BRIEFING PAPER

Carbon Capture and Storage in China

An E3G report for Germanwatch

E3G

GERMANWATCH

Brief Summary

To prevent climate change from breaching dangerous tipping points, global greenhouse gas (GHG) emissions will need to peak before 2020 and fall rapidly thereafter. Developed countries must take the lead by cutting their own emissions sharply and supporting the efforts of developing countries. China has ambitious targets on energy efficiency and renewable energy but will remain dependent on coal for at least the next few decades. Early development and deployment of Carbon Capture and Storage (CCS) is therefore essential if China is to play a meaningful role in global emissions reduction. CCS should be seen as one component of an ambitious overall clean energy strategy, not a substitute for other measures.

The EU has earmarked funding for 10-12 CCS demonstration plants but the money will not be available for projects in third countries such as China. This leaves question marks over future EU-China cooperation on CCS. The EU needs to be clear on what it wants to achieve and what it is willing to fund. Options range from small-scale technology development to a bigger investment in laying foundations for wider roll-out of CCS in China. The Italian G8 or the US-led Major Economies Forum could be possible opportunities to, *inter alia*, trigger progress on global CCS cooperation as a catalyser for wider efforts to achieve a fair and effective UN agreement on climate change in Copenhagen in December 2009.

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Contents

1 Executive summary

To prevent climate change from breaching dangerous tipping points, global greenhouse gas (GHG) emissions will need to peak before 2020 and fall rapidly thereafter to at least 80% below 1990 levels by 2050.[1] Developed countries must lead the way as they are responsible for around 70% of historical emissions, their per capita emissions remain well above average, and they have the technological and institutional capacity to reduce their emissions sharply over the next decade.

China's per capita carbon emissions are substantially lower than those of Europe or the United States.[2] However, in terms of total emissions, China has overtaken the US as the world's largest CO_2 emitter. This is mainly due to China's impressive growth and relatively high energy intensity compared to developed countries. For example, energy-intensive industries and the construction sector account for nearly half of China's energy use.[3] It is also because of China's role as a manufacturing hub in global supply chains: a recent study suggested that about one third of China's emissions were embedded in exports to the rest of the world in 2005.[4] All of the analysis points to a rapid rise in China's emissions under business-as-usual projections due to its growing energy demand and coal's unusually large share (around two thirds) in China's energy mix.

China has recognised the need to tackle climate change and improve its energy security. The focus is on improving energy efficiency and promoting renewables and alternative technologies including nuclear power. China leads the world in solar production and has a rapidly growing wind industry. It is also increasing the use of super-critical and other advanced coal-based technologies.

A number of recent studies have explored possible energy and emission futures for China. All of them indicate that even with strong policy incentives for energy efficiency, renewables and other low carbon technologies, coal will remain a major part of China's energy mix until at least 2030.

If China is to make a meaningful contribution to global efforts to reduce carbon emissions it will need to use the full range of opportunities available – energy efficiency, renewables, as well as cleaner coal technologies including carbon capture and storage (CCS). Hence, CCS should also be seen as one component of an ambitious overall clean energy strategy, not a substitute for other measures. A coal-free China is not a realistic medium-term option and there is no obvious alternative to CCS as a means to reduce China's emissions from coal on the scale required to avoid catastrophic climate change.

China's official view on CCS is that developed countries must take the lead in demonstrating CCS and provide a much stronger framework of incentives for action in developing countries. China is involved in a number of multilateral and bilateral CCS cooperation initiatives and there are plans for some small-scale demonstration projects. Chinese companies see CCS as a potential export opportunity and its Ministry of Science and Technology is developing a longer-

[1] Climate Action Network International (2009), *Position on an Annex I aggregate target, http://www.climateactionnetwork.ca/e/cop-15/can-int-annex1-position.pdf*

[2] The Netherlands Environmental Assessment Agency analysis has the following figures for 2006 (tCO_2/person): USA=19.4, Russia =11.8, EU-15=8.6, China=5.1 and India=1.8.

[3] International Energy Agency (2007) *World Energy Outlook: China and India Insight*, p 290

[4] Worldwatch Institute (2009) *State of the World*, p 85

term CCS R&D strategy. However the issue of domestic CCS demonstration and deployment remains sensitive and there is still a good deal of caution among Chinese policy makers. This is partly because of the “energy penalty”: installing CCS reduces a plant’s energy efficiency by up to 8-14 percentage points.

Current CCS activity in China is focused on developing a number of small, standalone demonstration projects to test different elements of the technology, with a particular focus on pre-combustion (Integrated Gasification Combined Cycle - IGCC) options. Enhanced Oil Recovery and Enhanced Coal Bed Methane Recovery are also of interest as they provide a possibility of additional revenue which could offset concerns around the energy penalty. Post-combustion is a more sensitive issue as this opens up wider questions around retrofitting existing power stations (a potentially huge and costly undertaking) although isolated initiatives are underway.

The United States, Australia, Japan, Canada and the EU all support CCS initiatives in China. Peabody, a US company, is a partner in the Chinese Greengen IGCC/CCS project. The Obama administration has signalled its interest in scaling up cooperation on clean coal technologies including CCS. Australia’s Commonwealth Scientific and Industrial Research Organisation (CSIRO) has developed a post-combustion carbon capture plant with China’s Huaneng Group at the Gaobeidian Beijing plant – the first demonstration of its kind in China. Japan and China have agreed to develop a CCS demonstration based on Enhanced Oil Recovery.

At the EU-China Summit in 2005 the two sides established a Climate Change Partnership. One of the main objectives agreed by both sides was to develop and demonstrate advanced, near-zero emissions coal (NZEC) technology through CCS by 2020 in China and the EU. Follow-up work is at an exploratory stage, with recommendations expected in autumn 2009. The EU has earmarked funding for 10-12 demonstration plants and aims to have these up and running by 2015. But the financing mechanism agreed in December 2008 excludes projects in third countries such as China, leaving question marks over the future of EU-China CCS cooperation.

If China is to move beyond the development of a few demonstration plants and seriously explore options for the broader roll-out of the technology, it will require a strong signal that the EU and other countries are prepared to support the global development of the technology, including a commitment to financing major projects in developing countries. The EU in turn needs to decide what it wants from its cooperation with China and tailor its support accordingly. Various options are conceivable, ranging from a stand-alone demonstration plant to a broader CCS initiative covering other industrial applications and wider infrastructure investment.

At the time of writing it is far from clear whether China will move quickly on CCS demonstration. Much depends on the funding question and wider international climate policy negotiations. In addition, three other factors will have a significant influence on the future of CCS in China: the location and adequacy of CO_2 storage sites in China; the development of a regulatory framework to manage the capture, storage and transport of CO_2; and the handling of Intellectual Property Rights (IPR) for any joint CCS development initiatives with an international dimension.

Initial studies by China's Ministry of Science and Technology and others indicate that China has adequate capacity to store its CO_2 emissions for the foreseeable future. There appears to be a good match between the main sources of CO_2 in China and proximity to possible storage sites. The majority of emissions from large point sources can be stored in large deep saline formations at estimated transport and storage costs of less than \$10/tCO_2 (not including monitoring costs).

