid CO_2 and the acquisition and testing of suitable storage reservoirs.

Overall, the key question is whether it would be in the public interest for governments to commit funding to CCS development in circumstances where the likely level of investment by the private sector may be inadequate. A key issue here is timing, and government support may be essential if a substantial reduction in the cost of CCS technologies is to be achieved within the required timeframe. Such support for the development of the technology would be in addition to any enabling regulatory approaches discussed later in this paper.

Market failure: the economics of government assistance to the CCS industry

Policy action to support the development of any low emissions technology must be efficient, effective and equitable. If a government decides to provide financial assistance to a particular industry or project, it follows that other industries and projects may be worse off. Where assistance is provided to selected industries without being subject to strict economic criteria, the allocation of capital and labour resources between industries in the economy will be distorted. The history of trade protection in many countries has demonstrated that this is not generally in the public interest.

Economic principles suggest, at least in a world of efficiently functioning markets, that government assistance should only be provided on a selective basis if two criteria can be satisfied.

1. Evidence of market failure (positive externalities) must exist, that is without government assistance the private sector will commit insufficient resources to the activity in question from the perspective of the public interest.
2. Even where the first criterion has been satisfied, it needs to be demonstrated that the provision of government support is likely to lead to a superior outcome overall.

Far from living in a world with efficient markets and perfect information, the major externality associated with climate change creates a myriad of uncertainties. For example, the evidence from the climate science suggests that urgent action is required. The longer the world continues to emit large quantities of greenhouse gases, the greater will be the degree of global warming and the greater will be the negative externality imposed unequally on the world's population. Technological change is required to effect the required reduction in emissions and it is not clear that the private sector will invest sufficiently in new greenhouse-friendly technologies in the timeframe required. If this is the case, by filling the gap government can reduce the future impact of the negative externality associated with climate change.

The broader CCS industry may ask why the private sector will not provide adequate investment in CCS or other game changing technologies. There are a number of issues here.

First of all, there may be little concordance between what governments say needs to be done and the existence of the necessary signals in the market place to achieve this outcome. This causes significant uncertainty for investors. Governments have signalled a desire to restrict temperature rises to two degrees Celsius, an ambitious goal and one that requires immediate policy action to ensure that global emissions peak no later than 2016 and are reduced by between 25 and 40 per cent by 2020. If investors believed this would occur, a very substantial private investment in CCS and other technologies may take place. But the uncertain outcome from Copenhagen suggests that only weak market signals (in terms of carbon pricing) may be introduced in the next few years.

This will have a negative impact on investment in new technologies. Since global policy action is, in effect, determined by the ambition of the slowest mover, individual governments with greater ambition may see a strong case for bridging the gap between the total investment required and the amount provided by the private sector. One difficulty with this is that where the costs are borne by the individual countries that have the greater ambition, the benefits (reduced global warming) are necessarily enjoyed equally by the communities in those countries that do nothing (the free rider problem).

Secondly, the classic argument for assistance to R&D is that because private researchers may not be able to appropriate all the benefits from their research, under-investment is likely to occur. It seems likely that the appropriability issue is an important one in regard to investing in R&D in low emissions technologies. Since success in these endeavours will substantially reduce the cost of abatement, with associated major public benefits, it may well be that any private firm would be able to capture only a fraction of the full social returns to an innovation. This suggests that the resources devoted to innovation activities in low emissions technologies such as CCS will be lower than is desirable from the viewpoint of the public interest. Nevertheless, the argument for support is stronger in the earlier stages of the research and development spectrum where it is more difficult to appropriate benefits from research. This reflects the philosophy of providing public assistance to innovation in and demonstration of CCS technologies. Once the processes are ready to be commercially deployed, the argument for government assistance is much weaker.

Thirdly, there are major risks in investing in the deployment of CCS technologies. Again, there may well be a substantial divergence between the public benefits from accepting these risks and the expected private returns. The risks and uncertainties involved in investing in CCS have been identified in the companion paper to this one, relating to the financing challenges faced by the CCS industry (see Figure 5).

