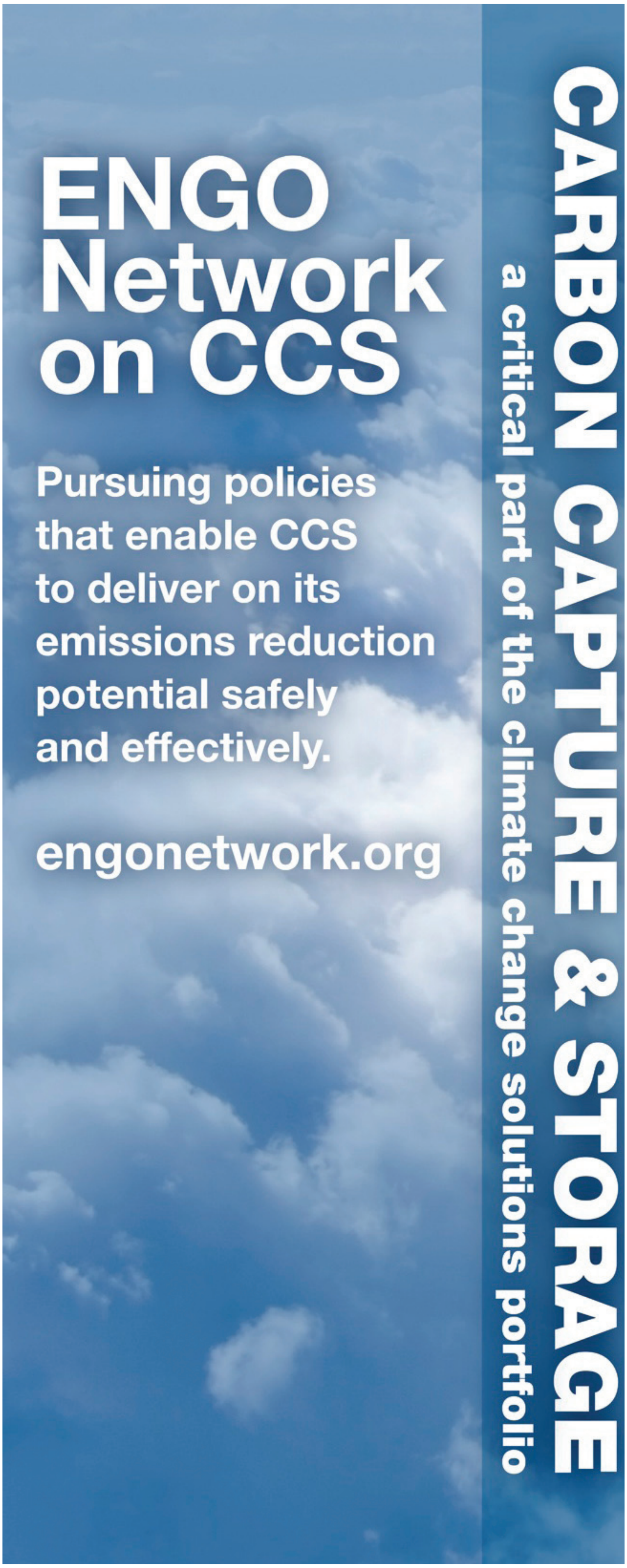

Environmental Non-Government Organisation (ENGO)

PERSPECTIVES ON

Carbon Capture and Storage (CCS)

Written by members from the international ENGO Network on CCS:

Clean Air Task Force

The Climate Institute

E3G

Natural Resources Defense Council

The Pembina Institute

World Resources Institute

Zero Emissions Resource Organisation

ABOUT THE INTERNATIONAL ENGO NETWORK ON CCS:

Created in 2011, the ENGO Network on CCS comprises organisations coming together around the safe and effective deployment of CCS as a timely mitigation tool for combating climate change. Because urgent reductions in greenhouse gas emissions are needed to prevent dangerous climate change, a variety of innovative solutions is necessary. Given the world's current and projected reliance on fossil fuels, CCS should be considered a critical mitigation technology that will provide faster and deeper emission reductions. The mission of the International ENGO Network on CCS is to pursue domestic and international policies, regulations and initiatives that enable CCS to deliver on its emissions reduction potential safely and effectively.

OUR SHARED GOALS INCLUDE THE FOLLOWING:

- ensure that CCS is performed and regulated safely, effectively and according to best practices, in a manner that protects our climate, human health and the environment;
- disseminate scientifically sound and objective information on CCS technology;
- work toward common positions and responses to international developments in the CCS arena;
- work to phase out the construction of new unabated, conventional coal-fired power stations as soon as possible, with CCS playing a part of the solution. In developed countries, no new, conventional coal-fired generation should be constructed without CCS; and
- work to incorporate CCS in other types of fossil-fired power generation, industrial sectors, and in combination with sustainable biomass.

CREDITS AND DISCLAIMERS:

Members of the ENGO Network on CCS are not expressing a position of support or opposition on any of the projects mentioned in this paper, rather merely including them for reference. This paper was made possible through funding from the Global CCS Institute, in the interest of broadening the discussion on CCS as a key climate change mitigation option. The views contained in this paper do not necessarily represent those of the Global CCS Institute or its members.

Introduction

Climate change is a pressing environmental problem that threatens human health, security and prosperity. The world's scientists have concluded that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level."[1] Anthropogenic emissions of greenhouse gases are responsible for the bulk of these trends, and unless we aggressively curb the carbon emissions[2] that cause climate change, the results will likely be disastrous. Climate change is not only an environmental problem, but also a public health, national security and prosperity problem: all of these dimensions are threatened if we do not take prompt action.

In order for global average temperatures to remain within bounds that may avoid the dangerous impacts of climate change, global CO_2 emissions would need to peak within the next decade, and decrease at the very least by 50-85% compared to year 2000 levels by mid-century.[3] The more we delay the needed reductions, the higher the degree of warming that the planet is locked into. The continued increase of greenhouse gases as a result of human activities poses a structural challenge to global energy systems and economies.

Fortunately, a number of technologies are available to mitigate emissions, although not as yet deployed at the scale necessary. These include increasing efficiency and reducing demand in all energy-consuming sectors, switching to renewable and lower carbon energy sources, increasing carbon uptake in forests and soils, and carbon capture and storage (CCS).

WHY CCS?

CCS is an important tool in the fight to reduce global carbon emissions for a range of reasons. Here, we look at several core motivations for the deployment of CCS.

The first reason is that it offers a pathway to reduce emissions from fossil-fuelled stationary sources. The heaviest carbon legacy that we have to deal with today is the vast installed base of fossil-fuelled industry. This base is projected to grow in most future economic scenarios, and would result in unacceptably high carbon emissions without policy action.[4] The bulk of the growth from current levels is expected to come from developing countries (Figure 1), even though industrialised countries are historically responsible for the majority of emissions to date.[5] In particular, emissions from the use of coal (mainly for power generation) present the largest need for CCS application due to their magnitude and also the long average lifetime of coal-fired power generation infrastructure[6] (Figure 2).

The sheer size of this installed base today and under common scenarios makes it a daunting proposal to try and replace it entirely through truly sustainable pathways such as efficiency and sustainable renewable energy and fuels. Even if such replacement were technically possible (and credible country analyses say that it is), very large economic, political and social inertia would need to be overcome for this to happen. Developing countries in particular may pose a greater challenge, since they must solve two problems simultaneously: rapid economic development and controlling emissions. Today, despite significant progress in increasing energy efficiency and tapping into renewable energy sources, the default mode of meeting increased electricity demand often remains the construction of fossil-fired power plants. CCS offers a pathway to curtail emissions from these plants, now or in the future.

1 Intergovernmental Panel on Climate Change; Climate Change 2007, Synthesis Report, Summary for Policy Makers.

2 Carbon dioxide from fossil fuel use represents about 57% of the world's greenhouse gas emissions, and about 74% if deforestation, biomass decay and other sources are also considered. Based on 2004 data. See id and http://epa.gov/climatechange/ghgemissions/global.html.

3 This corresponds to a concentration of CO_2-e of 445-490ppm in the atmosphere, which we know to be a weak target already. See id. Current consensus points to a level of 350ppm as a safer threshold.

4 See, for example, US Energy Information Administration; International Energy Outlook, 2011.

5 Id.

6 Which can routinely exceed 50 or 60 years.

From the standpoint of the environment and organisations advocating for its protection, it is not prudent to bet solely on such a large-scale transformation of the world's energy system. A balanced and hedged approach, at the very least, dictates having contingencies in place in case the shift away from fossil fuels takes longer than planned or desired. CCS offers precisely such a capability to dramatically reduce emissions from fossil fuel use both at existing facilities and at future ones.

It is worth noting that the applicability of CCS to fossil fuel infrastructure stretches beyond coal feedstocks and power generation. Although it remains true that this is where the greatest need lies, due to the large relative size of global emissions from coal-fired generation, CCS can and should be used with other fossil fuels too, and in non-power applications (which we discuss later in more detail). In particular, certain parts of the world are experiencing a rapid expansion of natural gas production and use. In the US, for example, widespread development of shale gas and tight gas resources has resulted in a decoupling of natural gas prices from the global oil price. The increased supply and suppressed price has led to increased gas use, and to displacement of coal use. The prospects today call for this trend to continue. Widespread use of gas, however, is not compatible with climate mitigation goals. Despite the lower carbon intensity of gas-fired power generation, which at the point of combustion is roughly half that of coal,[7] expansion of gas use will lead to unacceptable levels of emissions.[8] As such, CCS should also be used in natural gas applications.

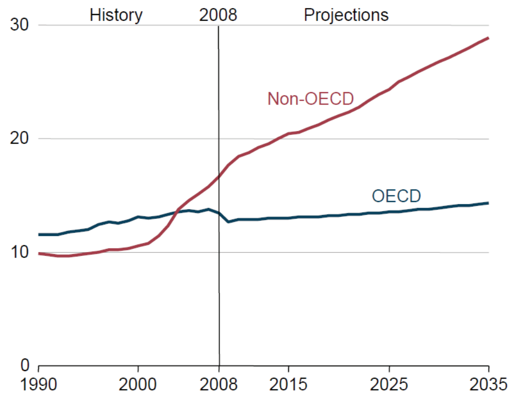

FIGURE 1 World energy-related carbon dioxide emissions, 1990-2035 (billion metric tons).
Source: US Energy Information Administration; International Energy Outlook, 2011.

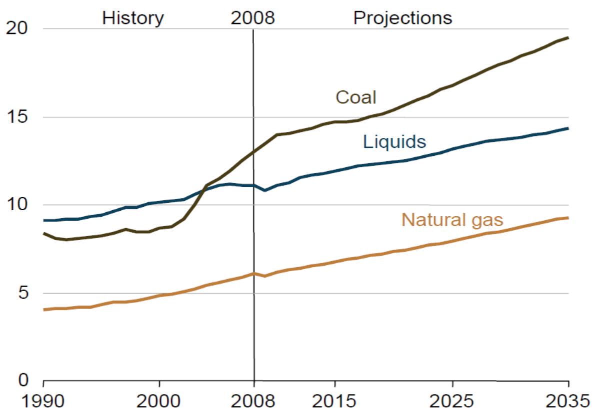

FIGURE 2 World energy-related carbon dioxide emissions by fuel type, 1990-2035 (billion metric tons).
Source: US Energy Information Administration; International Energy Outlook, 2011.