However, a regulatory framework for CCS does not currently exist in China. The EU and other countries around the world are beginning to put in place their own frameworks and China could draw on these in due course. Any international support for CCS demonstration in China is likely to require that the government implements environmental safeguards, e.g. site selection, site monitoring etc, that comply with minimum standards.

The development of CCS will use existing IPR as well as generate new IPR. China is seeking to exploit the export potential of CCS, so the ability to control new IPR arising from the various demonstration projects is a priority for Chinese companies. At the same time, China is looking for support from other governments and companies, who will want reassurances that any existing IPR is protected and that they have access to any new IPR that has been developed.

It is clear that there are concerns in Europe about the robustness of China's IPR regime and a sense that CCS cooperation with China could damage Europe's competitiveness. While some of these concerns are unfounded they could present a significant obstacle to future cooperation.[5] What is needed is an IPR framework that gives confidence to industrial partners about IPR protection and enforcement. This will require the development of contractual agreements between business and government and may also require government-to-government Memoranda of Understanding (MoUs) to provide additional protection and enhanced knowledge sharing.

The cost of building a CCS demonstration plant in China is estimated to be between €300m-€500m, depending on the level of ambition. The World Bank has established a portfolio of Climate Investment Funds (CIF) including the Clean Technology Fund and the Strategic Climate Fund which could provide one source of funds. Longer-term prospects depend on the outcome of current UNFCCC negotiations on a post-2012 international climate agreement. Other sources will be needed in the meantime if the EU is serious about accelerating CCS demonstration in China.

The European Investment Bank is another potential source of funding (€3 billion low carbon window for Asia including a €500 million China Climate Change Framework Loan). Some Member States (e.g. UK) may be prepared to make bilateral contributions to CCS but it is unclear whether the amounts involved would be adequate. The European Commission is in the process of developing a Communication on *'Financing CCS and other clean carbon technologies in emerging and developing countries.'* This will make recommendations on how to disburse around €60m, a substantial share of which is likely to be available for work in China.

[5] E3G (2008) *Innovation and Technology Transfer: Framework for a Global Climate Deal*

In June 2008, G8 Energy Minsters agreed to launch 20 large-scale CCS demonstration projects worldwide by 2010 and help accelerate demonstration activities in developing countries. This could provide the basis for an initiative under the Italian G8 Presidency or under the new Major Economies Forum convened by President Obama to inject momentum into global CCS cooperation.

2 The scale of the emissions reduction challenge in China

To prevent climate change from breaching dangerous tipping points, global greenhouse gas (GHG) emissions will need to peak before 2020 and fall rapidly thereafter to at least 80% below 1990 levels by 2050.[6] Developed countries must lead the way as they are responsible for around 70% of historical emissions, their per capita emissions remain well above average, and they have the technological and institutional capacity to reduce their emissions sharply over the next decade.

If global GHG emissions are to peak before 2020, then the US and other developed countries will need to adopt ambitious binding national emission reduction targets comparable to those of the EU. In addition, developing country emissions will need to deviate substantially below business-as-usual projections. This will require enhanced actions by developing countries, particularly the major economies, backed by increased support (technology, finance, capacity building) from developed countries.

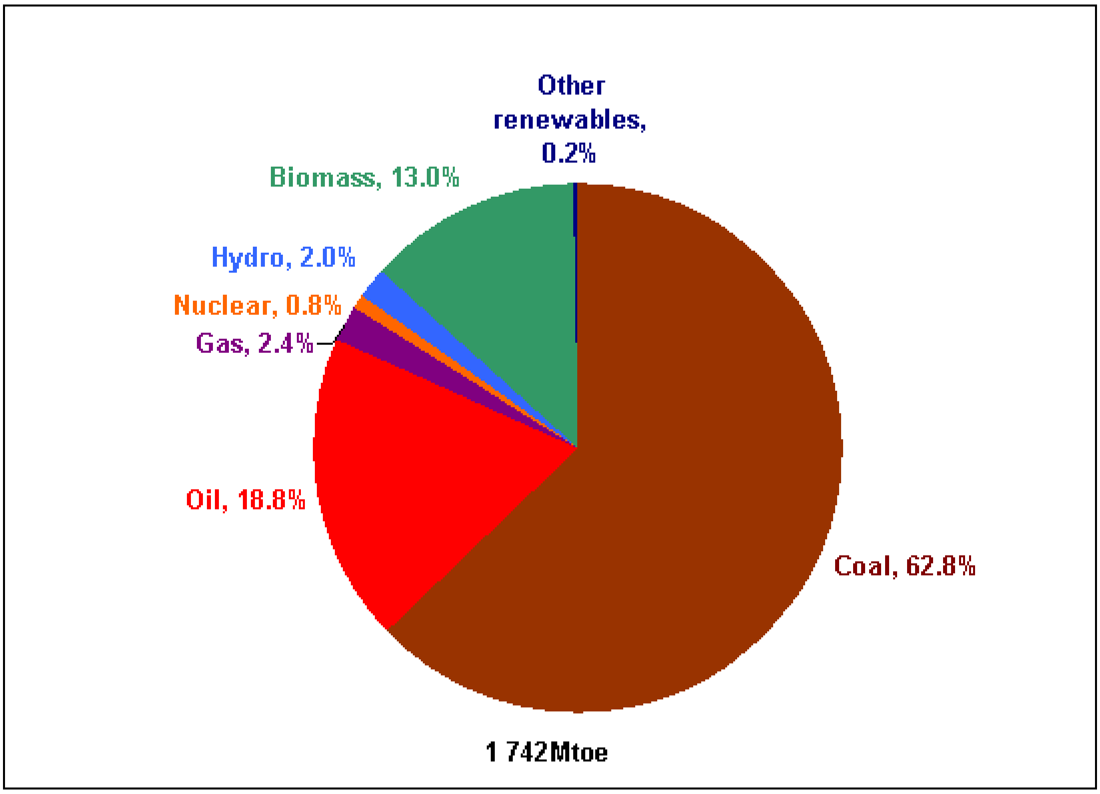
China's per capita emissions are substantially lower than those of Europe or the United States.[7] However, in terms of total emissions, China has overtaken the US as the world's largest CO_2 emitter. This is mainly due to China's impressive growth and relatively high energy intensity compared to developed countries. For example, energy-intensive industries and the construction sector account for nearly half of China's energy use.[8] It is also because of China's role as a manufacturing hub in global supply chains: a recent study suggested that about one third of China's emissions were embedded in exports to the rest of the world in 2005.[9]

Recent analysis by the Netherlands Environmental Assessment Agency[10] found that China accounted for 24% of global CO_2 emissions, with the US accounting for 21% and the EU-15 12%. The US Energy Information Agency (EIA) estimates China's annual emissions at 6.01 billion tonnes (Gt) of CO_2, with the US at 5.9Gt.[11] The International Energy Agency (IEA) estimates China's annual emissions at 5.61Gt of CO_2, with the US at 5.7Gt.[12] All of the analysis points to a rapid rise in China's emissions under business-as-usual projections.