FIGURE 5: RISKS AND UNCERTAINTIES FACING INVESTORS IN CCS

	RISK	DESCRIPTION	IMPLICATION
Execution risks	Technology/ construction risk	• Risks associated with FOAK, including exploration, construction (delays, cost overruns) and performance risks across capture, transport and storage	• Projects may cost more or deliver less than expected • Proponent not willing to accept risk
	Contractual and integration risk	• Viability of each is value chain element dependent on the successful implementation of the others • Lack of precedent for complicated contractual agreements	• Delay in FOAK projects due to 'chicken-and-egg' problem
Operating environment uncertainties	Uncertainty around CCS policy	• Uncertainty around CO_2 and electricity price development given lack of clear long term government policy • Potential changes in long term legal / regulatory regimes on carbon / CCS	• Proponents unable to forecast return on investment to any level of confidence
	Obsolescence risks	• Lower cost of abatement options become available, making CCS relatively uneconomical	• Investment value may be written down if risk materialises
Long tail liability	CO_2 storage risk	• Liability potentially spanning hundreds of years • Considered to be low risk of incident, but with very large consequences	• Proponents reluctant to take on extremely long-term liability

EARLY ESTIMATES SHOW PV OF ~US$700M IN COSTS PER PLANT1

1. Calculation based on the average of the 26 plants in the ideal portfolio, using cost information from Report 2: Economic Assessment of Carbon Capture and Storage Technologies

Source: Deloitte Project Finance Facilitation Report, Report 2: Economic Assessment of Carbon Capture and Storage Technologies, BCG Analysis

Fourthly, there may be a further lack of alignment between the public and the private interest. Potential investors in new technologies may not have the same interest that the public has in developing a portfolio of technologies, rather than just focusing on one or two. Potential investors in carbon capture technologies for electricity generation, for example, face a substantial risk that their investment will never produce a commercial return. Alternative technologies, such as nuclear, hydro and geothermal are all currently significantly cheaper than CCS. While hydro is a mature technology, the others are continuing to evolve. They are all benefiting from ongoing investment in R&D that is likely to reduce costs still further.

From the perspective of the public interest, however, there are benefits in having a portfolio of available technologies to provide base load electricity with very low or zero emissions. All the available technologies have some disadvantages. Hydro and geothermal resources are limited to certain locations, while solar thermal has a massive physical footprint and requires superior storage techniques than are currently available to provide electricity on a continuous basis when the sun is not shining. While nuclear is now attracting substantial investment, the community is sensitive to the perceived risks in nuclear power as well as the problem of waste. While private investors may place little value on diversification, it may well be in the public interest to support technologies such as CCS in electricity generation in order to offset risk to future power supplies if problems arise with other options.

Finally, not all countries will derive the same level of benefits from the success of CCS. Nations that have substantial reserves of coal on their notional balance sheets, or countries with substantial sunk capital in a coal export industry, for example, may well enjoy greater benefits, including public benefits, from the success of CCS in electricity generation. The competitiveness of CCS in this role, for example, would provide major benefits to Australia, the world's largest coal exporting country. This may provide those nations with significant investments in coal export industries with a rationale to make additional contributions to supporting the development of CCS technologies. To the extent that assessment of the any individual government benefits of funding are bounded by national interests, then even national support for innovation activity will only target a fraction of the social value of addressing a global problem like the GHG emissions. Coordinating actions internationally can address this problem and ensure that duplicative efforts are reduced and that there is trade and exchange in knowledge.

Support for innovation

In order to reduce the costs of CCS in its potentially most important application, fossil fuel based electricity generation, substantial further innovation will be required. This will also need to occur in a timeframe constricted by the urgent need to reduce GHG emissions if global warming is not to reach dangerous levels. In light of this urgency and the general tardiness on the part of the international community to introduce a significant carbon price, the willingness of the private sector to provide the required level of risk capital to fund this major R&D effort must be open to serious doubt.