7 For baseload generation.

8 See for example: Special Report, Annual Energy Outlook 2011, "Are We Entering the Golden Age of Gas?", International Energy Agency; N P Myhrvold and K Caldeira, "Greenhouse gases, climate change and the transition from coal to low-carbon electricity", 2012 *Environ. Res. Lett.* 7 014019

A second reason is that the deployment of a portfolio of technologies is not only likely to increase the probability of delivering economy-wide emission reduction outcomes, but is also likely to result in lower overall costs of mitigation. The scale of emission reductions needed to combat climate change means that no single measure or technology is going to be able to deliver those reductions alone on the scale required.[9] Although the exact mix of technologies is impossible to predict with accuracy, it is important to realise that several mitigation tools working in unison will result in deeper and faster emission cuts, as well as lower overall costs. This is because a 'cost curve' exists for each technology, whereby the initial cuts can be achieved at a lower price, whereas costs rise as the technology is pushed toward its limits in terms of deployment scale. Taking away any single solution means that all others are called to carry more of the overall mitigation load, pushing technologies higher up the cost curve.[10]

A third reason is that for some industrial applications, there are few – if any – other ways available today to achieve large emission reductions.[11] The manufacturing of cement and steel, for example, emit significant amounts of CO_2 as an integral part of the industrial process. Globally, a fifth of CO_2 emitted from fuel combustion comes from industrial processes, and while some of these processes can be improved or modified to be more efficient or to reduce emissions otherwise, these emissions cannot be completely eliminated as long as there is continued demand for their products.[12]

A fourth reason is that when CO_2 from facilities that use sustainable biomass is captured and stored, it results in net reductions of CO_2 from the atmosphere. Biomass is a considerable energy source accounting for almost 10% of the total global primary energy use as of 2010.[13] Bio-energy with CCS (BECCS) is applicable to a wide range of biomass-related technologies involving energy generation, such as power plants that co-fire biomass and fossil fuel, combined heat and power plants and a range of flue gas streams from the pulp and paper industry, fermentation in ethanol production and biogas upgrading processes.[14] BECCS can help achieve emission reductions in countries such as Australia, Brazil, Canada, Sweden and Finland if appropriate feedstocks are used.[15,16] The amount of appropriate biomass available for energy production is limited by several ecological and economic factors, but the combination of CCS and biomass that is acquired without causing permanent deforestation or otherwise compromising its lifecycle emissions footprint can open up an emissions reduction pathway that 'scrubs' carbon dioxide from the atmosphere.

Overall, we hold the common view that CCS is an important part of the climate mitigation portfolio. Deploying CCS and subsequently reducing costs will positively impact and accelerate national and international policy development, and enable deeper emission cuts. The rationale for its use is not the perpetuation of fossil fuel use, but its ability to achieve deep emission cuts from large sources when fossil fuel use is inevitable or is already taking place.

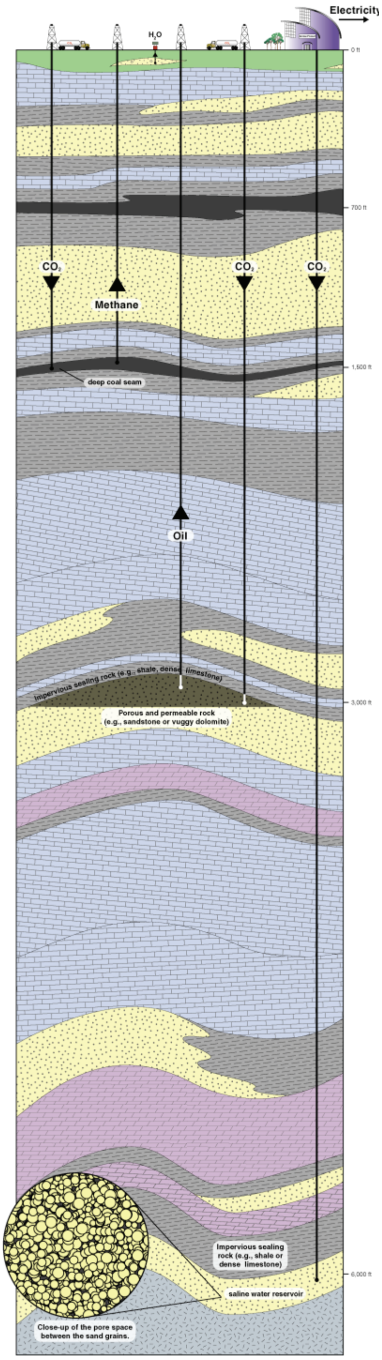

FIGURE 3 Cross section of a typical stratigraphy from the Illinois Basin, showing multiple layers of caprocks (grey).
Source: Illinois State Geological Survey and Midwest Geological Sequestration Consortium.

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9 Princeton CMI wedges. http://cmi.princeton.edu/wedges/.

10 The International Energy Agency has calculated that, without CCS, overall costs to reduce emissions to 2005 levels by 2050 increase by 70%. See: IEA; Technology Roadmap, Carbon Capture & Storage (2010).

11 http://www.iea.org/Papers/roadmaps/ccs_industry.pdf.

12 http://www.iea.org/co2highlights/co2highlights.pdf.

13 Most of this is used for small scale cooking and heating purposes. http://biorecro.com/BECCS_Rapport_100922_Biorecro.pdf.

14 The chemical pulp industry, for example, emitted over 300 million tons of biogenic CO_2 in 2009. http://biorecro.com/BECCS_Rapport_100922_Biorecro.pdf.

15 Id.

16 Such as logging debris that would otherwise be burned in situ or left to decompose; the use of healthy whole trees as an energy feedstock does not achieve timely emissions reductions in most cases.

IS CCS READY FOR DEPLOYMENT? IS IT SAFE?

As would be expected, our organisations have approached CCS with caution. The prospect of injecting millions of tons of compressed carbon dioxide in the subsurface has to be taken seriously. After long and careful study of the available science, we have concluded that CCS can be carried out safely and effectively, provided it is adequately regulated. Our conclusions are based on and are backed by an overwhelming consensus of the scientific literature and prominent research institutions.

Research on CCS has been taking place for many years now, with major international conferences occurring since the early 1990s. Since then, scientific knowledge on the subject has greatly expanded, to the extent that the IPCC issued a special report on CCS in 2005. This report represents the most significant landmark in terms of relevant publications, and underwent the well known, rigorous Intergovernmental Panel on Climate Change (IPCC) peer review standards. There is a very high degree of consensus on the science of CCS.

CO_2 capture is a reality today. CO_2 is stripped from the slipstreams of power plants or industrial facilities to supply the food industry. It is also routinely removed in natural gas processing facilities and at synthetic fuel production facilities to reduce the CO_2 content of the gas to commercial specifications and at synthetic fuel production facilities. Several large-scale capture projects at power plants are also operating today. With additional experience applying CO_2 capture to power plants over the coming few years, considerable progress is expected in terms of efficiency and cost in CO_2 capture.

Pipelines operate as a mature market technology and are the most common method for transporting CO_2. The first long-distance CO_2 pipeline came into operation in the early 1970s. In the US today, over 3900 miles[17] of pipelines in the US annually transport approximately 65 million tons of CO_2.[18]

Some 72 million tons of CO_2 annually in the US[19] are injected in mature oil reservoirs for the purposes of enhanced oil recovery (EOR), a practice that has been around for several decades. The CO_2 aids in retrieving oil that is otherwise stranded in reservoirs, which would be near the end of their economic life without such advanced techniques. Although the objective in this process initially was to maximise oil yields and not to sequester CO_2, the two processes are fundamentally similar and share much of the same operational engineering.

Moreover, several commercial and research projects worldwide capture and/or inject CO_2 in geological formations. Of these, three stand out because of their scale and their widely publicised results: Sleipner in Norway, Weyburn in North Dakota/Canada and In Salah in Algeria. These projects have been operating since 1996, 2000 and 2004 respectively, and have been studied intensely.

These projects give us a great deal of confidence that CO_2 can remain permanently stored in geological reservoirs. There are multiple trapping mechanisms for CO_2 in these reservoirs, operating at various time scales. Residual trapping limits CO_2 mobility in a formation through capillary forces, much like a sponge traps air that has to be squeezed repeatedly in order to let water in. Solubility trapping, whereby CO_2 dissolves in the formation fluids, ensures that the CO_2 is no longer buoyant and therefore tends to sink rather than rising towards the surface. Stratigraphic trapping occurs when overlying, impermeable rock formations prevent any upward movement of CO_2 from the underlying reservoir rock, effectively acting as lids (Figure 3). Appropriately selected CO_2 injection sites will possess several layers of such caprocks, and thus multiple reinforcements to the other trapping mechanisms. Finally, mineralisation trapping takes place when the CO_2 over time forms carbonate minerals and essentially becomes part of the solid rock into which

17 Dooley JJ, RT Dahowski, and CL Davidson. 2009. "Comparing Existing Pipeline Networks with the Potential Scale of Future US CO_2 Pipeline Networks." In Energy Procedia: 9th International Conference on Greenhouse Gas Control Technologies (GHGT9), vol. 1, no. 1, pp. 1595-1602. Elsevier, London, United Kingdom. doi:10.1016/j.egypro.2009.01.209.

18 Melzer, L. S. (2012). Carbon Dioxide Enhanced Oil Recovery (CO_2 EOR): Factors Involved in Adding Carbon Capture, Utilization and Storage (CCUS) to Enhanced Oil Recovery.

19 Advanced Resources International, (2011). Improving Domestic Energy Security and Lowering CO_2 Emissions with "Next Generation" CO2-Enhanced Oil Recovery (CO_2-EOR).

it was injected. In fact, fluids in nature such as oil and gas, CO_2 and brines, have had residence times in the order of millions to hundreds of millions of years. Nature sequestered CO_2 in different forms well before we embarked on it as a human endeavour!

In assessing the global risks associated with CCS, the IPCC Special Report concluded the following:

"*Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1000 years. For well-selected, designed and managed geological storage sites, the vast majority of the CO_2 will gradually be immobilised by various trapping mechanisms and, in that case, could be retained for up to millions of years. Because of these mechanisms, storage could become more secure over longer timeframes.*"

In support of that statement, an Massachusetts Institute of Technology (MIT) study[20] concluded that:

"*Although substantial work remains to characterise and quantify these mechanisms, they are understood well enough today to trust estimates of the percentage of CO_2 stored over some period of time – the result of decades of studies in analogous hydrocarbon systems, natural gas storage operations, and CO_2-EOR. Specifically, it is very likely that the fraction of stored CO_2 will be greater than 99% over 100 years, and likely that the fraction of stored CO_2 will exceed 99% for 1000 years. Moreover, some mechanisms appear to be self-reinforcing. Additional work will reduce the uncertainties associated with long-term efficacy and numerical estimates of storage volume capacity, but no knowledge gaps today appear to cast doubt on the fundamental likelihood of the feasibility of CCS.*"

The remaining 1% is a number used by IPCC authors to take into account any uncertainties such as very small amounts of CO_2 that might be vented during the operation of sites due to human factors over those very long periods, and does not reflect reduced confidence in the underlying geology or the ability of formations to retain the overwhelming majority of the injected CO_2. There is every possibility that even this small fraction will not reach the atmosphere with proper site operation and regulation, bringing the total retained fraction to 100%. The 1% figure in no way implies leakages that could harm human health or the environment.

A sound regulatory framework for the safe injection and proper monitoring and accounting of captured, transported and sequestered carbon dioxide is paramount. This framework should cover enhanced hydrocarbon recovery projects as well as deep saline injection. Rigorous regulation is necessary to ensure that projects are sited and operated responsibly by capable entities, that shortcuts are not taken that could endanger public health or the environment, and to establish public trust in the application of the technology.

Globally, there has been tremendous progress toward developing and implementing environmental health and safety regulations for CCS. Regional and country and state/province-specific regulations are in force in the European Union, the US,[21] Canada, Norway and Australia.[22] Many other countries are currently drafting their CCS regulations. In addition to environmental regulations, the UNFCCC has adopted modalities and procedures for CCS actions under the Clean Development Mechanism, and the International Organization for Standardization has formed a technical committee to develop international CCS standards.