[6] Climate Action Network International (2009), *Position on an Annex I aggregate target, http://www.climateactionnetwork.ca/e/cop-15/can-int-annex1-position.pdf*
[7] The Netherlands Environmental Assessment Agency analysis has the following figures for 2006 (tCO_2/person): USA=19.4, Russia =11.8, EU-15=8.6, China=5.1 and India=1.8.
[8] International Energy Agency (2007) *World Energy Outlook: China and India Insight*, p 290
[9] Worldwatch Institute (2009) *State of the World*, p 85
[10] Netherlands Environmental Assessment Agency, *China Contributing Two Thirds to Increase in CO2 Emissions*, 13 June 2008
[11] EIA (2008) *World Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels, 1980-2006* http://www.eia.doe.gov/iea/carbon.html
[12] IEA (2008) *CO2 Emissions from Fuel Combustion* http://www.iea.org/w/bookshop/add.aspx?id=36

3 The importance of coal in China

Coal accounts for nearly two-thirds of China's energy needs - 80% of electricity, 50% of industrial fuel use and 60% of chemical fuel use[13] as shown in Figure 1 below, from the IEA World Energy Outlook (2007).



*Includes other energy sector, transport, services, agriculture, non-energy use and non-specified.

Figure 1: Total Primary Energy Demand in China. 2005

China's domestic coal reserves are the second largest in the world after Russia. According to the IEA, in 1999 China's coal reserves were identified as 1,003 billion tonnes, although only 115 billion tonnes can be regarded as proven reserves. This yields a reserve-to-production ratio of around 50 years at current production levels. More recent assessments conclude that proven reserves could be as high as 192 billion tonnes, and a prospecting programme is underway to expand this. It is therefore likely that China has more than 50 years of coal available.

Rapid growth in the power sector is the main driver of increasing coal use. In 2006, China had around 622 GW of installed electricity generation capacity, up by 100 GW in 2005. This was the largest year-on-year increase ever recorded in China, or indeed in any nation in the world. Over 90% of this capacity increase in 2006 was coal fired. An additional 1,312 GW of capacity is expected to be installed by 2030, leading to a total installed capacity of 1,755 GW – equivalent to the current installed capacity of the US and EU combined. In a business-as-usual

[13] IEA (2007)

scenario the majority of this will be based on sub-critical pulverised coal technology, with an efficiency of less than 40%.

Industrial sectors such as steel are also heavy consumers of coal – accounting for around 26% of annual coal consumption in China. Industrial use of coal is expected to grow by 2.1% a year between now and 2030. China is also exploring coal-to-fuels technology to reduce its dependence on oil imports, which are expected to quadruple by 2030 under business-as-usual projections.[14] It has invested some $128 billion in a programme to develop coal-based synthetic fuels and chemical feedstocks[15]. Coal-to-liquid projects are a particular focus and there are around 20 coal-to-oil projects under construction. The IEA has estimated that after 2010, coal use for coal-to-liquids (CTL) plants is expected to rise rapidly, reaching 72 Mtoe in 2030.

Given China's huge reserves of coal, and its desire to continue to use them to improve its security of supply, it is impossible to imagine a situation where China is not using coal to meet its energy needs in the coming decades. This makes the development of CCS technology critical.

4 Current efforts in China to reduce dependence on coal

China has recognised the need to tackle climate change and to reduce its reliance on coal to improve its security of supply. The government published a detailed National Climate Change Programme in 2007 and established a "Climate Change Leading Group" in the State Council. It has also begun to implement a range of ambitious policies and measures to reduce its reliance on coal. The focus is on improving energy efficiency and promoting renewables and alternative technologies including nuclear power. Key measures include[16]:

- A target to reduce the overall share of coal in the energy mix to around 60% by 2010;
- A target to reduce energy intensity by 20% between 2006-2010 with a specific target to improve the efficiency of coal use for power generation from 392 gce/kWh to 355 gce/kWh in 2010;
- A requirement that 15% of total primary energy consumption should come from renewable sources by 2020 and 10% by 2010 – from 8% in 2006. A Renewable Energy Law requires the state grid to purchase power from renewable energy projects and provides premium prices for wind power and biomass;
- A target of 60 GW[17] (or more than 5% of the total power installed capacity) of nuclear power by 2020 (up from 6.6 GW in 2005);

[14] The IEA estimates that China's oil imports will increase from 3.1 Mb/d in 2005 to 13.1 Mb/d in 2030
[15] IEA (2007)
[16] These targets can be found in the general 11th FYP of Energy Development, China's Sustainable Development Energy Strategy, and individual medium- and long-term development plans for renewable energy and nuclear energy.
[17] Under the new 'New Energy Promotion Plan' that is going to be introduced by the Chinese government, the target is going to be increased to over 70GW, Finance, *New Energy Promotion Plan Stimulus Provides New Opportunities*, 10th May 2009. http://finance.qq.com/a/20090510/000270.htm

- A requirement, since 2005, that all new large power plants (600 MW and above) use high efficiency super-critical coal-fired technology;
- An expected improvement in the average coal power generation efficiency - from 32% in 2000 to 39% in 2030, through the use of more efficient power generation technology;
- The closure, in 2007, of 553 small, inefficient plants with a total capacity of around 14GW. Retirement of inefficient power plants will total 50GW by 2010 (NDRC);
- An R&D focus on efficient power generation technologies including super and ultra-super-critical power generation, coal gasification including Integrated Gasification Combined Cycle (IGCC) and poly-generation.

China is becoming a world leader in the renewables industry. It is the world's largest supplier of solar panels and the largest user of solar hot water systems, installing 80% of all new solar hot water heater systems worldwide in 2005.[18] Wind power capacity in China grew by 125% in 2007, making China the fifth largest market in the world, and was expected to grow a further 67% to reach 10GW by the end of 2008[19]. This reflects both the commercial acumen of Chinese business and strong policy incentives provided by the Chinese government.

One result of the focus on energy efficiency in the power sector is the increase in the use of super-critical and other advanced coal-based technologies. In 2006 China built 18GW of super-critical plant, bringing total super-critical capacity to 30GW with a further 100GW on order. China is also developing ultra-super-critical and IGCC based generation technologies, as indicated below.

Table 1: Coal-Based Power Generation Technology in China

Technology	**Efficiency**	**Cost ($ per kW)**	**Status**
Subcritical	30%-36%	500-600	Main base of China's current generating fleet
Supercritical	41%*	600-900	About half of current new orders
Ultra-supercritical	43%*	600-900	Two 1000 MW plants in operation
IGCC	45%-55%	1100-1400	Twelve units waiting for approval by NDRC

* Indicates current efficiency. Improvements are expected in the future.

Source: IEA analysis based on data obtained from industry experts

[18] Environmental California Research and Policy Center (2007) *Solar Water Heating: How California Can Reduce Its Dependence on Natural Gas* http://www.environmentcalifornia.org/uploads/at/56/at563bKwmfrtJI6fKl9U_w/Solar-Water-Heating.pdf

[19] Global Wind Energy Council (2007) *Global Wind 2007 Report* http://www.gwec.net/index.php?id=90

5 Potential role of energy efficiency and renewables in reducing China's emissions from coal

A number of recent studies have explored possible energy and emissions futures for China, including the IEA World Energy Outlook 2007[20], joint work by the Global Wind Energy Council (GWEC), Greenpeace and China's Energy Research Institute (ERI), and a project by the Tyndall Centre.