There is a strong argument for the government to provide support for further innovation in the industry so as to bring down the costs of CCS. Many innovation projects in this area are underway and the Institute could play an important role as a repository of knowledge regarding CCS innovation policies around the world.

Support for specific innovation projects is likely to come mainly from individual governments investing in R&D within their own jurisdiction. For example, an approach used by the UK Government to accelerate the development of low emission technologies, including CCS, is to partner with industry to create the Energy Technologies Institute (ETI) (see Box 1).

BOX 1—ENERGY TECHNOLOGIES INSTITUTE

The ETI has been provided £1 billion over 10 years to bridge the gulf between laboratory proven technologies and full scale commercially tested systems. This ETI aims to:

- increase the level of funding devoted to R&D to meet the UK's energy goals both domestically and internationally;
- deliver R&D that facilitates the rapid deployment of cost effective low carbon energy technologies. Exceptionally, this may include small demonstration projects;
- provide better strategic focus for commercially applicable energy-related R&D in the UK;
- connect and manage networks of the best scientists and engineers both within the UK and overseas, to deliver focused energy R&D projects to accelerate eventual deployment; and
- build R&D capacity in the UK in the relevant technical disciplines to deliver UK energy policy goals.

Source: www.energytechnologies.co.uk

Support for demonstration projects to reduce risk

While some CCS technologies are well developed, at least in their application to industrial emissions, they are still surrounded by a level of risk that may make them unattractive to private investors and financial institutions. Risks considered here relate to first mover exposure, the inability of the technologies to work effectively at scale and, overwhelmingly, cost (other risks concerning leakage and contingent liability are considered in Chapter 5). First of a kind (FOAK) projects are typically not commercially viable and the first mover disadvantage needs to be addressed by government.

In order to provide confidence to private investors, the technologies need to be demonstrated at a cost effective scale. Unless it is confident of a large potential market for its technology and its ability to appropriate substantial benefits, a private sector entity is unlikely to provide all the funding required for a demonstration plant (although it may be reasonably expected to provide a share of the funding). At least some public funding will be required, perhaps at a significant level. There is evidence that governments are recognising the need for this support and moving to directly support large scale CCS projects (see Box 2).

BOX 2—EXAMPLES OF CURRENT GOVERNMENT SUPPORT FOR CCS DEMONSTRATION PROJECTS

- the UK Government has launched a £1 billion competition to award funding for a large scale CCS demonstration;
- the Norwegian government has in the last few years provided approximately US$1 billion to CCS, most of this to the Karsto and Mongstad CCS projects;
- the Australian Government has announced that it will spend up to AU$120 million on prefeasibility work to assess four CCS projects as part of its flagships program which provides AU$2 billion for large scale CCS demonstration; and
- the US and the EU announced US$3.4 billion and €1.050 billion to support the development and deployment of large scale CCS as part of their GFC recovery plans.

It is important to note that government support for CCS plants will not be a permanent part of the landscape. The intention is for government to demonstrate the technologies at scale and in an environment where there is no established regulatory framework dedicated to CCS. Most demonstration projects will occur under the regulatory frameworks developed for the oil and gas industry, where carbon sequestration is a mature technology.

Support for infrastructure investment

As the IEA projections show, if CCS is to make a significant contribution to GHG mitigation by 2050, very considerable investment in associated infrastructure will be required. Not only will suitable storage reservoirs need to be acquired and extensively tested for their structural integrity, but an enormous pipeline network will be required worldwide. Ultimately most of this investment will need to come from the private sector. In the absence of external support, the private sector is unlikely to see this as a commercially attractive opportunity for many years to come. The risks of carbon capture technologies not being taken up at any scale are too great.

Given the urgency of the mitigation task, if the infrastructure is to be in place when it is required governments will need to play a role in ensuring the necessary investment takes place. There are a number of options ranging from government ownership of the infrastructure through private/public partnerships to joint ventures and leasing the infrastructure to private interests. This is very much a matter for individual jurisdictions. Again, the role for the Institute is in helping to develop policy approaches that deliver effective and efficient infrastructure investment.