These existing rules reflect a unified understanding of protecting human health and the environment during CCS, including the following provisions:

- siting requirements that address geologic characteristics to ensure the integrity of the storage site;
- requiring that site-specific risk assessments be conducted and contingency plans be developed prior to injection;

20 Massachusetts Institute of Technology. "The Future of Coal – Options for a Carbon Constrained World, An Interdisciplinary MIT Study", 2007. Available at: http://web.mit.edu/coal/.

21 See: http://water.epa.gov/type/groundwater/uic/class6/gsclass6wells.cfm.

22 http://www.ret.gov.au/resources/carbon_dioxide_capture_and_geological_storage/Pages/ccs_legislation.aspx.

- rigorous processes for establishing a monitoring area, based on simulation models and actual data collected during operation; and
- ensuring that the area for monitoring goes beyond the injected CO_2 itself to encompass any areas of elevated pressure within the subsurface reservoir.

First generation CCS technology is ready to be used in large-scale projects today. All three components of CCS – the capture, transportation and injection of CO_2 – have been demonstrated at large scale in commercial projects. Significant technical and cost improvements are, naturally, expected after wider uptake, and combining those components does involve additional operational, regulatory and financial burden. Nonetheless, the technological pieces are in place to allow the first wave of CCS plants to be built and operated safely and effectively. Below we examine the barriers that stand in the way of CCS deployment, the critically needed policy steps and assessment of their prospects for adoption in the near term.

BARRIERS TO CCS DEPLOYMENT

The single biggest barrier standing in the way of CCS deployment is the absence of comprehensive climate policies that place a significant market value on avoided emissions. Without such policies and legislation, economic drivers for CCS are simply lacking, as there is little other reason to capture and sequester carbon, with the exception of niche applications such as EOR utilising CO_2 that is relatively inexpensive to capture from certain industrial operations, such as fertiliser manufacturing and natural gas processing. For power plant emissions, the capital and operational cost of CO_2 capture, compression and transportation would be prohibitive in the absence of carbon markets. CCS has been acknowledged widely as being technologically ready to begin deployment if the economic gap is bridged.[23]

Although economic and regulatory barriers constitute the majority of the impediments for CCS, another area bears examining. This is the interface between the producers of the CO_2 – mainly power producers (who are risk averse, do not tolerate uncertainty when tasked with delivering reliable power 24 hours a day, and make fewer and more conservative investment decisions) – and those who will be injecting the CO_2 into the subsurface – mainly oil and gas and related companies (that routinely carry a business risk portfolio and are far more accustomed to dealing with uncertainty cumulatively) in the early years. The bulk of expertise related to CO_2 injection resides with the oil-and-gas industry, with little diffusion of experience and know-how to the power sector where CCS is most urgently needed and most intensely discussed. It is not yet clear who will fill the business gap of storage services. We are still in the early days of this process. However, despite the seeming novelty of the task, the private sector is remarkably good at providing fast answers to such questions in a competitive and profitable environment.

In addition, the lack of CCS education and a long standing mistrust of the coal and oil industries by the public and elected officials in some settings have also limited broader support for accelerated deployment policies, driven by doubts on the feasibility and efficacy of geological storage and with CCS being seen as a means to perpetuate fossil fuel use. CCS is often portrayed as an experimental technology by sceptics, and as a lifeline for the continued use of coal and other fossil fuels that detract from efforts to shift to a truly sustainable energy system. Politically or otherwise-driven industry claims that CCS is unproven only compound this scepticism, and even environmental groups that see a role for CCS alongside solutions such as conservation and renewable energy, find themselves with a formidable task when it comes to education and shaping public perception.

23 See, for example: MIT, 2007, "there do not appear to be unresolvable open technical issues underlying these questions. Of equal importance, the hurdles to answering these technical questions well appear manageable and surmountable. As such, it appears that geological carbon sequestration is likely to be safe, effective, and competitive with many other options on an economic basis." and Obama CCS Task Force report on CCS (http://www.epa.gov/climatechange/Downloads/ccs/CCS-Task-Force-Report-2010.pdf), which reaffirms that the challenges are in the policy and regulatory arenas mainly, although progress has been made in the latter.

POLICY NEEDS FOR CCS

Governments have the most important role to play in advancing CCS. Since the technology is ready to begin deployment but is being held back by market and regulatory conditions, concerted policy intervention holds the key to its future prospects.

The biggest policy imperative for CCS, or indeed other large-scale clean energy technologies, is for limits on carbon emissions and an associated price on carbon. Without limits and a price – be it direct or indirect – there is no real need for markets to gravitate toward a technology that is specifically targeted toward reducing carbon emissions.

The second most pressing task is for governments to help overcome the initial high-cost hurdle for projects. CCS comes at a price premium today, but significant cost reductions are expected to be achieved once the initial 'hump' is overcome.[24] Governments have a long track record in assisting technologies through these initial stages until technological improvements and a sufficient body of experience and know-how enable costs to come down. A correctly structured subsidy or assistance program would act as a catalyst to enable broader and faster deployment at lower cost. It is worth noting that such programs generally cover a portion of the capital costs of a technology, but by themselves cannot provide a viable pathway toward deployment, since operating costs also need to be covered on an ongoing basis. For that reason, a price on carbon is a necessary prerequisite for subsidies or assistance programs. Finally, alongside such programs, sustained basic research and development (R&D) would ensure that a new generation of technologies is ready to replace existing ones.

We also believe that regulations mandating or providing a pathway for CCS deployment are necessary, and complementary to limits and a price on carbon emissions. Performance standards for particular types of facilities, for example, can safeguard against market failures and provide a clear pathway for CCS deployment that provides the needed certainty for the large capital investments needed. Although some have argued that the market should deliver the optimal solutions, there is ample evidence that markets do not operate as intended and that failures due to bad design, application or unforeseen circumstances can cause significant distortions and delays.[25]

The first tranche of announced demonstration projects – let alone the 100 projects by 2020 suggested by the IEA in its CCS Roadmap[26] – will require not only significant financial investments by industry and the private sector, but also a robust regulatory framework for ensuring that projects proceed safely. The development of rigorous regulations for ensuring environmental protection and managing the risks associated with CCS efforts is paramount, and pilot regulatory frameworks for protecting environmental health and safety have been developed – and in some cases adopted – for the European Union and some member states, Australia, and the US.

24 See, for example: Edward S. Rubin, "The Importance of CCS in a Low-Carbon Energy Future", Keynote Presentation to the World Bank Workshop on "Addressing Barriers to Carbon Capture and Storage in Developing Countries", Washington, DC, September 7, 2011 (http://siteresources.worldbank.org/INTENERGY2/Resources/4114191-1316103699379/Rubin_WB_CCS_keynote.pdf); and Edward S. Rubin, "How to Reduce the Cost of Carbon Capture", Presentation to the GCEP Carbon Capture Workshop, Stanford, California, May 26, 2011 (http://www.cmu.edu/epp/iecm/rubin/PDF%20files/2011/ERubin_HowtoReduceCarbonCaptureCost_Stanford_May2011.pdf).

25 E.g., the European Union Emissions Trading Scheme.

26 Energy Roadmap: Carbon Capture and Storage. International Energy Agency, 2009.

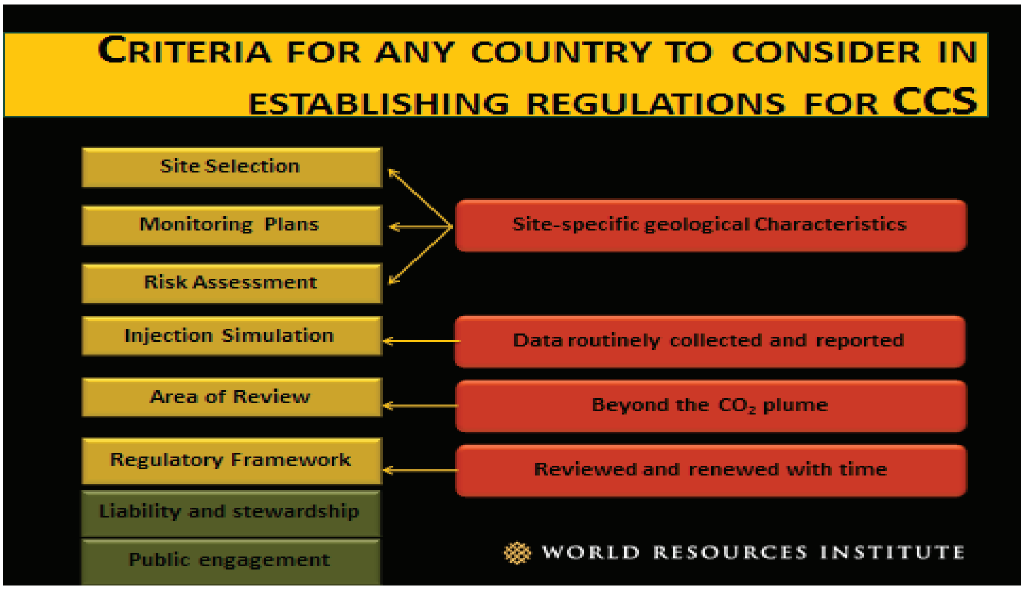

FIGURE 4 - Criteria for any country to consider in establishing regulations for CCS.
Source: World Resources Institute.

It is important to ensure that CCS environmental regulatory frameworks are in place to scale-up projects, while protecting the environment and communities involved. In developing appropriate regulations, it is essential to get the details right (Figure 4). Part of the challenge for implementing CCS regulations is that, in most countries, responsibility for CCS falls under several different ministries, agencies and/or tiers of government administration. Another challenge most governments face is that many aspects of CCS are covered under existing rules and regulations, which must now be revised to effectively accommodate CCS.

Finally, a carbon price alone, even combined with incentives, will not be enough to ensure the wide uptake of the CCS technology. Demonstrations are an essential next step in the innovation cycle for CCS, but even if they are successful, they will not magically result in technology uptake. For that uptake to become reality, limits on carbon emissions and regulations against business-as-usual will be necessary.

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CCS in Australia

INTRODUCTION/OVERVIEW

While Australia has committed substantial investment to CCS research and development, its legal and regulatory framework lacks a pathway to commercial-scale CCS deployment in the timeframe required. Modelling suggests Australia's newly implemented carbon price is not projected to facilitate CCS deployment until the mid-late 2030s.[27]

REGIONAL CCS STATUS/ISSUES

CCS policy in Australia struggles to bridge the 'valley of death' between research and deployment. Australia has made substantial commitments to CCS research, through the establishment of the Global CCS Institute and the AU$1.68 billion CCS Flagships Program and investment in a portfolio of world-leading demonstration projects. Australia has also made progress in implementing necessary regulations to enable offshore carbon storage.[28]

However, policies that would allow CCS to compete as one of a range of low-emissions technologies are absent. The Commonwealth Government had promised in 2010 to introduce an emissions performance standard (EPS) and CCS-readiness requirements for new coal-fired power stations. The EPS was not specified but would be below 0.86 Mt CO_2/MWh and set "with reference to the best practice coal-fired electricity generation technology".[29] The following year the Government withdrew this commitment on the basis that it would no longer be necessary under the carbon pricing mechanism introduced that came into effect on 1 July 2012.[30]

The carbon price shifts from a fixed charge of AU$23-25 per tonne of CO_2 to a cap-and-trade scheme in 2015. Australia and the European Union have committed to linking their schemes (with one-way purchases by Australia from 2015 and fully bilateral carbon trading from 2018). From 2015 Australian entities will be able to purchase up to 50% of their carbon permits internationally, with a sub-limit of 12.5% on Kyoto permits. With full international trading opportunities, after 2015, Australia's carbon price will be strongly influenced by the prevailing EU allowance prices and possibly other linked trading schemes.