IEA World Energy Outlook 2007

The IEA analysed the potential impact of a range of policies on China's energy sector in the period up to 2030. It presented two possible scenarios in that timeframe: The Reference Scenario, which looks at the evolution of the energy market based on current government policies; and The Alternative Policy Scenario, which is based on China fully implementing existing policies and measures, supplemented by new measures where necessary. For example the latter assumes that structural change within the economy is more vigorous than in the Reference Scenario and that switching to natural gas is actively promoted. The results are summarised below.

Table 2: China's Primary Energy Demand in the Alternative Policy Scenario (Mtoe)

					Difference from the Reference Scenario in 2030	
	2005	2015	2030	2005 - 2030*	Mtoe	%
Coal	1094	1743	1842	2.1%	-556	-23.2
Oil	327	518	653	2.8%	-155	-19.2
Gas	42	126	225	6.9%	25	12.6
Nuclear	14	44	120	9.0%	53	79.4
Hydro	34	75	109	4.8%	25	26.4
Biomass & Waste	227	223	255	0.5%	28	12.4
Other Renewables	3	14	52	11.9%	19	57.4
Total	**1741**	**2743**	**3256**	**2.5%**	**-563**	**-14.7**

* Average annual rate of growth.

Source: IEA World Energy Outlook 2007

[20] IEA (2007)

Energy savings of around 15% are achievable by 2030

As shown in table 2, primary energy demand in 2030 is reduced by about 15% compared to the Reference Scenario but energy demand still increases by around 90% between 2005 and 2030.

Coal demand is reduced by 23% in 2030

In contrast, and as shown above, demand for all other fuels – natural gas, nuclear and renewables – increases. The main driver of this reduction is policies directed at the industrial sector, both through structural change and improved energy efficiency. More efficient industrial applications and increasing reliance on lighter industries directly contribute 22% of all the savings in coal use. Close to 40% comes from reduced electricity demand – to which industry contributes two-thirds – reducing the need for coal-fired power generation. More efficient coal-fired power plants and fuel switching account for another 30%.

Dramatic reduction in CO_2 emissions, by 2.6 giga tonnes in 2030

The biggest reduction comes from the power sector, which emits 1.5Gt less than predicted in the Reference Scenario. This sector alone contributes 57% of the reductions in emissions in China, thanks to policies aimed at reducing underlying electricity demand, promoting carbon-free power generation and improving the efficiency of coal-fired generation. Most of the short-term energy savings come from stricter implementation of the central government's policy of closing small, inefficient industrial facilities and power plants and their replacement by modern plants. In the longer term, economic restructuring (e.g. shift from manufacturing to services) drives faster improvement in energy intensity, alongside more widespread use of efficient energy production and consumption technologies.

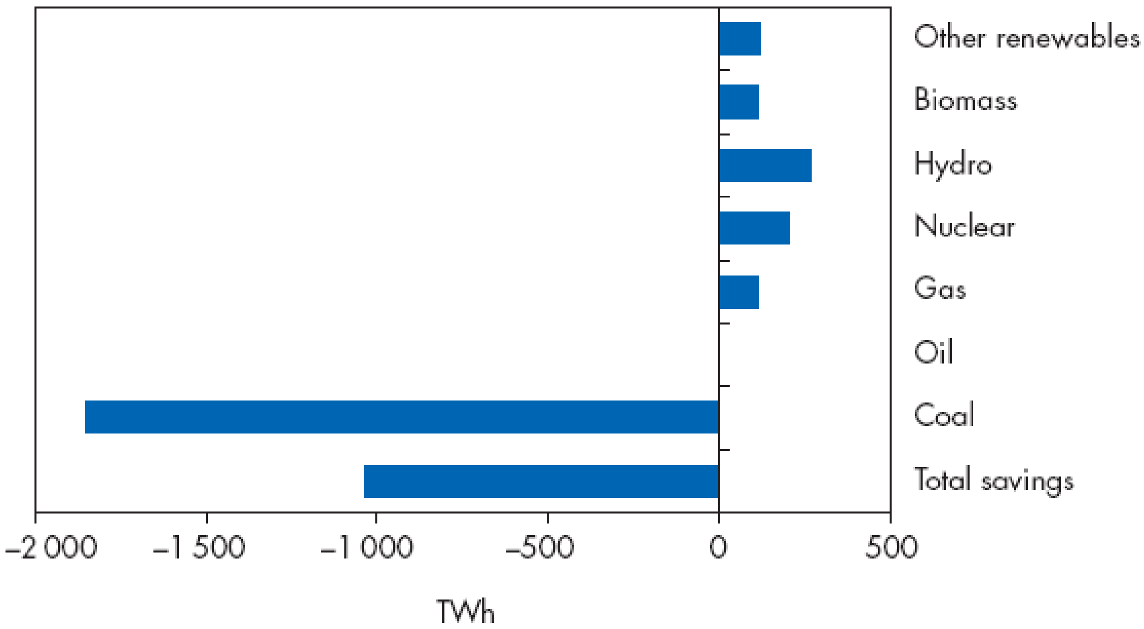
Coal demand increases by approximately 70% between 2005 and 2030

China remains largely self-sufficient in coal with net coal imports peaking at around 24Mtce in 2015 and declining to 4Mtce in 2030. Coking coal exports increase as domestic demand is significantly lower.

Electricity generation mix in 2030 is markedly different

As table 2 and figure 2 show, despite the dramatic improvement in energy efficiency and increase in renewable energy, coal continues to be the dominant fuel. However its contribution is substantially lower: 64% of total supply in 2030 compared to 78% in the Reference Scenario. Coal-fired power generation is cut by around 1,850TWh, which is close to the total level of coal-based electricity produced in China in 2005. Installed coal-fired capacity is lower by about 350GW.

Figure 2: Changes in China's Electricity Generation in the Alternative Policy scenario and Savings Relative to the Reference Scenario, 2030



Source: IEA World Energy Outlook 2007

Global Wind Energy Council / Greenpeace / Energy Research Institute[21]

This analysis is based on four scenarios: business-as-usual, Policy Baseline, Low Energy Demand, and Advanced Technology – with a range of assumptions about the implementation of policies to drive energy efficiency and the deployment of renewable energy technologies. The three alternative scenarios reduce the amount of energy generated and increase the amount of renewable energy relative to business-as-usual. In the first two scenarios, coal still represents about 70% of the total installed capacity in the period up to 2030. In contrast, in the last two scenarios, coal represents about 43% and 36% respectively of the total installed capacity in the period up to 2030 respectively.

Tyndall Centre

In September 2008 the Tyndall Centre published a working paper[22] as part of its research project on *China's Energy Transition: Strategies to Mitigate Carbon Lock-In*. The paper outlines a new set of cumulative carbon emission scenarios for China up to 2050 and 2100. These take as their starting point the IPCC Fourth Assessment Report conclusion that global cumulative emissions for this century need to be no more than 490GtC in order to stabilise CO_2 concentrations at 450 ppm (equivalent to a concentration for all greenhouse gases of around 550ppm CO_2-equivalent). It then apportions this global budget to China using two

[21] This is a discussion paper prepared by the Energy Research Institute (China) for GWEC and Greenpeace. The full title of the paper is 'A Discussion Paper on a Mechanism for Sectoral Emission Reduction Action: The Case of China's Electricity Sector' (2008).