The work of the Carbon Storage Taskforce in Australia is an example of the early work required by policy makers to develop robust policy approaches (see Box 3).

BOX 3—DEVELOPING A BASIS FOR NATIONAL CARBON MAPPING AND INFRASTRUCTURE PLAN

In 2008, the Australian Government established a carbon storage taskforce to develop the national carbon mapping and infrastructure plan. The taskforce noted that if CCS was fully deployed, Australia would require 5,000km of pipeline infrastructure to transport CO_2.

In order to develop the infrastructure required for the demonstration and deployment of CCS, the Taskforce recommended that:

- a nationally consistent approach to CO_2 pipeline regulation be developed;
- awareness and capacity building activities be conducted for regulators, industry operators and the public, so that CO_2 transport and injection infrastructure can be developed and operated safely in Australia. It was also noted that the program should primarily draw on existing international experience in CO_2 pipeline construction and operations, supplemented by a targeted R&D program designed to complement international programs;
- investment in emissions hub-storage basin combinations that are lowest cost, and optimise initial infrastructure design for anticipated future loads be prioritised;
- national and local planning activity is coordinated to ensure options for strategic pipeline corridors for potential future use are retained; and
- deployment of lowest cost options that are more likely to remain economically competitive against other energy generation options in the longer term (30–40 years) are prioritised. The taskforce noted that early learnings should be used to demonstrate proof of concept and identify opportunities for cost reduction, before committing to longer distance pipelines.

Source: http://www.ret.gov.au/resources/Documents/Programs/CS%20Taskforce.pdf

Additional policy action to support rapid development of CCS: How can the Global CCS Institute influence the outcome?

Although in the medium to long-term CCS will be supported and driven by the international carbon market, in the period up to 2020 the cost requirements for early-stage demonstration plants are extremely challenging. Hence both recognition of CCS by the market as a creditable mitigation technology and a substantial public contribution to the funding of the projects necessary to bring CCS to fruition, in both developing and developed countries will be required. Government support will be required in three areas, namely innovation, demonstration projects and infrastructure investment.

What role should the Institute play in advancing these policy issues and seeking some resolution by governments? The Institute is already acting to increase the understanding of financing options available for CCS projects. For example, in a brokering role the Institute is conducting Financing Round Tables such as in April 2010 in Washington. The Institute has also signalled its intention to develop regional profiles to establish the status of CCS efforts and opportunities. That work will help guide the particular regional focus of the Institute's efforts. More generally, and as currently occurs in relation to capacity building, it is also reasonable to expect that the Institute will respond to requests from national governments for policy, regulatory and legal policy and program advice. Recent work undertaken by the Institute at the request of the Indonesian and Malaysian Government is shown in Box 4.

BOX 4—OVERARCHING REGULATORY AND LEGISLATIVE REQUIREMENTS FOR CCS

At the request of the respective governments, the Institute has organised CCS Workshops in Malaysia and Vietnam (in partnership with Alstom Power), and has also sponsored workshops in Indonesia and South Africa, which were delivered by the Institute's partners organisations.

The purpose of the workshops is to help build knowledge and awareness of CCS. Workshop participants are drawn from both government and industry. CCS technical, commercial and community engagement issues were discussed. In addition, the workshops consider the role for government in establishing the required regulatory and legal frameworks.

Conducting these workshops provides a platform for future dialogue between these governments, the Institute and our partner organisations.

An important future role for the Institute is to work with governments, at their invitation to assist in the development of policy frameworks in innovation, demonstration projects and infrastructure investment. In relation to innovation, it is important that the Institute develops the knowledge base to bring together agencies and companies around the world pursuing similar or complementary lines of innovation. This work is anticipated to take place under the Knowledge Sharing strategy. The Institute could potentially act in a brokering role in this area. Secondly, at the invitation of governments, the Institute could act in identifying promising demonstration projects, particularly in developing countries, and assisting individual governments to leverage the international funds required to develop them. Thirdly, the Institute could develop a mud map of the global infrastructure requirements of CCS and begin a conversation with governments in this regard.