The carbon price could provide a long-term investment signal for CCS. Commonwealth Treasury modelling of the carbon price projects that it will enable CCS-coal to enter the domestic electricity generation supply around 2035-38, at a carbon price of about AU$70-80 per tonne of CO_2.[31] By 2050 generation with CCS would make up 30% of Australia's electricity supply, reducing domestic emissions by 25 Mt CO_2 in 2050, compared with a scenario without CCS deployment.[32] However, in the short-medium term the price is unlikely to be sufficient to drive CCS deployment without complementary policies.

Moreover, CCS investment has been explicitly prohibited from consideration by the Government's new Clean Energy Finance Corporation (CEFC), which has been set up with AU$10 billion and a mandate to de-risk

27 Commonwealth Treasury, Strong Growth Low Pollution: Modelling a carbon price, Table 5.12 (2011) http://carbonpricemodelling.treasury.gov.au/carbonpricemodelling/content/chart_table_data/chapter5.asp.

28 Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011.

29 Australian Labor Party, A cleaner future for power stations, 2010, http://www.alp.org.au/getattachment/1c885f7d-da5c-45b8-98ff-a646ff2fb2cd/cleaner-power-stations/.

30 Speech by the Minister for Resources Energy and Tourism to launch the Draft Energy White Paper 2011, http://www.alp.org.au/federal-government/news/draft-energy-white-paper-released/.

31 Commonwealth Treasury, op. cit.

32 Commonwealth Treasury, op. cit, Table 5.4.2.

investment in low- and zero-emissions energy technologies.[33] Excluding CCS was part of the agreement of the Multi-Party Committee on Climate Change (MPCCC) established by the minority Commonwealth Government in 2010 to build legislative support for the carbon price and associated measures. The MPCCC included several members of The Greens, a minority party that strongly opposes public investment in CCS and whose support was vital for the Government's climate policy legislation to pass in the Australian Senate.[34]

Neither Australia's fossil fuel producers nor its major green groups are strong advocates for CCS deployment. The positions of Australia's three major green groups range from support for demonstration (WWF[35]) to scepticism (Australia Conservation Foundation[36]) and vocal opposition (Greenpeace Australia Pacific). Greenpeace released a report in May 2012 describing CCS as 'dead and buried'.[37] The Australian Coal Association has been an active supporter of industry and government investment in CCS research, through initiatives such as the 10-year AU$1 billion COAL21 Fund.[38] However, the association and others representing fossil fuel extractors campaigned strongly against the introduction of the carbon price.[39]

SIGNIFICANT REGIONAL CCS PROJECTS

Callide Oxyfuel Project, Callide A Power Station in central Queensland. This demonstration project involves retrofitting an existing 30MW unit with oxy-firing technology to produce a clean stream of liquid CO_2. Commissioning commenced in March 2012, with CO_2 capture expected by the end of the year. A second stage of the project may involve the injection and storage of captured CO_2.

CO2CRC Otway Project, Victoria. Australia's only operational storage demonstration project involves storage and close monitoring of 65,000 tons of CO_2-rich gas in a depleted gas field 2 km below ground. Monitoring of air, soil, groundwater and subsurface has shown that the injected gas has stabilised and is not leaking, consistent with CO2CRC computer modelling. The second stage of the project involves test injections and monitoring of CO_2 into saline formations, the largest form of storage capacity globally. This confirmation and refinement of models of gas storage is an important contribution to CCS research.[40]

Gorgon CO_2 Injection Project, Western Australia. This involves capturing the CO_2 stripped during processing of natural gas from the Gorgon gas field, and injecting it more than 2 km below the surface of nearby Barrow Island. This is intended to reduce emissions from the gas project by 40%. Gas production and CO_2 injection is forecast to begin in 2014.

Two hub projects have recently won funding through the CCS Flagship Program. **The South West Hub Project, Western Australia**, has the potential to become Australia's first major onshore CCS project, with possible storage of up to 7.5 Mt CO_2 p.a. from industrial emissions streams (coal-based urea plant, alumina production and power generation). The Project is currently undertaking research into the geosequestration potential of the Lesueur Sandstone Formation. Base case capture (Perdaman Collie Urea project) is expected to begin in 2015.[41] **The CarbonNet Project, Victoria**, likewise aims to capture emissions from power plants, industrial processes and new coal-based industries in the Latrobe Valley for storage in nearby geological basins. Funding for CarbonNet feasibility studies was announced in February 2012.[42]

33 *Clean Energy Finance Corporation Act 2012* http://www.comlaw.gov.au/Details/C2012A00104/Html/Text#_Toc330982495.

34 The Greens, Climate Change and Energy, http://greens.org.au/policies/climate-change-and-energy/climate-change-and-energy

35 WWF, personal communication 12 October 2012.

36 Australian Conservation Foundation, ZeroGen collapse shows it's time for clean energy, 28 September 2011, http://www.acfonline.org.au/news-media/releases/zerogen-collapse-shows-it%E2%80%99s-time-clean-energy.

37 Greenpeace Australia Pacific, Dead and Buried: The demise of carbon capture and storage, 2012 http://www.greenpeace.org/australia/en/what-we-do/climate/resources/reports/Dead-and-Buried-The-demise-of-carbon-capture-and-storage/.

38 Australian Coal Association, Australian Coal Association, Coal21, http://www.australiancoal.com.au/coal21.html.

39 Australia Trade and Industry Alliance, 'About us' (2010)http://www.getcarbonpolicyright.com.au/about-us.aspx.

40 CO2CRC, The CO2CRC Otway Project, 2011, http://www.CO2crc.com.au/dls/brochures/Otway%20brochure%202011_spread.pdf.

41 Global CCS Institute, South West CO2 Geosequestration Hub (formerly Collie-South West Hub), http://www.globalccsinstitute.com/projects/12651.

42 Department of Resources Energy and Tourism, Carbon Capture and Storage Flagship Program, 19 September 2012, http://www.ret.gov.au/energy/clean/ccsfp/Pages/default.aspx.

The withdrawn **ZeroGen Project**, **Queensland** provided valuable early lessons for CCS deployment. Launched in 2006, ZeroGen was intended as a commercial scale IGCC plant with 65-90% CCS, operational by 2015. This tight timeline was necessary to attract Commonwealth Government funding, which was also supplemented by funding from the Queensland Government. However, after more than three years and AU$90 million in exploration and appraisal, the proposed storage site, the Denison Trough, was found to be unsuitable (though geologically viable), and the project was cancelled.

RECOMMENDATIONS/MOVING FORWARD

Given that the existing legal and regulatory framework do not support early investment in CCS deployment, The Climate Institute considers that Australia should immediately introduce emissions performance standards for all new fossil fuel power stations and major expansions or refurbishments of existing generators. The proposed EPS is 0.5 t CO_2e/MWh, dropping to 0.2 t CO_2e/MWh after 2020 for new coal. Non-peaking gas plants should also be required to retrofit to full CCS 15 years after their commissioning.[43] The mandate of the newly established Clean Energy Finance Corporation should be extended to allow the financing of technologies that have negative net emissions, such as CCS with bio-energy. In addition, policy mechanisms that provide predictability around ongoing carbon costs and ensure an ongoing return on investment should be implemented.[44] To date industry investment in CCS has been insufficient and sporadic. Six years into the 10-year Coal21 commitment, just over a quarter of funding has been committed.[45] Along with clear government policies to provide longer-term investment certainty, fossil fuel producers and users need to match government funds to drive faster CCS deployment.

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43 Excepting peaking plants operating <10 % of the time. See Southern Cross Climate Coalition, A Policy platform for a low pollution economy, April 2011, http://acoss.org.au/images/uploads/SCCC_A_Policy_Platform_for_a_Low_Pollution_Economy_April_2011.pdf.

44 See for example, a recent proposal by the Grattan Institute in Tony Wood, Building the bridge: a practical plan for a low-cost, low-emissions energy future, Grattan Institute, July 2012.

45 Australian Coal Association, op. cit.

CCS in Canada

INTRODUCTION/OVERVIEW

Canada has positioned itself as an international leader in the commercial scale deployment of carbon capture and storage – for the moment.

A large-scale commitment of public funding totalling CA$3 billion[46] has directly translated into the commencement of construction of two large-scale CCS projects (see Significant Regional CCS Projects). Two additional publicly subsidised projects are advancing to the regulatory approval stage,[47] and much work has been completed to ensure that a robust regulatory framework will be in place to support CCS development by the time the first two projects begin operating in 2014.[48] All of this has been accomplished with very little public opposition to specific CCS projects. In spite of these successes, the Government of Canada has failed to implement a comprehensive climate policy that will drive the adoption of CCS by Canadian industry in the future.

SIGNIFICANT REGIONAL CCS PROJECTS

SaskPower Boundary Dam. In April 2011, the Saskatchewan Government approved the Saskatchewan Boundary Dam Integrated Carbon Capture and Storage Project.[49] The project will retrofit an existing coal-fired generation unit with a post combustion carbon capture system.[50] It is designed to capture approximately 1 MT/annually using the Cansolv system that utilises rechargeable amines to capture CO_2 and SO_2.[51] The project is expected to cost CA$1.24 billion with the Government of Canada contributing CA$240 million.[52] The project is due to be complete in 2014. Captured CO_2 will be stored in a deep saline aquifer and used for EOR.

Shell Quest. Shell announced in September 2012 that it will proceed to build the Shell Quest CCS project.[53] The project will capture 1.1 megatons of CO_2 from the Scotford Upgrader near Edmonton Alberta. The facility converts bitumen into synthetic crude oil. The existing concentrated CO_2 stream will be captured from a unit called a 'steam methane reformer'. It will be transported in liquid form 80 km by underground pipeline and injected approximately 2 km below the ground surface in a saline porous rock formation. The scheme was approved by the federal government and the Alberta Government earlier in 2012. The Alberta Government has committed CA$745 million to the project and the Government of Canada will invest CA$120 million. The project will also receive two-for-one credits for 10 years from the Alberta Government. Under the Alberta Government Specified Gas Emitters Regulation, credits are currently valued at AU$15/ton.[54]

46 Government of Canada and the governments of Alberta, Saskatchewan, and British Columbia, http://www.nrcan.gc.ca/energy/science/1421 (September 11, 2012).

47 Alberta Carbon Trunk Line and Swan Hills Synfuels, http://www.solutionsstarthere.ca/24.asp, September 11, 2012.

48 The Province of Alberta is developing a comprehensive regulatory framework to support the expanded development of CCS. The Alberta framework is likely to be adopted by other provinces with CCS projects (Saskatchewan). http://www.solutionsstarthere.ca/29.asp, (September 11, 2012).

49 http://www.gov.sk.ca/news?newsId=ae413247-80ce-4c9a-b7e3-4cc39e89da94 (September 8, 2012).

50 http://www.saskpower.com/sustainable_growth/projects/carbon_capture_storage.shtml - September 8, 2012.

51 http://www.carboncapturejournal.com/displaynews.php?NewsID=809 (September 8, 2012).

52 http://www.gov.sk.ca/news?newsId=ae413247-80ce-4c9a-b7e3-4cc39e89da94 (September 8, 2012).

53 http://www.shell.ca/home/content/can-en/aboutshell/media_centre/news_and_media_releases/2012/0905quest.html - September 8, 2012.

54 http://alberta.ca/home/NewsFrame.cfm?ReleaseID=/acn/201106/30771C28EE8FC-F24F-E03C-1BA374D3C893A32B.html (Alberta Environment, June 24, 2011).