[22] Tyndall Centre (2008) *Carbon Emission Scenarios for China to 2100*
http://www.tyndall.ac.uk/publications/working_papers/twp121.pdf

Contraction and Convergence (C&C) methods: one based on equal carbon emissions per capita and the other based on equal carbon emissions intensity relative to GDP. This produces two different cumulative budgets for China – 70GtC over the 21st century if based on per capita and 111GtC over the 21st century if based on GDP.

From this Tyndall Centre developed four carbon emissions pathways based on existing analysis by the IEA and the Chinese Energy Research Institute. These pathways reflect a range of assumptions about China's economic and industrial structures. All require China's emissions to peak in the period 2020-2030. The analysis does not contain quantitative analyses of the energy mix in each scenario; however, it does give details of the likely evolution of various energy technologies. In the scenarios with the lowest cumulative budgets, renewables become the main source of power by 2030. However for the economy as a whole coal remains the dominant fuel source, at least until 2020-2030, and CCS is therefore a critical influence on China's emissions. In the scenarios with higher budgets CCS is less important in the early years but begins to expand from 2020.

In April 2009 the Tyndall Centre published a report on China's Energy Transition: Pathways for Low Carbon Development,[23] which was based mainly on the earlier work. Among the findings of the report are: a peak in Chinese emissions can happen between 2020 and 2030; renewable energy could contribute more than 40% of China's total energy demand in 2050; and CCS plays an important role in three out of the four scenarios in helping China to develop within a carbon budget.

These studies, and others, indicate that even with strong policy incentives for energy efficiency, renewables and other low carbon technologies, coal will remain a major part of China's energy mix until at least 2030. What happens beyond that cannot be predicted with certainty but it seems likely that coal will continue to play a major role in powering China's economy.

If China is to make a meaningful contribution to global efforts to reduce carbon emissions it will need to use the full range of opportunities available – energy efficiency, renewables but also cleaner coal technologies including CCS. Hence, CCS should be seen as one component of an ambitious overall clean energy strategy, not a substitute for other measures. A coal-free China is not a realistic medium-term option and there is no obvious alternative to CCS as a means to reduce China's emissions from coal on the scale required to avoid dangerous climate change.

[23] Watson, J and Wang T (2009) *China's Energy Transition: Pathways for Low Carbon Development* http://www.tyndall.ac.uk/publications/tyndallchinaapril09.pdf

6 Current thinking and activity on CCS in China

China is involved in a number of multilateral and bilateral CCS initiatives and there are plans for some small-scale demonstration projects. A number of Chinese companies see CCS as a potential export opportunity and the Ministry of Science and Technology is developing a longer-term CCS R&D strategy. However the issue of domestic CCS demonstration and deployment remains sensitive and there is still a good deal of caution among Chinese policy makers. This is partly because of the “energy penalty” -- installing CCS reduces a plant’s energy efficiency by up to 10 percentage points. It also reflects China’s view that developed countries must take the lead on demonstrating CCS and provide a much stronger framework of incentives for action in developing countries.

6.1 Examples of current CCS activity in China

Current CCS activity in China is focused on developing a number of small, standalone demonstration projects to test different elements of the technology, with a particular focus on pre-combustion (IGCC) options. Enhanced Oil Recovery and Enhanced Coal Bed Methane Recovery are also of interest as they provide a possibility of additional revenue which could offset concerns around the energy penalty. Post-combustion is a more sensitive issue as this opens up wider questions around retrofitting existing power stations (a potentially huge and costly undertaking) although isolated initiatives are underway. Examples of activity in each area are set out below.

Enhanced Oil Recovery (EOR)

Various EOR projects are underway at, among others, Shengli (Shandong), Zhongyuan (Henan), Daqing (Heilongjiang) and Dagang (Tianjian) oilfields. In May 2008 Japan and China signed a deal to develop a project to capture 1 to 3MtCO_2 annually from the Harbin Thermal Power Plant in Heilongjiang province, and potentially other plants, and then transport it 100 km by pipeline about to China’s largest oil field, Daqing, for injection and storage in the oil field.

Enhanced Coal Bed Methane

The China Coalbed Methane Technology/ CO_2 sequestration project was launched in 2005 in Qinshui, Shanxi Province, with a budget of $9 million. It was a partnership between the Canadian government, Chinese Ministry of Commerce and China United Coal Bed Methane Corp. The project is now finished.[24]

Greengen IGCC (Pre-combustion)

This is being developed by a consortium of 8 Chinese energy companies and a US partner, Peabody. It aims to develop and demonstrate an integrated coal gasification, hydrogen production, hydrogen power generation and CO_2

[24] www.cslforum.org/documents/FinalReportCCBMproject.pdf

sequestration system. Based in Tianjin, the project has three phases with the ultimate aim of having a 400 MW CCS demonstration plant in operation by 2015.

Huaneng Beijing Power Plant (Post-combustion)

This is a partnership between Australia (led by CSIRO) and China (Huaneng Group and the Thermal Power Research Institute), under the Asia Pacific Partnership for Climate and Development and has resulted in the construction of a post-combustion research pilot plant at the Huaneng Beijing Cogeneration plant. Commissioned in July 2008, the project will capture around 3,000 tonnes of CO_2 per annum – about 1% of the total CO_2 emitted from the plant – which will be used in the soft drinks industry.

6.2 Cooperation with the United States, Australia, Japan and Canada

Each of the above examples involves an element of international cooperation, notably with the US, Australia, Japan and Canada. These countries are also involved in a range of other bilateral and multilateral initiatives with China on clean coal technology, as set out below.

The United States is funding a range of projects including "Building Regulatory Capacity in China - Guidelines for Safe and Effective Carbon Capture and Storage" and "Promoting Better Use of Coal Mine Methane". The latter has started with a feasibility study at the Hebi mine in Henan Province, funded by the US Environmental Protection Agency. The Obama administration has signalled its interest in scaling up cooperation on clean coal technologies including CCS.

Australia recently launched a Global CCS Institute, with the aim of facilitating CCS demonstrations worldwide. It has a strong interest in expanding CCS cooperation with China, building on the existing Australia-China Joint Coordination Group on Clean Coal Technology, established in 2007. In April 2008 Australia announced that it was going to invest AUS$20 million in cooperation in China.