The necessary investment in CCS development is likely to come from individual governments helping to fund projects within their own jurisdictions. The Institute could usefully explore the possibility of working with governments to help select promising projects for support. Initially, one possibility is for the Institute to develop a series of papers on the three key policy areas identified above.

5. REGULATORY ISSUES

Investors in CCS technologies and processes will need to have confidence in the regulatory framework surrounding their industry. CCS involves a large number of regulatory issues, ranging from safety and security to third party access to pipelines and reservoirs. Designing an effective regulatory framework, particularly for carbon transportation and storage, raises some challenges peculiar to the industry. At the same time, in order to support the establishment of demonstration plants in the short term and commercial investment in CCS in the timeframe required if the industry is to make a significant contribution to GHG mitigation, an intense focus on regulation is required in the immediate future. Box 5 describes the IEA's recommended overarching regulatory and legislative requirements for CCS as well as proposing a timeframe for initial action.

BOX 5—OVERARCHING REGULATORY AND LEGISLATIVE REQUIREMENTS FOR CCS

The 2009 IEA CCS technology roadmap proposes that the development of CCS requires countries to:

- review existing legal and regulatory frameworks for their ability to regulate CCS;
- identify legal and regulatory barriers or gaps; and
- create a comprehensive CCS regulatory framework if required, by 2020.

The Roadmap also recommends that reviews and adaptations to existing legal frameworks be conducted in the following timeframes:

- 2011 in OECD countries;
- 2013 in early-mover non-OECD countries; and
- 2015 in all non-OECD countries with CCS potential.

Public awareness and regulation of public consultation requirements for CCS are also significant regulatory issues. These issues are not considered in this paper as they will be addressed through a standalone work program developed in Institute's Public Awareness Enabling Strategy.

Significant work is already underway to address regulatory issues and promote the rapid development of regulatory frameworks for CCS. Key contributors to this work include the IEA and the CSLF. For example, the IEA is currently developing a 'model' legal and regulatory framework for the CCS industry (see Box 6).

BOX 6—IEA MODEL LEGAL AND REGULATORY FRAMEWORK FOR CCS

The IEA is developing a model framework to provide governments with a tool to assist in the development of national legal and regulatory frameworks. This framework will be non prescriptive in nature and draw on existing CCS legal and regulatory developments in Europe, Australia, the USA, and elsewhere.

It is expected that the framework will provide the background information on the 30 key issues listed below and present examples of model text that could be used. In addition, the framework will provide alternative options and recommendations as to the types of situation in which they may be applied for some of the more contentious issues.

Issues addressed in the IEA's model legal and regulatory framework:

- Scope and prohibition
- Closure and post-closure obligations
- Financial security
- Definitions and terminology
- Transfer of responsibility
- Property rights
- Project boundaries
- Long-term liability
- Public engagement
- Exploration permit
- Corrective measures in case of CO_2 leakage
- Transboundary cooperation
- Site selection
- Transportation of CO_2
- Marine legislation
- Permitting of storage operations
- Third party access to storage site and transport infrastructure
- Demonstration framework
- Environmental impact assessment
- Composition of CO_2 stream
- Competition with other resources
- Monitoring and verification
- Health and safety
- CCS and biomass
- Inspections
- CO_2 classification
- CCS and enhanced hydrocarbon recovery
- Liability for leakage during operation
- CCS incentives
- Interaction with other legislation

Regulatory issues are discussed below. Some of the discussion is drawn from the outcomes of a conference, funded by the Institute and held recently in the United States.[16]

Storage of carbon dioxide

The most complex regulatory issues relate to the underground storage of CO_2. The issues span the need to develop monitoring, verification and accounting techniques (primary, secondary and potential additional technologies); establishing responsibilities and liabilities pre-operation, operation, closure and post-closure; and application of environmental assessment processes.