Weyburn. Canada is also home to the International Energy Agency Greenhouse Gas Weyburn-Midale CO_2 Monitoring and Storage Project, one of the world's most intensively researched CO_2 EOR projects. The goal of the work is to understand the behaviour and fate of injected carbon in the Weyburn-Midale oil formation and to guide future CO_2 storage projects.[55]

Operated by Cenovus Energy, the Weyburn operation has been injecting CO_2 since 2000. Cenovus estimates that to date, it has stored more than 17 million tons of CO_2 in the formation. Cenovus purchases CO_2 from Dakota Gasification's Great Plain Synfuels Plant in Beulah, North Dakota. The gas is transported 323 km by pipeline to Weyburn Saskatchewan. [56]

RECOMMENDATIONS/MOVING FORWARD

The next phase of development of CCS in Canada remains uncertain. No new public subsidies for CCS are expected and previously committed funds tied to a cancelled Alberta CCS project[57] have not been re-allocated to another CCS project.

In spite of avoiding local opposition to individual projects, general public support for CCS as a climate change solution is at risk. It is now clear that federal and provincial governments significantly overstated the potential for CCS to quickly reduce greenhouse gas pollution from Canada's extensive coal-fired power industry or its rapidly expanding oil sands industry.[58] The Alberta Government's publicly stated assumption that CCS will account for approximately a 50 Mt reduction by 2020 is not viewed as credible today.[59]

Public subsidies must continue to be available or Canadian industry will have virtually no incentive to invest in CCS. Alberta's carbon price of CA$15/ton is too small to affect investment decisions.[60] Canadian companies that had been anticipating a nationwide cap and trade system in 2009 are waiting instead for the Government of Canada to unveil a sector-by-sector regulatory approach. First in line has been the coal powered generation industry, however the final version of these regulations announced recently allow existing units to avoid retrofitting with CCS until they are 50 years old.[61] No new coal units utilising CCS have been announced. Similar regulations are anticipated for the oil and gas industry and the oil sands industry, but no draft versions have been made public to date.

The Pembina Institute has concluded that CCS in the oil sands sector will only occur if federal and provincial governments establish a price on carbon in the range of CA$95-255 per ton or impose mandatory implementation of CCS for new facilities.[62]

The Pembina Institute believes that if the right conditions are established to incentivise companies to adopt CCS, Canadian regulators will be ready to regulate the activity. Alberta's CCS Regulatory Framework Assessment (RFA) process is expected to be complete by the end of 2012 and implemented by 2014. According to the Province: "This review will result in the creation of a world-class regulatory system, based on international best practices, which will ensure CCS technology is used safely in Alberta."[63] The process, led by Alberta Energy, includes participants from industry, government, ENGOs, academia, international experts, as well as direct participation by the federal government and the Saskatchewan government. The Pembina Institute recommends that Saskatchewan adopt a similar regulatory framework.

55 http://www.cenovus.com/operations/oil/weyburn.html (September 14, 2012).
56 http://www.cenovus.com/operations/docs/Weyburn-Facility-Profile.pdf (September 14, 2012).
57 TransAlta's Project Pioneer (post combustion coal powered generation) was cancelled on April 26, 2012. http://www.projectpioneer.ca/.
58 Bramley, Matthew, Marc Huot, Simon Dyer and Matt Horne, Responsible Action? An assessment of Alberta's greenhouse gas policies, December 2011.
59 http://www.solutionsstarthere.ca/21.asp, (September 12, 2012).
60 Bramley, Matthew, Marc Huot, Simon Dyer and Matt Horne Responsible Action? An assessment of Alberta's greenhouse gas policies December 2011.
61 P.J. Partingon, Addressing "misperceptions" about Canada's coal power regulations, September 7, 2012, http://www.pembina.org/blog/647 (September 12. 2012).
62 Bramley, Matthew, Marc Huot, Simon Dyer and Matt Horne Responsible Action? An assessment of Alberta's greenhouse gas policies December 2011.
63 http://www.solutionsstarthere.ca/29.asp - Alberta Energy, September 8, 2012.

Canada is providing leadership in the area of international standards for CCS. CSA Standards, a developer of standards, codes, and certification programs, has joined with the International Performance Assessment Centre for Geologic Storage of Carbon Dioxide and have been jointly developing a CCS standard for submission to the Standards Council of Canada since June 2010.[64] The Standards Council of Canada in turn has initiated an International Organization for Standardization (ISO) process (May 2011) – the first step on a long path toward establishment of an internationally agreed upon standard for CCS.[65]

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64 http://www.csa.ca/cm/ca/en/news/article/deep-earth-storage-industrial-carbon-emissions, (September 12, 2012).

65 http://www.globalccsinstitute.com/publications/global-status-ccs-2012/online/48151 (October 13, 2012).

CCS in the European Union

INTRODUCTION/OVERVIEW

The development of a policy framework for CCS in the European Union (EU) has taken positive steps forward over recent years. But the combination of the economic crisis and public opposition has slowed progress toward securing the desired number of CCS demonstration projects.

Two funding mechanisms for CCS are in place, with further decisions on their allocation due before the close of 2012. Yet the future deployment of CCS in Europe will depend in large part on whether EU member states can address the economic and political barriers currently facing CCS projects. Already under way is an effort to strengthen the Emissions Trading Scheme (ETS), which would improve the underlying business case for investment in CCS. Alongside this, there needs to be a renewed political strategy that engages with public concerns about CO_2 storage. This must take as its starting point the opportunity for CCS to drive decarbonisation and maintain jobs in Europe's industrial sectors.

REGIONAL CCS STATUS/ISSUES

In 2007, the EU agreed to enable commercial deployment of CCS by 2020 through the development of a demonstration programme of 10-12 CCS plants by 2015. With the EU ETS already in operation providing a carbon price, attention turned to the missing parts of the policy framework. The Climate and Energy Package agreed to in 2008-09 addressed two areas. First, the CO_2 Storage Directive set out requirements for the appropriate characterisation, permitting and monitoring of CO_2 stored in geological formations, together with a liability framework for operators and requirements for a new fossil fuel generating plant to undertake 'capture readiness' assessments.

Alongside this, a new funding mechanism was created for CCS and innovative renewables. Three hundred million allowances were taken from the New Entrants Reserve of the ETS, to be monetised by the European Investment Bank, by selling them on the carbon market. It was intended that the revenue stream from this process would be used to provide additional financial assistance to CCS projects, which would be selected over two bidding rounds.

The European economic crisis has had a major negative impact on the prospects for CCS, although at first it appeared that stimulus spending through the European Economic Recovery Plan would give a further boost to efforts to secure the intended number of demonstration projects. A new mechanism awarded funding to six CCS projects in December 2009 to further assist their development, and stimulated the creation of an EU project network (since 2012 facilitated by the Global CCS Institute). Further efforts to progress these projects to the point of Final Investment Decision will continue throughout 2012.

This positive step was however overshadowed by the wider economic recession and corresponding impact on the carbon price. Allocations of ETS permits had been set on the assumption of continued economic growth, resulting in an oversupply of allowances and a crash in the carbon price. This not only radically undermined the emerging business case for CCS into the medium term, but dramatically reduced the level of funding available for the NER300 mechanism. With total funding cuts as a result of the fall in the carbon price, the European Commission hopes to be able to award funding for two or three projects by the end of 2012. While 13 initial bids had been received, three have since been withdrawn and expectations are that at least a further two projects have little prospect of going forward.[66]

66 http://www.ner300.com/.

To facilitate knowledge sharing, the European Commission set up the European CCS Demonstration Project Network, which aims to foster links amongst large-scale demonstration projects and contribute to raising public awareness and understanding of CCS.

EU CCS policy has been informed by cross-sectoral input convened by ZEP – The European Technology Platform for Zero Emission Fossil Fuel Power Plants. This includes representatives from utilities, oil and gas, equipment manufacturers, academic and research institutes, and NGOs. At times, ZEP has been able to secure useful agreement on how CCS policy in the EU can be accelerated.

However, and unlike the productive dialogue that has been possible in the UK, the European conversation about the place of CCS within European decarbonisation efforts is far more fragmented, both within sectors and across national boundaries. This has made it more difficult to find ways forward on thorny topics such as the role of regulatory drivers or performance standards.

Further, the public response to potential CCS projects has differed across Europe. In Germany and the Netherlands, projects have been cancelled following active opposition to onshore CO_2 storage, also resulting in the case of Germany delaying agreement on CCS legislation and regional governments taking opposing positions on whether they will permit projects in their territory. Early opposition to CCS was inspired in large part by groups acting to tackle the environmental damage and climate impact of continued coal and lignite use, with CCS viewed as a smokescreen that would allow for continued exploitation of fossil fuels rather than the transition to an energy sector dominated by renewable energy.

RECOMMENDATIONS/MOVING FORWARD

If CCS is to move forward in key member states such as Germany, it will be necessary to persuade NGOs and citizen groups that CCS can clearly form part of a low-carbon future. This is more clearly the case for the use of CCS on industrial sources of CO_2 emissions or on gas-fired power plants. Such an approach would also appeal to politicians who are concerned by the impact of the economic crisis and the risk of carbon leakage and job losses. A positive motivation for CCS is sorely needed to counteract the (often erroneously) negative perceptions of CCS to date.

Simultaneously, however, the problem of how to address continued coal and lignite use is unlikely to be solved completely without a role for CCS. The anti-coal campaign in Europe has succeeded in reducing the planned coal build considerably, and this trend is set to continue in the face of reduced demand for electricity and increased variability in generation due to increasing levels of renewable energy.

Yet many utilities are presently backing away from developing CCS projects as a result of the economic crisis and the lack of a business case through the ETS. The efforts under way now to bolster the carbon price signal represent a last chance for this market-based method to demonstrate that it can be an effective means of reducing emissions and shaping investment decisions for assets with long lifetimes. Failing this, there will be increased likelihood of regulatory measures being imposed to drive reductions in CO_2, just as has been achieved for classical pollutants.

In the EU, the CO_2 emissions avoided through CCS in 2030 could account for some 15% of the reductions required. The EC's Energy Infrastructure Priorities for 2020 and Beyond – A Blueprint for an Integrated European Energy Network – calls for pilot plants to come on line in 2015 with commercial start-up in electricity generation and industrial applications by 2020-25.

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CCS in Germany

INTRODUCTION/OVERVIEW

Germany has a large industry sector and the highest CO_2 emissions in Europe. Almost half of the country's 900 Mt annual CO_2 emissions derive from large point sources, of which energy production is responsible for the largest share. The energy intensive industry sector (e.g., cement, steel, lime, paper, etc.) emits almost 100 Mt CO_2/year.

Although the German government has set up ambitious aims for introducing renewable energy and energy savings, there is still a strong need for measures to cut emissions in the short- to medium-term in the power sector – especially if nuclear power is to be phased out – as well as in the long-term in the industrial sector. We therefore perceive CCS as an inevitable tool in order to meet the necessary climate goals.

REGIONAL CCS STATUS/ISSUES

Public acceptance of CCS in Germany is not widespread due to, amongst other reasons, a general mistrust against the energy industry and nuclear waste management. This has resulted in a heated public debate around the CCS bill, which was postponed several times, and finally agreed upon in the summer of 2012. The bill is designed as a 'research and development-bill', which only allows the storage of 1.3 million tons/year per storage unity, and a maximum storage capacity of four million tons in Germany. Parliament had previously voted in favour of an annual storage capacity of three million tons and a total storage capacity of eight million tons of CO_2, which was then rejected by the upper house in September 2011. Compared to Germany's enormous point emissions, this is far too little and does not correspond to the need for emissions reductions.

The CCS law's passage is not yet assured as the mediation committee approved the compromise by a slim majority. If it eventually becomes a law, the compromise will still allow individual states to reject (veto) any capture projects in their region.