China was one of the founder members of the **Carbon Sequestration Leadership Forum (CSLF)**, a US-led initiative launched in 2003. Under this framework it has been working with the United States on a project to identify major existing point sources, assess CO_2 storage location and capacity, and build CO_2 cost curves describing CCS potential versus cost.[25]

China is also a founding member of the **Asia Pacific Partnership on Clean Development and Climate Change** (APP) and an active participant in its Cleaner Fossil Energy Taskforce. Two projects are of particular note:

- **China Australia Geological Storage (CAGS):** A collaborative project to develop China's capacity to assess potential CO_2 storage sites, led by Geoscience Australia and Ministry of Science and Technology, China.[26]
- **Enhanced Coal Bed Methane:** A joint initiative between Australia, China and Japan to validate the use of CO_2 injection into coal seams to enhance

[25] http://www.cslforum.org/documents/Assessing_Market_Opportunities_for_CO2_CCS_in_China.pdf
[26] http://asiapacificpartnership.org/CFE_Projects/01_CFE-0601_CO2_Capture_and_Storage_update.pdf

methane recovery. Initial field trials will be undertaken in Australia with later stages of the project involving field trials in China and participation of Chinese industry and other parties.

China is also involved in an initiative on Carbon Dioxide Capture and Geological Sequestration Potential of the **Asia-Pacific Economic Cooperation (APEC)** Region.

6.3 Cooperation with the European Union (EU)

At the EU-China Summit in 2005 the two sides established a Climate Change Partnership focusing on practical measures to bring forward the development of low-carbon technologies. One of the main objectives agreed by both sides was to develop and demonstrate advanced, near-zero emissions coal technology through CCS by 2020 in China and EU. Two specific initiatives are now being taken forward to support this initiative:

- **COACH (COoperation Action within CCS CHina-EU):** An EU R&D project exploring various aspects of CCS technology in partnership with China, with a focus on capture, transportation and storage of CO_2 from an IGCC plant.
- **NZEC (Near Zero Emissions Coal):** A UK-China initiative designed to share best practices on CCS, explore options for CCS, and develop a roadmap for future action.

Two other initiatives have also been developed to explore issues around storage and regulation:

- **Geo-Capacity:** Part of the EU's Framework Programme 6 (FP6) for Research & Development, this project aims to assess European capacity for geological storage of CO_2 and includes international collaboration. China's Tsinghua University is a participant.[27]
- **STRACO$_2$ (Support to Regulatory Activities for Carbon Capture and Storage):** Part of EU Framework Programme 7 (FP7), this is supporting the ongoing development and implementation of a regulatory framework for the deployment of CCS in the EU and China. It is due to publish conclusions in the second half of 2009.[28]

Both COACH and NZEC are currently in an initial, exploratory phase of activity. Their longer-term direction is unclear and will depend ultimately on decisions by Chinese policy-makers. NZEC Phase 1 is due to report its findings at a meeting in Beijing in autumn 2009. According to the project website, Phase 2 will then "carry out further development work on storage and capture options leading to Phase 3, which will construct a demonstration plant by 2014".[29]

Given the range of activity already underway, it is technically possible to deliver a CCS demonstration project in China by 2014. The EU itself aims to build up to 12 demonstration plants by 2015 and earmarked substantial funds for this as part of the Climate and Energy Package agreed in December 2008. Demonstrating CCS in China within a similar timeframe would provide significant opportunities for

[27] http://www.geology.cz/geocapacity
[28] http://www.euchina-ccs.org/

knowledge sharing and help galvanise activity in other parts of the world. However the CCS financing mechanism agreed as part of the Climate and Energy Package excluded projects in third countries such as China.

All of this raises big questions about the future of NZEC and of wider EU-China CCS cooperation. The EU remains committed rhetorically to early demonstration of CCS in developing countries, but in the absence of a credible European financing mechanism it is hard to see China agreeing to bring forward the date of CCS demonstration from 2020. This would be a significant setback in the EU's efforts to accelerate the global transition to a low carbon economy and to limit global average temperature increases below 2°C.

7 Options for accelerating CCS demonstration in China

If China is to move beyond the development of a few demonstration plants and seriously explore options for the broader roll-out of the technology, it will require a strong signal that other countries, including the EU, are prepared to support the global development of the technology, including a commitment to financing major projects in developing countries. The EU, in turn, needs to decide what it wants from its cooperation with China and tailor its support accordingly.

To facilitate the debate the following section sets out three broad strategic options for future EU-China CCS cooperation. These options are purely illustrative and do not reflect official thinking either in Europe or China. Each option has different pros and cons for the EU and China respectively. Each option also has different implications for the type and scale of EU co-financing likely to be required. Ultimately the decision on how to move forward rests with China but the level of ambition will be shaped in part by the level of support the EU is prepared to offer.

Option 1: A stand-alone demonstration plant

Description: This would be a one-off power plant used to demonstrate various elements of a specific CCS technology option. To minimise cost, it is likely that CO_2 would be stored nearby in a well-researched depleted gas or oil field; combining this with enhanced oil recovery could also lower costs. The minimum additional cost of this option is around €300 million, compared to €800 million in the EU. Chinese co-financing might be available in return for control of the resulting IPR.

Advantages: this type of project would be a useful addition to the global demonstration of CCS capture technology variants, particularly if it uses pre-combustion IGCC, where China has considerable expertise. A limited scope would allow for speed in authorisation and construction of the facilities, present lower risks to project developers and require smaller levels of European financial support. The European contribution could potentially be affordable for a small coalition of willing Member States, rather than needing EU-wide support.

[29] http://nzec.aeastaging.co.uk/en/what-is-nzec/

Disadvantages: under this scenario there would be no engagement in broader programmes of knowledge-sharing and intellectual property associated with the project would remain with commercial partners. Little would be learned about large-scale geological storage and the infrastructure would be unlikely to be scalable to include further applications or capture technology variants. This would reduce China's ability to use the project as a platform for further demonstration of CCS.

Option 2: Large-scale project closely aligned with EU demonstration programme

Description: the Chinese demonstration project would be aligned as closely as possible to the EU's CCS flagship demonstration programme. This would imply a minimum project size of 300MW; saline aquifer storage; advanced storage monitoring; and high regulatory standards. While the project would not be eligible for the CCS funding earmarked in the December 2008 Climate and Energy Package, it might be able to participate in the EU's CCS knowledge sharing programme. The project would be more expensive than Option 1 – minimum cost to the EU of €350 - €400 million.

Advantages: this scenario would result in a larger scale and more comprehensive project which would do more than just demonstrate CCS technology. Saline aquifer storage and comprehensive characterisation and monitoring of geological storage would build knowledge useful in other parts of China. Membership of the EU's knowledge sharing programme would give Chinese companies and officials the opportunity to learn from (and engage directly with) projects using different capture technologies across a range of geologies and involving large scale infrastructure with multiple industrial sources.

Disadvantages: the stricter criteria for the EU programme would increase costs, complexity and risk hence may not be compatible with Chinese objectives. EU knowledge sharing obligations on project partners may also cause some concerns, especially the requirement to make all IPR available on fair licensing terms or be subject to compulsory licensing.

Option 3: Broader CCS initiative covering other industrial applications and wider infrastructure investment

Description: In this scenario, the focus would be on the development of a significant "CCS hub" in a specific region of China, rather than simply on the construction of a single CCS plant. It would put in place sufficient transport and storage infrastructure to allow a number of CCS applications to be developed, including different power capture technologies, and industrial applications such as cement, steel and refineries. The scope of EU-China cooperation could be expanded to include technological collaboration on industrial applications of CCS (involving the existing EU Technology Platforms in these areas), enhanced R&D cooperation through the Framework 7 programme, and an expansion of current EU-China work on improving efficiency along the coal supply chain. The cost is hard to estimate with any certainty.