16 Capture & Storage Global Legal Symposium, 15–16 March 2010, New York University, New York USA.

Key issues requiring resolution relate to developing protocols for monitoring, measuring and verifying the behaviour of CO_2 in its storage site. Currently, it is not possible to accurately measure the volume of CO_2 that is stored in a particular site. This has implications for greenhouse gas accounting standards and the capacity of individual countries to demonstrate that they are meeting any international mitigation obligations. Further, as discussed above, there are also issues about how to react should unexpected emissions arise in the storage sites.

There is also the associated issue of health and safety in the context of underground water supplies.

A major issue relating to storage concerns the stewardship of storage reservoirs and longer term liability issues when the storage sites are full. There are many complex issues here regarding the duty of care under common law and the role of government in the longer term (see Box 7 below).

There is also a view in industry that when a CCS project terminates that government should take over liability for any leakages of the CO_2 produced by that project since the responsible company will not be around anymore. While clearly that would be one option, a parallel with the nuclear industry offers an alternative solution. The accepted practice these days is for an allowance for end of life nuclear plant decommissioning, including the disposal of waste hitherto stored on the site, to be built into the electricity price. A similar approach could be adopted for CCS, with a charge for future insurance against contingent liabilities being incorporated into the price of electricity or other commodities produced with a CCS-based process. Revenue from this charge could be paid into an interest bearing industry fund.

In some countries, more difficult issues relate to property rights to the storage space in circumstances where oil, gas and other minerals tenement holders have existing rights to underground space. There is the issue that the underground sequestration of CO_2 can have unforeseen impacts on the recovery of oil and gas from adjacent tenements. These issues also impinge on the development of protocols for third party access to underground storage space and to the surface land, where a separate set of property rights may exist. Finally, there is a question as to the circumstances in which commercial enhanced hydrocarbon recovery operations (or EOR) can be properly considered as a permanent storage component to a large-scale integrated CCS project.

At present there is very little incentive for the private sector to explore for suitable sites for CO_2 storage. This is mainly because the widespread application of CCS is far from certain, while proving a site takes many years and the costs are high. Nevertheless, this situation could change at any time, when it will be important to have a regulatory framework in place that supports not only exploration but also testing the physical integrity of potential storage sites.

BOX 7—APPROACHES TO LONG TERM LIABILITY ISSUES

Legislation has been developed in various jurisdictions to account for long term liability for CO_2 leakage. These developments have largely followed the polluter pays principle whereby the operator has regard to the long term storage stability. However, some governments are beginning to accept some levels of responsibility for long term liability in order to accelerate CCS project deployment.

Australia

Australia provides an example of the differing levels of responsibility governments are willing to take regarding long term liability. Under the amendments made to the *Commonwealth Offshore Petroleum Act 2006*, the Australian federal government assumes statutory indemnity for long term liability 15 years after injection operations have ceased.

In contrast, the Queensland and Victorian State Governments have no indemnity and common law liabilities remain with the storage proponent indefinitely. The legislation in Victoria and Queensland also provides for the payment of bonds against the cost of rehabilitating storage sites. This includes post well closure.

The Western Australian Government has taken a different approach to liability by enacting the project-specific *Barrow Island Act 2003*. The Act provides that Joint Venturers under the Agreement will indemnify the State against third party claims, except in respect of State negligence. The agreement does not specifically exclude common law liabilities and it is likely that the proponent will be subject to common law liability, as is the case with the other state regulatory models.

The EU

In the EU, the operator of a storage site remains responsible for maintenance, monitoring, reporting, and corrective measures following closure. These obligations will eventually transfer to the relevant member State once certain conditions have been met. These conditions include:

- that all available evidence indicates that the stored CO_2 will be completely and permanently contained;
- that a minimum period (no less than 20 years) has elapsed unless the member State is convinced that the stored CO_2 will be completely and permanently contained;
- that the operator has provided an adequate financial contribution to the anticipated costs of monitoring for a period of 30 years; and
- that the site has been sealed and injection facilities have been removed.

The US and FutureGen

Like the Gorgon example in Australia, the state of Illinois was prepared to provide project specific indemnification for liability and to accept title to the stored CO_2 post-injection in order to guarantee the FutureGen project. It could then sell carbon offsets associated with the sequestered gas to a willing buyer. It is important to note that these developments were directly related to the competition between Illinois and Texas to gain the FutureGen project and that this development would not necessarily have wider application.