SIGNIFICANT REGIONAL CCS PROJECTS

There are several test projects in Germany for the development of capture technology, but no large-scale projects for capture, transport and storage. The Swedish utility Vattenfall abandoned its promising plans for a larger, EU-financed pilot project at Jänschwalde CCS in December 2011 citing "insufficient will in German federal politics to implement the European directive so that a CCS demonstration project in Germany could be possible". It also shelved plans to explore possible storage facilities in Eastern Germany.

At Ketzin outside of Berlin, the GFZ German Research Centre for Geosciences operates Europe's longest-running on-shore CO_2 storage site. Since 2008 almost 60,000 tons of CO_2 have been stored via one injection well into 630 to 650 m deep sandstone units.

RECOMMENDATIONS/MOVING FORWARD

The most important step for Germany is to ensure the establishment of a CCS law that allows for the testing and demonstration of the whole CCS chain. However without a shift in political perceptions and increased support for CCS, this is unlikely to be achieved speedily. Given current stakeholder opposition to CCS it will be necessary to identify alternative approaches that can secure greater support. The potential for CCS to be applied on industrial applications (potentially also including scope for utilisation of CO_2) provides an as yet under-explored but promising angle for engagement. Given the location of significant industrial emitters in Southwest Germany, it may be possible for CO_2 to be exported via The Netherlands for storage offshore in the North Sea.

Further practical developments can also continue in respect to the technical development and health and safety testing of CO_2 pipeline infrastructure and the characterisation of potential geological storage locations. German regions and power utilities have also expressed interest in the potential development of a European pipeline infrastructure for CO_2.

Clearly, significant work remains to be done to disseminate scientifically accurate information to stakeholder groups and civil society informing about the potential risks and benefits of CCS technology, and it is important that this be carried out by actors that carry objectivity and credibility.

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CCS in Norway

INTRODUCTION/OVERVIEW

The first government policy for CCS in Norwegian power plants dates back to 1997 when the pollution authorities gave permission to build a new gas-fired power plant at Kårstø, with an obligation to build and use CCS from day one.

In 2000 there arose a conflict in the Parliament considering this permit. This was due to the fact that the opposition allowed startup of the gas power plant without a CCS obligation, leading to the resignation of the Bondevik government, which would not accept such a solution. It was followed by the Stoltenberg (I) government, which changed the CCS obligation connected to the startup of Kårstø and Mongstad.

In 2005 the new Stoltenberg (II) coalition government promised in its government declaration that from that date, no new gas-fired power plants would be built in Norway without carbon capture, and it would contribute toward the building of a full-scale capture plant at Kårstø and Mongstad as soon as possible. The planned date of the investment decision has since then been postponed several times, making it unsure when the CCS projects will be operational.

REGIONAL CCS STATUS/ISSUES

Norway has been doing research on CCS for more than two decades. The first report for a CCS project in Norway came in 1987. The main focus has been on CCS from gas power plants. Within research and development, the Norwegian environment has produced significant results and built several pilots, including the BIGCCS and SUCCESS research centres.

The main objective of the BIGCCS Centre is to contribute to the ambitious targets in the Climate agreement in the Norwegian parliament. The BIGCCS Centre will enable sustainable power generation from fossil fuels based on cost-effective CO_2 capture, and safe transport and underground storage of CO_2. This will be achieved by building expertise and closing critical knowledge gaps of the CO_2 chain, and developing novel technologies in an extensive collaborative research effort.

The SUCCESS centre addresses several important areas for CO_2 storage in the subsurface: storage performance, sealing properties, injection, monitoring and consequences for the marine environment. The 'CO_2-School' is in addition, a major educational program. The selected activities will involve fundamental experimental and theoretical work, analysis of samples from outcrops and case studies, development of mathematical models, modelling activities and testing in case study environments. The centre will as far as possible try to bridge gaps from details to concepts and applications, from small to large scale, and to transfer data and knowledge between many related fields.

SIGNIFICANT REGIONAL CCS PROJECTS

Kårstø. In 2006, the government began planning of a full-scale CO_2 capture facility from Naturkraft's gas-fired power plant at Kårstø. The plans included a solution for transportation and secure storage of CO_2, and the project was to be financed by the Norwegian government. Since then, a significant amount of preparatory work has been done, on all aspects of construction of the full-scale CCS facility. The project was ready to start the tender for vendors early in 2009, with construction startup plans that autumn. The project was then stopped, due to the low electricity prices and a high price on gas, which has made the dispatch regularity of the plant uncertain. After 2009, technical planning work has been done for integrating of the power plant with the neighbouring gas compression station for supplying gas from Norway to Europe. As of today no decision has been made either for this integration or for the CCS project, which is on hold.

Mongstad. In 2006, the Norwegian government granted Statoil permission for the building of a combined heat and power plant (CHP) at Mongstad. The government and Statoil agreed on build CCS at Mongstad in two stages. First to build a CO_2 Capture Technology Centre (TCM) with a capacity of 100,000 ton/y, followed by the construction of a large-scale plant that includes CO_2 capture, transport and storage. Originally the full scale capture plant was planned to be operational in 2014, but because of lack of clear and efficient organisation, decisions and responsibility for this joint government and private venture, it has been postponed several times. The agreement made between the government and Statoil has insufficient incentives for fast and economically effective deployment. The model does not state clear enough deadlines and limits on investments. The first stage of the agreement – the CO_2 TCM, was officially opened in May 2012, and contains two capture facilities (amine plant by Aker Clean Carbon and Chilled Ammonia by Alstom), which can switch between these two different flue gasses – or a mix between them. One source of emissions is the existing catalytic cracker facility at the Mongstad Refinery, and the other is emissions from the gas-fired combined heat and power plant. The partnership consists of Gassnova, on behalf of the Norwegian state, Statoil, Shell, and Sasol.

Norcem. Norcem is a cement manufacturer that emits approximately 800,000 ton of CO_2 each year. The last few years NORCEM has looked closely into the possibility of using CCS technology in the cement industry. One project has examined the extent to which excess energy from production of cement can be utilised for capturing of CO_2. There are plans to build a test centre for CCS technologies at the factory in Brevik in Southern Norway.

Sleipner/Snøhvit. The world's largest projects and perhaps best known are the capturing of CO_2 from natural gas production at Sleipner in the North Sea and Snøhvit close to Hammerfest in Northern Norway. These two projects were initiated by the Norwegian government's introduction of an offshore CO_2 tax in 1991 that made it commercially preferable to capture and store the CO_2 from the natural gas, rather than emitting it to the atmosphere. In the Sleipner project, approximately 1 Mt of CO_2 has been injected every year into a saline aquifer in the Utsira formation since 1996. Significant knowledge about CO_2 injection technology, monitoring and storage safety has been gained from this project. Snøhvit is a very similar project that started its injection in 2008. Quite different geological properties of the storage formation have introduced some challenges to the project, but approximately 3 Mt has been injected the last five years.

RECOMMENDATIONS/MOVING FORWARD

ZERO recommends that the policy of obligatory CCS in the permits (from the pollution authority) for any new gas-fired power, must be continued and extended to existing plants. The Norwegian Government must fulfill its promise to build full-scale CCS projects, while also establishing infrastructure for transport and storage.

Further, ZERO believes that a new political framework must be put into place to make CCS economically feasible for industry. As well, the CO_2 tax on offshore plants should be increased and earmarked for a fund dedicated to climate change technological solutions, including CCS.

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CCS in the United Kingdom

INTRODUCTION/OVERVIEW

The UK played a leading role in placing CCS on the international scene, but over recent years has struggled to deliver domestic action. Decisions in late 2012 will show whether the UK is at last able to live up to its potential and enable CCS projects to proceed. In so doing, it will tackle the difficult challenge of how incentives for CCS can be integrated into the power market to provide a business case for investment.

Success in the UK is essential to help maintain momentum for CCS in the EU as a whole. But a long-term UK policy will also require proactive efforts to foster the application of CCS on gas and industrial sources of CO_2, requiring greater attention to the development of CCS clusters.

REGIONAL CCS STATUS/ISSUES

In 2005 the UK used its joint presidencies of the G8 and European Union to push for accelerated action against climate change. As part of this diplomatic effort, the G8 Gleneagles Plan of Action included agreement to "accelerate the development and commercialisation of CCS technology".[67] The UK was subsequently at the heart of efforts to include CCS within the EU's Climate and Energy package of 2008, and worked bilaterally with China to develop the NZEC project.[68]

Unfortunately, however, the economic crisis resulted in cuts to UK Government spending, including on the support of CCS development overseas. Some new financial support was at last committed at the April 2012 London meeting of the Clean Energy Ministerial,[69] with £60 million of funding from the UK's International Climate Finance commitments directed towards accelerating CCS developments in China, Indonesia and South Africa.

Despite this history of fluctuating funding for international CCS projects, the UK continues to be recognised as a strong promoter of CCS. Not only has the UK engaged positively in initiatives such as the Carbon Sequestration Leadership Forum, but over a number of years the challenge of coal and the essential role of CCS were actively addressed by the Foreign and Commonwealth Office.

The UK approach recognised that it was imperative for climate diplomacy to not put all its effort into negotiating the text of international agreements, but must actively seek to shape the political conditions that would allow a global deal on climate change to be agreed. The deployment of CCS was thereby readily identified as a potential game-changing intervention. For without a means of decarbonising economies that remain dependent on coal reserves it would be very difficult to secure a shift in support for key actors in the global climate negotiations. While China figures prominently in media discussion of continued coal use, the voting influence of US senators from 'coal states' on any potential US climate legislation meant that CCS has a role to play in reshaping expectations of the practicality and desirability of reducing carbon emissions.

The UK's strong international support for CCS lies in part on the positive potential for deployment of CCS domestically. The UK benefits from extensive offshore geological storage capacity for captured CO_2. When combined with a world-leading academic community and the engineering and skills base of the offshore

67 http://www.decc.gov.uk/assets/decc/what%20we%20do/global%20climate%20change%20and%20energy/tackling%20climate%20change/intl_strategy/gleneagles/gleneagles-planofaction.pdf.

68 http://www.nzec.info/en/.

69 http://www.decc.gov.uk/en/content/cms/news/pn12_053/pn12_053.aspx.

oil and gas industrial sector, this presents the UK with the opportunity to develop CO_2 storage solutions at a level beyond all other EU countries, with only Norway able to act at similar scale. With the UK power sector also facing the need to replace ageing generating and transmission infrastructure, the time appeared ripe for the UK to integrate a proactive CCS policy into its energy strategy. The extended use of North Sea assets via carbon storage (and potentially the development of Enhanced Oil Recovery) has additional appeal to policy makers given the declining production of oil and gas reserves.

Yet despite this positive backdrop, the UK has struggled to secure investment in domestic CCS projects and to integrate CCS into its wider energy policy. The UK's first CCS Competition was launched in 2007 but failed to secure a project able to proceed with investment despite four years of effort. The UK government was strongly criticised by the National Audit Office for its failure to manage the "significant technical, commercial and regulatory risks" of the project.[70] A common view of NGOs and utilities was that the government had failed to anticipate the scale of the procurement challenge, with the demonstration of CCS conceived at the time as a Research and Development experiment rather than an integrated element of a power station. This left all sides dissatisfied, with increased commercial risk for developers and insufficient attention paid to how CCS fitted into a decarbonisation framework.

Efforts by government to launch a second CCS competition in 2010-11 also suffered as a result of the economic crisis, with a planned levy on electricity bills being withdrawn by the Treasury. But thanks to the inclusion of seven UK projects within the EU's NER300 funding competition (see EU chapter), the nascent CCS industry in the UK was able to maintain some limited momentum.

Finally, a new CCS Commercialisation Programme was launched in 2012. At the time of writing the details of bidding projects have yet to be announced, but full chain projects are expected to include the UK's four remaining bidders for NER300 support (Don Valley, Drax, Peterhead, Teesside) plus the Scottish sister project to Summit Power's Texas Clean Energy Project. While some limited capital funding is available, the UK government faces two challenges if it is to secure a viable financial offer to projects.