Advantages: this project would provide the basis for a comprehensive exploration of CCS technologies and applications in China, and allow the development of business models covering large-scale infrastructure and storage. The broader framework would give greater opportunities for EU-China cooperation around a single strategic programme, subsequently increasing efficiency and giving greater access to EU expertise and financing programmes.

Disadvantages: a programme at this scale would require a large financial commitment, and its complexity may add further delays and risk, especially around infrastructure planning and development. Not all of the additional funding would need to come from the EU, as Multilateral Development Banks and/or technology diffusion funds available in future under the UNFCCC would enable co-financing. The programme could be phased in over time to reduce cost and complexity, but the upfront infrastructure issues would remain. This option may be seen by China as focusing too much on CCS deployment, before it has decided on this as a policy goal. EU companies in energy-intensive trade sectors (e.g. steel, aluminium) may also be reluctant to co-develop advanced low carbon technologies with competitors in China, although the currently high levels of European investment and joint ventures in China may mitigate this. Resolving EU concerns around IPR protection would be particularly critical in this scenario, and may cause further delays.

8 Charting the way forward: key issues

At the time of writing it is far from clear that China will end up choosing any of the above options. Chinese policy-makers may simply decide to bide their time until the EU, US and others have shown a stronger lead. Much depends on the funding question and on the wider international climate negotiations, as discussed in the final section of the paper. However before addressing these questions it is worth exploring three other factors that will have a significant influence on the future of CCS in China:

- the location and adequacy of CO_2 storage sites in China;
- the development of a regulatory framework to manage the capture, storage and transport of CO_2; and
- the handling of IPR for any joint CCS development initiatives with an international dimension.

Location and adequacy of CO_2 storage sites in China

Initial estimates by China's Ministry of Science and Technology[30] have indicated the following storage capacity in China:

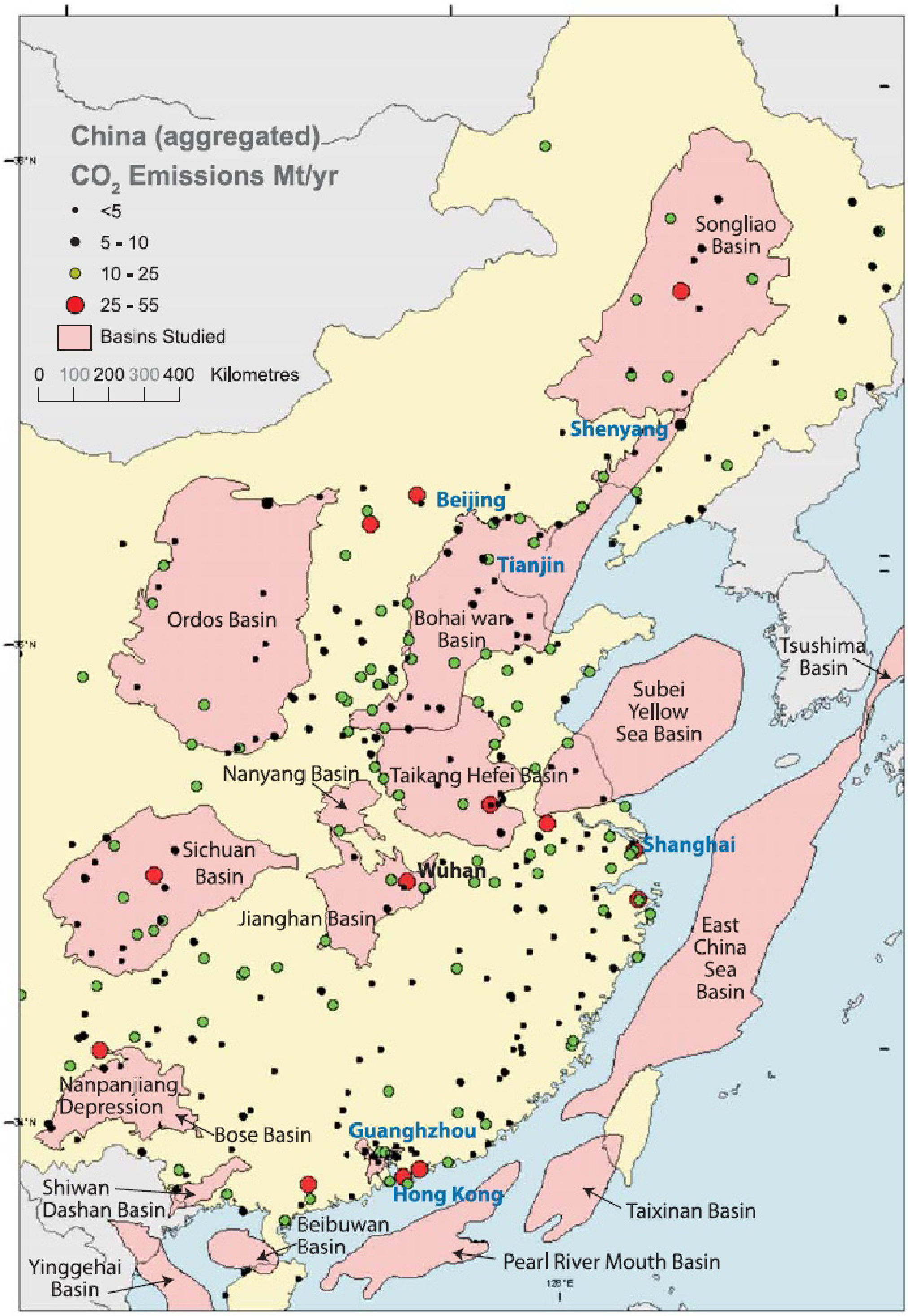
- 46 oil and gas reservoirs with a capacity to store 7.2 billion tonnes of CO_2
- 68 un-mineable coal beds with methane recovery and the capacity to store 12 billion tonnes of CO_2
- 24 saline aquifers with the capacity to store 1,435 billion tonnes of CO_2

With annual emissions of around 6 billion tonnes, this analysis would indicate that China has adequate capacity to store its CO_2 emissions for the foreseeable future.