Carbon capture

The regulatory issues around carbon capture relate to safety and security concerns. Safety standards will need to be developed to ensure the physical integrity of the carbon capture process. This is particularly important in new applications, such as electricity generation, since industries such as oil and gas already have well established processes for stripping out CO_2 at or near the wellhead. As discussed above, potential new investors in CCS in electricity generation are concerned at their common law duty of care obligations and the risks and contingent liabilities involved. A well founded regulatory framework could provide a degree of comfort to investors.

The second issue here is that the capture process must be subject to a rigorous carbon accounting methodology. It is essential to know exactly how much carbon is being captured, particularly where there are important financial considerations. There would be significant savings if carbon accounting standards could be developed on an international basis because this is one area where global consistency is particularly important.

Transporting CO_2

If CCS becomes a large-scale abatement mechanism, major new pipeline networks will be required. Again, there are a number of areas where regulation will be required.

The first issue once again is safety and security. This will be particularly important where pipelines pass through areas of high population density. The safety issues are similar to those applying to gas pipelines and it seems likely that there would be little difficulty in adapting regulations governing gas pipelines to those shipping CO_2.

Associated with this is the need to have a clear definition of CO_2 relating to purity standards. Some hazards can occur if there are impurities in the CO_2 and this issue needs to be better understood. Regulations are required to cover monitoring corrosion in pipelines. Standards also need to be determined for limits on compression and operating pressures.

There are also some restraints on pipelines crossing national borders. While these are currently being addressed by governments and draft protocols have been agreed for cross-border transport, it may take a long time before the amendments to the London Protocol are ratified.[17]

Finally, there are some significant issues around third party access to CO_2 pipelines and storage reservoirs. These facilities, where they are few, may be regarded as natural monopolies where the public interest is best served by regulating third party access so as to attempt to mimic a competitive outcome. Once again, a regulatory code could be established based on access to gas pipelines; conceptually, at least, the issues are similar. Once a network of pipes and storage sites has been established within a jurisdiction, third party access may no longer be required and the best outcome may be derived from facilities based competition.

Regulatory approaches to date

Individual countries are developing and implementing policy approaches to these issues. For example, the EU has issued a Directive that states that while member governments have the right to determine which sites within their jurisdiction should be available for CO_2 storage they must ensure there is no discrimination against other interests. The Australian Government has developed draft legislation in regards to storage sites in its offshore jurisdiction (onshore sites lie within the jurisdiction of State governments). Two US States have legislated to the effect that the holder of property rights to the surface land has the right to inject CO_2 into the underground pore space. The IEA has been active in responding to these issues and for example, is well advanced on a CCS Model Legal and Regulatory Framework (see Box 6).

Regulatory issues: How can the Global CCS Institute influence the outcome?

Clearly this is a critical area and significant work needs to be done. The goal of the Institute's activities in this area is to work collaboratively, building on the work done to date and taking steps where needed to accelerate the global deployment of CCS.

The absence of effective regulatory and legal frameworks fosters uncertainty for industry and this can be a disincentive to private sector investment. While industry would benefit from an internationally-based regulatory framework for CCS, realistically this is very unlikely to occur. Existing regulatory frameworks—for gas pipelines and third party access, for example—reflect different philosophies between jurisdictions and these are likely to be adapted to the requirements of CCS.

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17 The London Protocol is one of the first global conventions to protect the marine environment, and has been considered a barrier to the implementation of CCS in terms of sub-seabed storage. Amendments have been agreed to the Protocol to provide specific guidelines for assessment of carbon dioxide streams for disposal into sub-seabed geological formations.

Nevertheless, a robust regulatory framework is required to support private investment in the industry and it would be helpful to have as much consistency as possible between the protocols developed in different jurisdictions. Specific issues are:

- efficient, effective and equitable management of long-term liability issues;
- ensuring workable permitting arrangements are in place; and
- improved understanding the implications of the different approaches to treating CO_2 leakage both technical and offset issues.