First, it must align its timetable for decisions with that of the NER300 to enable one or more projects to receive EU support. Second, it must ensure that timely decisions are taken on the proposed Electricity Market Reform (EMR) legislation to provide access for CCS projects to a form of Feed in Tariff. This will provide the majority of funding for projects over their lifetime, yet details are still to be fully confirmed.

Similarly, an accompanying Emissions Performance Standard requires further changes if it is to become a driver for CCS deployment. An early draft of legislation proposed that it be set at a level of 450gm/kWh, with gas plant grandfathered until 2045 and CCS projects exempted. As such, the EPS would fail to provide a forward driver for investment in CCS (particularly given continued political rhetoric from some leading politicians in support of unabated gas), and would increase scepticism that CCS is a fig leaf for the continuation of the fossil fuel economy rather than a vital transition technology.

RECOMMENDATIONS/MOVING FORWARD

UK NGOs have played a constructive role in debates around CCS in the UK. As with colleagues in Germany, the US and elsewhere, UK NGOs actively opposed proposals for new coal power stations through direct action and political mobilisation. Thanks to NGO advocacy the introduction of the UK's Climate Change Act in 2009 provided a framework for power sector decarbonisation in line with carbon budgets, enabling CCS to be considered as an exit strategy from conflicts around coal. The previous Labour government therefore widened its ambitions from a single demonstration plant to four projects. Without NGO pressure it is unlikely that this would have been secured in the face of inertia within government energy policy that saw CCS as an expensive additional extra rather than an integral part of any future fossil fuel policy.

70 http://www.nao.org.uk/publications/1012/carbon_capture_and_storage.aspx.

The UK experience has been that having a clear policy framework for decarbonisation also enables constructive dialogue between the CCS industry and NGOs. Project developers, equipment suppliers, and the providers of CO_2 transport and storage services are all keen to see a growing market for CCS, just as NGOs are looking for effective decarbonisation of the power sector. Only in the case of projects involving significant new unabated coal capacity has there been a divergence of views. But even in these cases, NGOs have been willing to engage on how CCS can be a solution to CO_2 emissions. Thanks to the availability of offshore CO_2 storage, the UK has a greater opportunity to avoid adverse public opposition as has occurred elsewhere in Europe.

The next six months offer the prospect of renewed momentum for UK CCS policy. If the government is able to accelerate the development of a number of projects through the Commercialisation Programme, CCS will begin to feel more tangible for policy makers and industry alike. This will require continued effort to secure credible and durable incentives for CCS within Electricity Market Reform. Lessons learned in the UK will be valuable for the rest of the EU and beyond.

Yet there remains much more to do. The potential for CCS on gas has been marginal in this debate, reflecting the erroneous assumption that CCS is only viable for coal. Instead, the forthcoming UK gas generating strategy will need to set out a route map for the transition to gas CCS. A removal of any requirements for CO_2 emissions reduction from gas plants risks crowding out investment in CCS and inciting campaigning opposition to gas in the same way that coal has been targeted over recent years.

Further, with continuing concerns about the potential for local industry to move to another location with less stringent emissions controls (i.e. carbon leakage) and the offshoring of jobs in energy intensive and process industries, the acceleration of CCS for industrial CO_2 emitters is a necessary next step. CCS offers itself as a job retention technology that can foster industrial ecologies around the re-use of CO_2 and the reduction of costs through the development of clusters. CCS on industry is thereby an attractive political proposition (and indeed less at risk of public opposition). With governments looking to reboot economic growth, CCS can provide a means of adding value to existing industries and equipping economies for a carbon-constrained future.

With progress on CCS in the power sector slower than desired internationally, smaller-scale industrial projects also offer the prospect of fast tracking the development of CO_2 transport and storage infrastructures. While CCS in the power sector continues to be considered just one option among competing low-carbon alternatives, CCS on industry is an inescapable requirement. This calls for an active approach from the UK government approach that is more willing to identify the geographies and geologies that will accelerate CCS deployment in the UK. The pressure is on: the UK has all the attributes to be a pathfinder for CCS. It simply needs to make it happen.

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CCS in the United States

INTRODUCTION/OVERVIEW

The US began its research and development on CCS in 1997, and has completed a series of basic and applied research projects as well as more than 30 pilot test injections.

At the federal level the government has also provided loan guarantees for CCS projects and initiated a series of government co-funded demonstrations through public-private partnership programs (Clean Coal Power Initiative, Industrial CCS projects, FutureGen, and Regional Carbon Sequestration Partnership Program). Many of the significant CCS projects listed below are part of these government-sponsored efforts.

SIGNIFICANT REGIONAL CCS PROJECTS[71]

FutureGen 2.0. The US FutureGen project is reconfigured from its original design as an IGCC/CCS project. It is now focused on retrofitting the 200MW Meredosia coal plant in Illinois with an advanced oxy-combustion system and sequestering 1.3 million tons per year in a saline aquifer in Illinois.

Hydrogen Energy California. Hydrogen Energy California (HECA) has proposed a power/polygeneration project (similar to TCEP by Summit, described below) in California – using petroleum coke (petcoke) instead of coal as fuel and EOR as the sequestration target. HECA, under the new owners SCS California Energy, filed an amended application for certification with the California Energy Commission (the permitting agency) in May of 2012.[72]

Indiana Gasification. Indiana Gasification will generate substitute natural gas and spur the development of the first CO_2 pipeline moving anthropogenic CO_2 from Midwest to the Gulf Coast region for use by Denbury Resources for the purpose of enhanced oil recovery. The project is currently in negotiations with the Department of Energy for federal loan guarantees.

Port Arthur. Air Products will supply one million tons of CO_2 from its steam methane reforming plant in Port Arthur, Texas to Denbury Resource's Green Pipeline for sequestration through CO_2-EOR. The first 500,000 tons is slated to come on-line in November of 2012. The project will provide an important initial step in evaluating the economics of lowering emissions from natural gas power through blended methane/hydrogen fuel.

Plant Ratcliffe. Plant Ratcliffe is Southern Company's 582 MW IGCC in Kemper County, Mississippi. The project is under construction and is slated for completion in 2014, and will likely be the world's first integrated CCS power project. It will provide 3.5 million tons of CO_2 for enhanced oil recovery to Denbury Resources oil fields in the Gulf Coast region.

Point Comfort. Summit Power has proposed the first commercial scale (250 MW) natural gas power/CCS project proposed in the US in Point Comfort, Texas. The proposed project is slated to come on-line in 2016.

Texas Clean Energy Project (TCEP). TCEP is a Summit Power's 400 MW power/polygeneration project in Odessa, Texas. It will capture roughly three million tons of CO_2 per year for sequestration through CO_2-EOR.

71 Information for most projects can be found at http://sequestration.mit.edu/tools/projects/index.html. FutureGen 2.0 information can be found at http://www.futuregenalliance.org/. Information on Point Comfort can be located at http://www.summitpower.com/projects/carbon-capture/.

72 http://hydrogenenergycalifornia.com/wp-content/uploads/2012/06/FINAL-HECA_Newsletter_062612.pdf.

TCEP recently announced that the Import-Export Bank of China will provide project financing and Sinopec will become a major contractor in the project – making it the first joint US-Sino commercial scale CCS project. The project is expected to break ground in late 2012/early 2013[73].

Washington Parrish. NRG is a 60 MW post combustion capture retrofit on an existing coal plant using Fluor's Econoamine technology near Houston Texas. The project's CO_2 will be stored through enhanced oil recovery. NRG has discussed expanding the project size and recently announced plans to construct a 75MW NGCC project to provide make-up power for the project. There is no estimated date for breaking ground.

REGIONAL CCS STATUS/ISSUES

The US has finalised environmental regulations for storing CO_2 underground and protecting underground sources of drinking water. Although enabling policies such as federal funding and state tax or other incentives, or government support through offtake contracts for plants' products are helpful for individual projects — broad deployment of CCS is unlikely without something more. The current projects most likely to become operational rely on a combination of those incentives and almost always revenue from EOR.

US legislation targeting the development of an economy-wide cap and trade failed to pass in 2010, and adoption in the near-term appears less likely. The two most likely opportunities to move CCS through policy are performance standards developed under the Clean Air Act and incentives developed for EOR-CCS.

Under the Clean Air Act, CO_2 emission limits are required to be set through the New Source Performance Standards (NSPS) program. The Obama Administration proposed setting a limit for new fossil power plants of 1000 lb/MWh — which would require roughly a 50% reduction in CO_2 emissions from a newly built conventional coal-fired power plant. Thus if the rule is finalised as proposed, future coal plants will be required to include in the order of 50% partial CCS systems[74].

The proposed emissions standards do not necessitate carbon controls on combined cycle natural gas power plants today, but the standards must be re-evaluated every eight years, providing the opportunity for reduction of emission levels on new gas plants that would necessitate CCS, as well as additional reductions from new coal-fired power plants. Furthermore, NSPS sets the 'floor' for air pollution control permits, which ultimately requires the use of best available control technology. Thus, in the US, as coal and gas plants move forward, the air pollution permitting process may require CCS on new fossil power generation even if emissions standards do not, by themselves, drive use of the technology.

In addition, the administration (current or next) will be required to set performance standards for existing power plants under the NSPS program. Unlike the 'new source' portion of NSPS, the 'existing source' program does not require an eight-year review and could be designed for a longer timeframe. Thus, while it is initially unlikely to drive CCS, the existing new source standard could provide a regulatory glide-path for decarbonising existing fossil units over time.

At the state level, Maine and Idaho have temporary moratoriums on coal until CCS is developed, while Illinois and Montana have standards that require 90% CCS for all new coal plants. California, New York and Washington have emission performance standards for new baseload electricity procurements that reflect the performance level of combined cycle gas plants.

73 Wall Street Journal, September 12, 2012.

74 http://epa.gov/carbonpollutionstandard/pdfs/20120327proposal.pdf.

RECOMMENDATIONS/MOVING FORWARD

According to studies by Advanced Resources International prepared for the US Department of Energy, CO_2 enhanced oil recovery has the potential to produce 67 billion barrels of oil at an oil price of US$85 per barrel using next generation technology, while roughly twice that amount is technically recoverable. To produce the 67 billion barrels, about 20 billion tons of CO_2 would be needed.[75] Emerging sources of EOR potential, residual oil zones (ROZ), are estimated to create additional demand for 13 billion tons.[76] Combined, this opportunity could result in over 176 GW of CCS projects. In addition, EOR is a mature industry in the US, with more than 40 years of experience in managing injected CO_2.

The National EOR Initiative (NEORI) is a stakeholder collaboration of ENGOs (including the Natural Resources Defense Council and the Clean Air Task Force), fossil energy companies, and bio energy companies. NEORI has recommended a federal tax incentive for EOR-CCS intended to drive CCS deployment at large-scale. The proposed structure of the credit would feature competitive bidding to maximise the program deployment. In addition, it is expected that the additional revenue from US domestic oil production would not only be 'self financing', but it would more than offset the cost of the program to the federal treasury. Analysis by the NEORI of its recommendations found the program would produce a positive net present value of US$100 billion to the US Treasury over a 40 year period.[77]

A similar program was introduced in the 112th Congress by Senator Richard Lugar (R-IN), in his proposed Practical Climate and Energy Plan legislation. The NEORI recommendations are currently under consideration in Congress.

In order to make 80% or greater reductions in power sector CO_2 emissions by mid-century in the US, CCS must be deployed on all fossil power generation units. There are several projects in the US that would apply CCS to both coal and natural gas, and potentially expand CO_2 pipeline infrastructure.

And while the prospects for a national economy-wide climate policy seem less promising than two years ago, provisions of the Clean Air Act are providing an opportunity to address emissions reduction from the power sector, and a potential driver for CCS deployment. In addition, the significant potential for CO_2 EOR in the US provides a viable pathway for large-scale CCS deployment incentives.

CHAPTER AUTHOR:
Kurt Waltzer (Clean Air Task Force)

75 "Improving Domestic Energy Security and Lowering CO_2 Emissions with "Next Generation" CO_2-Enhanced Oil Recovery (CO_2-EOR)". National Energy Technology Laboratory, July, 2011.

76 Using the Economic Value of CO_2-EOR to Accelerate the Deployment of CO_2 Capture, Utilization and Storage (CCUS). Prepared for the Electric Power Research Institute CCS Workshop by Advanced Resources International, April, 2012.

77 http://neori.org/publications/neori-report/.

CCS in Major Emerging Economies

INTRODUCTION/OVERVIEW

This chapter summarises the research and policy actions three emerging economies are taking toward CCS: China, India, and South Africa. The actions described are not exhaustive, but provide a snapshot for how three different coal-dependent countries are moving forward with evaluating the future of CCS.

From an emerging economy perspective, the costs and efficiency losses associated with CCS pose significant challenges. Why should a developing country bear the extra costs and impacts of CCS if the rest of the world isn't using the technology? Actions taken on CCS in each of these countries extend beyond international cooperation and include forward-thinking policies and plans to determine whether and how CCS fits into the future energy portfolio.[78]

CHINA

Research for CCS in China has been conducted since 2006 under the National Basic Research Program of China (973 Program), and since 2007 under the National High-tech Research and Development Program of China (863 Program), which includes a focused research area on CCS. China is also investing in CCS demonstrations abroad, including a September 2012 investment in one of the US Demonstrations, the Texas Clean Energy Project.

Importantly, a series of CCS demonstrations are planned and under way in China. These efforts include pre-and post combustion capture research and demonstration as well as demonstrations of geologic storage and CO_2-EOR. Notably, China's portfolio of demonstration projects include the construction and operation of GreenGen, an IGCC with CCS planned in its third phase, as well as a test injection at a direct coal liquefaction plant in Inner Mongolia, and an operational post-combustion CO_2 capture on a supercritical coal plant near Shanghai.

In August 2012 the Asian Development Bank announced plans to work with the National Development Reform Commission to develop a roadmap for CCS deployment in China. Key milestones in development of CCS in China, include:

1. National Medium and Long-term Science & Technology Development Plan (2006-20)
   - Formally establishes CCS as leading-edge technology
2. China's National Climate Change Program (2007-10)
   - Sets the goal of the development and dissemination of CCS
3. China's Special Science & Technology Action in Response to Climate Change (2007-20)
   - Establishes the key task of R&D on CCS
4. National 12th Five-year Plan Science and Technology Development Plan (2011-15)
   - Prompt CCS R&D
     - Provisions:
       - Develop Carbon Sink techniques (e.g., grass carbon sequestration), Mitigation of Greenhouse Gases in Agriculture and Land Use, and CCUS technologies to tackle climate change challenges

78 http://www.engineeringnews.co.za/article/newly-launched-atlas-identifies-viable-sites-for-sa-carbon-storage-2010-09-10/page:4.

◇ Focus on the research and development of advanced technologies, including Gen IV Nuclear Energy Systems, Hydrogen and Fuel Cells, Ocean Energy, Geothermal Energy and CCUS.

There has been significant international cooperation on CCS research in China, including engagement in the Carbon Sequestration Leadership Forum and the Global CCS Institute, as well as focused cooperative research efforts such as the EU-UK CCS Cooperative Action within China, or COACH program, the US-China Clean Energy Research Center (CERC), the China-EU Cooperation on Near Zero Emissions Coal (NZEC) and the Asia-Pacific Partnership on Clean Development and Climate. Cooperative efforts under these programs have spanned basic and applied research and have also included efforts designed to inform policy and regulatory developments that would enable CCS in China.[79]

INDIA

India has generally approached CCS cautiously (Rajamani, 2012). Historical actions on CCS in India have included engagement in the international research and development of the technology, including:

- internationally funded geological storage assessments;
- demonstration of CO_2 capture with co-benefits, such as capture and utilisation via fertiliser generation;
- participation in the Carbon Sequestration Leadership Forum; and
- participation in the original FutureGen demonstration project.

The approach document and working group reports that have contributed toward the development of India's 12th Five-Year Plan (2012-17), anticipate the following future provisions for CCS in India:

In the **Faster, Sustainable and More Inclusive Growth-An Approach to the Twelfth Five-Year Plan**, the Indian government will encourage the application of Integrated Gasification Combined Cycle (IGCC). The plan also includes provisions for carefully monitoring the development of technology for CCS and assessing the suitability and cost effectiveness of CCS in India.

The **Energy Constitution of the working groups** identified areas that need attention during the 12th plan, including enhancing domestic oil and gas production via enhanced oil recovery (EOR) for existing oil fields.[80]

79 For more information on CCS in China, please see: CCS in China: Towards an Environmental Health and Safety Regulatory Framework. WRI Issue Brief. http://www.wri.org/publication/ccs-in-china, and Guidelines for Carbon dioxide Capture and Storage in China, Tshingua University Press. 2012.

80 For more information on CCS in India, please see: Carbon capture and storage emerging legal and regulatory issues, 2011. Hart publishing. Edited by Havercroft et. Al. Chapter 14: India and Climate Change: Contextualising India's approach to CCS technology by Lavanya Rajamani. Pages 211-221. Faster, Sustainable and More Inclusive Growth-An Approach to the Twelfth Five Year Plan, Planning Commission, Government of India, 2011. http://planningcommission.nic.in/plans/planrel/12appdrft/appraoch_12plan.pdf. Energy Constitution, Working Groups / Steering Committees for the Twelfth Five Year Plan (2012-2017), Planning Commission, Government of India, 2011. http://planningcommission.gov.in/aboutus/committee/wrkgrp12/wg_energy.pdf.

SOUTH AFRICA

South Africa established its South African CCS Centre (SACCS) in March of 2009 with a strategy of developing and implementing a roadmap for deploying CCS in South Africa. The Roadmap outlines the following milestones:

- 2004. CCS Potential (completed)
- 2010. Carbon Atlas (completed)
- 2016. Test injection, 10s thousands of tons of CO_2
- 2020. Demonstration plant, 100s thousands of tons of CO_2
- 2025. Commercial CCS, millions of tons of CO_2.

The Atlas was published in 2010 and indicated that South Africa has 150 Gigatons of storage capacity. Only 2% of the estimated storage capacity was found onshore. Additional research is under way to move from theoretical to estimates toward projections with more certainty. Planning for the test injection is under way.

The World Bank is currently investing US$1.1 million of its CCS fund on efforts in South Africa, including work on legal and regulatory issues as well as public engagement on CCS.

Although much of the work on CCS in South Africa has centred on geologic storage, the government supports the development and implementation of CCS and has placed a carbon capture readiness requirement on Eskom's 5400 MW Kusile power station. [81]

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81 For more information on CCS in South Africa, please see: Carbon Atlas: http://www.sacccs.org.za/wp-content/uploads/2010/11/Atlas.pdf and http://www.globalccsinstitute.com/community/blogs/authors/tony-surridge/2011/02/23/south-africa-carbon-capture-and-storage.

CCS in the international arena

The treatment of CCS under the United Nations Framework Convention on Climate Change (UNFCCC) has been a topic of particular interest to ENGOs. A recent debate circled around the inclusion or not of CCS as an eligible activity in the Clean Development Mechanism (CDM). Some of the organisations under our Network (not all – and along with several more outside the Network) had stated that it would be ill-advised and potentially problematic to recognise CCS as a valid methodology in the CDM process, because of CDM-related aspects. The Conference of Parties (COP) has now formally accepted it as an eligible activity however, and has largely finalised the modalities for the technology under the CDM.

Rather than continuing to debate the merits of this decision, our groups urge that the modalities be implemented and overseen in a way that will ensure maximum environmental integrity and minimal unintended consequences. It will be paramount for expertise that resides mostly in industrialised countries to be transferred to host countries in order to ensure sound site selection, operation, monitoring, accounting and project closure. The CDM should not be allowed to lead to a second-tier approach to CCS implementation, nor should it result in the tarnishing of the excellent track record that CCS projects have created to date. Doing so would jeopardise its future prospects for broader development.

Overall, we see the inclusion of CCS in the CDM as conducive to the development of a limited number of lower cost projects (such as natural gas processing applications), but as unlikely to result in the broad deployment of the technology at the scale needed to mitigate climate change. This is because of the price level associated with credits, and with its potential for instability and fluctuation. Nonetheless, if carried out safely and effectively, such projects under the CDM could build valuable and important experience and expertise in developing countries that will expedite the broader deployment of the technology.

Regardless of the particulars and suitability of the CDM for CCS, our groups are supportive of an international mechanism that will facilitate the development of CCS in developing countries with assistance (technical or financial) from industrialised countries. We believe that a CCS-specific mechanism is needed in order to ensure meaningful deployment in developing countries, its safety and effectiveness, as well as broad acceptance. We therefore note with interest that a CCS mechanism was mentioned in a 2009 Long-term Cooperative Action (LCA)[82] report that reflected the informal discussions by parties at that time, and which aimed to assist the end-of-year climate change negotiations. The proposal for a specific new mechanism for CCS, however, was not subsequently supported by Parties. CCS was also noted in the same report as one example of an eligible component of parties' Technology Action Plan,[83] and as an element of a Technology Incentive Development and Transfer.[84] Developed and developing country governments should now agree on principles to a mechanism that will provide for:

- financing aid for CCS projects in developing countries;
- transfer of scientific knowledge and technical know-how from developed to developing countries;
- efforts to map the geological storage capacity for CO_2 in developing countries;
- tapping the value of CCS to the carbon market in a way that additional reductions are recognised, learning from the weaknesses of the CDM practice to date; and
- capacity building assistance to developed countries to build appropriate regulatory frameworks that will ensure the safety and effectiveness of CCS projects in their borders.

Member countries of the Major Economies Forum on Energy and Climate should strengthen the Technology Action Plan pledged under the forum, with special emphasis on providing financing for early projects and beyond.

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81 See: FCCC/AWGLCA/2009/14.

82 Ibid, "Elements of a national Technology Action Plan", p. 167.

83 Ibid, "Possible elements of a technology incentive development and transfer", p. 169.

Conclusions

Tackling climate change requires aggressive and prompt action. A number of technologies are available to reduce global carbon emissions. CCS has a valuable role to play in the climate mitigation portfolio, alongside other solutions. First generation CCS technology is commercially available today, enabling the deployment of the technology to begin worldwide immediately. Extensive research has shown that this can be done safely and effectively, with the right regulatory oversight. Regulatory frameworks for carbon dioxide injection are being finalised in various countries around the world, and it is important that these contain adequate safeguards for public health and the environment, and that all countries abide by minimum standards.

The main barrier for its adoption today is the price premium that it entails, but significant cost improvements are expected in the near future once serious deployment begins. Governments have a pivotal role to play in enabling CCS deployment through complementary policies that include limits and a price on carbon emissions, incentives for early deployment and performance standards for specific types of facility. Enhanced oil recovery using carbon dioxide is expected to play an important role in the early years of CCS deployment in certain countries, but appropriate regulation of the practice is needed to ensure permanent sequestration. Internationally, a dedicated financing mechanism to enable CCS deployment in developing countries with industrialised country participation is needed.

CCS has an excellent track record to date. Nonetheless, support for the technology is not universal, for a variety of reasons. Our organisations are engaged in advocating for the safe, effective and prompt deployment of CCS technology as a climate mitigation tool. The earth's climate will not wait — nor should we.

FOR MORE INFORMATION:
engonetwork.org