In addition, to help the rapid development of regulatory frameworks in individual nations, the Institute should seek to work collaboratively with the IEA in completing this framework. If individual jurisdictions then invite the Institute to work with them in implementing the framework, or in adapting it to their own particular legal and regulatory regime, this would constitute a further valuable area of work.

6. SUMMARY OF PROPOSED ACTIVITIES AND NEXT STEPS

The paper:

- provides a scene setting issues paper for the Members' Meeting in Pittsburgh in May 2010; and
- describes at a high level how and in what areas the Institute should act to promote policies and programs that would address some of the barriers to the success of CCS technologies.

The chapters have proposed a series of activities for the Institute intended to progress the policy, regulatory and legal frameworks for CCS. Table 1 below, summarises these proposed activities and high level approach. This table is provided to facilitate discussion about both the proposed activities and approach.

Further development of the document is expected to include:

- substantiating early views about areas where progress is most critical;
- testing with CCS industry stakeholders the potential roles of the Institute canvassed in the high-level work plans; and
- converting the high-level work plans to more tested, concrete and timetabled actions.

ATTACHMENT 1: GLOBAL CCS INSTITUTE: PROPOSED AREAS OF POLICY, REGULATORY AND LEGAL WORK

AREAS OF FOCUS	ACTIONS	APPROACH
GLOBAL POLICY APPROACH TO CLIMATE CHANGE		
Supporting a global policy approach to climate change	Maintain information on the global state of CCS including policy, regulatory and legislative development.	Build on existing knowledge-base. Link to projects and financial and commercial work.
	Develop papers that support the case that technologies such as CCS are to be deployed to reduce GHG emissions in a substantial way.	The Institute staff to develop with input from Working Group.
	Provide regular reports on global policy innovations and emerging issues.	Build on existing reports. Work collaboratively with CCS organisations.
Supporting CCS in developing nations	Identify international funding options to accelerate CCS project deployment in developing nations.	The Institute staff to work with governments and Members to develop an influence strategy.
	At the invitation of governments in developing nations develop a role in identifying promising CCS demonstration projects.	The Institute to build capacity and work with individual governments.
	Make the case that the CDM or something similar needs to continue after 2012 and ensure that CCS projects are included in future mechanisms.	Prepare a report for the Cancun conference in 2010 showing how this could be achieved.
ADDITIONAL POLICY ACTION TO SUPPORT RAPID DEPLOYMENT OF CCS		
Innovation, demonstration projects and infrastructure investment	The Institute will respond to requests from national governments and other stakeholders for policy, regulatory and legal policy and program advice.	Develop expertise and build relationships.
	At the invitations of governments work with them as they develop policy frameworks in innovation, demonstration projects and infrastructure investment. Develop a series of papers that summarise policy experience in innovation, demonstration and infrastructure investment.	Collaborate with partner organisations and members to develop policy frameworks.
Demonstration projects	At the invitation of governments identify promising demonstration projects, particularly in developing countries, and helping individual governments to leverage the international funds required to develop them.	Bring project knowledge to engage with governments and funding organisations.
Infrastructure investment	Develop an understanding of the global infrastructure requirements of CCS and begin a conversation with governments in this regard.	Develop knowledge and engage with governments and industry.
REGULATORY ISSUES		
Supporting global development of effective regulatory and legal frameworks	Identify experience of legal and regulatory barriers and solutions.	Work collaboratively with Members and CCS organisations such as IEA and CSLF. Commission reports as required.
	Work to address key priority legislative and regulatory issues including: • long-term liability issues; • permitting arrangements; and • technical and offset issues with CO_2 leakage.	Work collaboratively with Members and CCS organisations such as IEA and CSLF. Commission reports as required.
	Assist individual nations, on their request, as they develop CCS regulatory frameworks based on the IEA model regulatory and legislative framework.	Work collaboratively with Members and CCS organisations such as IEA and CSLF.