[30] Presentation at IEA/CSLF Workshop on Near Term Opportunities for Carbon Capture and Storage, Aug 2006. Li Gao, Office of Global Environmental Affairs, MOST

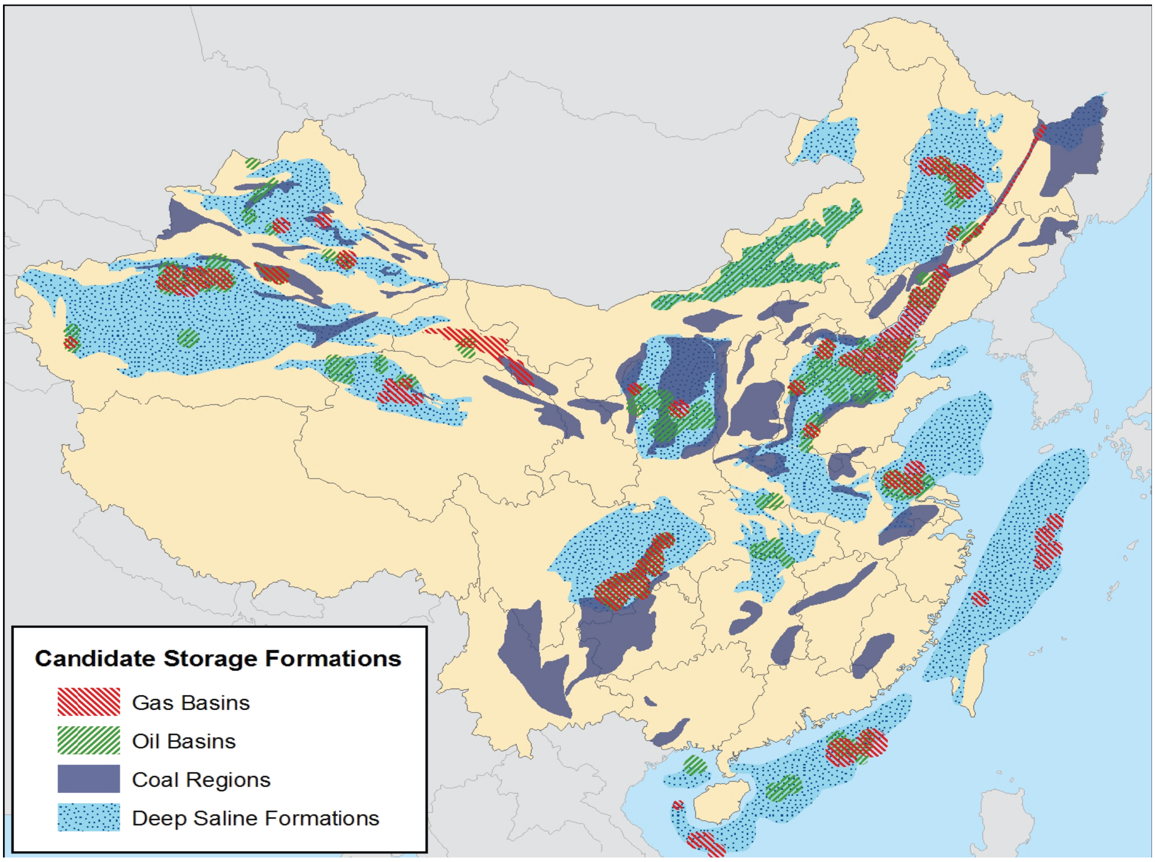
A study carried out by CO_2CRC as part of a wider APEC project[31] gives an initial indication of the main sources of CO_2 and their proximity to possible storage sites in Eastern China, suggesting a good match between the two.

Figure 3: Eastern China aggregated CO_2 sources and basins in proximity to concentrated emissions[32]



[31] APEC (2005) *Assessment of Geological Storage Potential of Carbon Dioxide in the APEC Region – Phase 1* http://www.co2crc.com.au/dls/pubs/regional/apec/APEC_05_0007.pdf
[32] Ibid.

Figure 4: Map Showing Combined the Combined Location and Extent of Candidate Geologic CO_2 Storage Formations[33]



A more recent analysis that looks at both the storage capacity and locations confirms that China has the theoretical capacity to store the CO_2 produced from its major point sources.[34] This analysis found that:

- China has storage capacity in excess of 2,300 billion tonnes CO_2 in onshore basins, with deep saline-filled sedimentary basins accounting for over 99% of the total;
- There are over 1620 large stationary CO_2 point sources that emit a combined 3.89 billion tonnes CO_2/year and 91% are within 100 miles (161 km) of a candidate deep geological storage formation;
- Preliminary analysis suggests that the majority of emissions from China's large CO_2 point sources can be stored in large deep saline formations at estimated transport and storage costs of less than $10/t$CO_2$ (not including monitoring costs).

Other work is underway through projects such as COACH, NZEC and GeoCapacity. More detailed site-specific studies may be needed in due course, depending on decisions around demonstration.

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[33] RT Dahowski et al (2008) A Preliminary Cost Curve Assessment of Carbon Dioxide Capture and Storage Potential in China, *Energy Procedia*, http://www.pnl.gov/gtsp/publications/2008/papers/2008_dahowski_cost_curve_assessment.pdf

[34] Ibid.

Development of a regulatory framework for CCS in China

A regulatory framework for CCS does not currently exist in China. The EU and other countries around the world are beginning to put in place their own frameworks and China could draw on these in due course. Any international support for CCS demonstration in China is likely to require that the government implements environmental safeguards (e.g. site selection and site monitoring) that comply with minimum standards.[35]

The EU recently agreed a legal framework for CCS (hereafter CCS directive), based on proposals tabled in January 2008[36]. This provides an indication of the complex issues involved in establishing a similar framework in China. The EU framework is a combination of adapting existing laws and a specific new regime covering geological storage. Member states must transpose the new provisions into national regulations and procedures within two years of official publication, i.e. by early 2011.

Unlike many other low-carbon technologies, such as renewable energy or nuclear power, CCS produces no directly-accessible economic benefit at the moment – there is no electricity to sell or heat to conserve. For industry, the benefit of practising CCS is only realised if an economic value is given to avoided CO_2 emissions. In Europe, this will be achieved by adjusting the emissions trading scheme (EU ETS): a tonne of CO_2 stored will be treated as not emitted so operators need not surrender ETS allowances. Providing that the price of EU allowances is higher than the cost of CCS, this will form the underlying economic rationale for CCS deployment by businesses.

Providing economic rewards for CCS through ETS also requires accurate measurement of CO_2 in the system. To do this, the existing ETS monitoring and reporting rules are to be adapted to include CO_2 capture, transport and storage installations.

In addition, the new legal framework may need to amend other environmental protection laws. The most important of these is the inclusion of *capture* as a process within industrial pollution control law. Currently this means adjusting both the 1996 Directive on Integrated Pollution Prevention and Control (IPPC), and the 1989 Directive on Large Combustion Plants (LCP). The established and integrated (industrial) regulatory regimes under the two directives already have well-understood concepts and procedures that need be adapted for CO_2 capture. It should also be noted, however, that the IPPC, LCP and several other related regulations are soon to be merged into a new directive on Industrial Emissions.

Other EU legislation which needs adjusting to incorporate the new CCS framework are the directives on environmental impact assessment, water, environmental liability and waste, and the rules on waste shipments.

Where existing law cannot be adapted for CCS development, new law is needed. This applies particularly to geological *storage* of CO_2, where the CCS directive

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[35] In December 2008, a joint project between Tsinghua University and World Resource Institute (WRI) was launched, which aims to develop Guidelines for Safe and Effective CCS in China. This is a two-year effort and is modelled after a successful project in drafting CCS guidelines for the US. http://www.wri.org/stories/2009/03/ensuring-safe-carbon-capture-and-storage-china

[36] Climate Action (23 January 2008) The Climate Action and Renewable Energy Package, Europe's Climate Change Opportunity
http://ec.europa.eu/environment/climat/climate_action.htm

provides, *inter alia*, new rules on: storage site selection; site exploration permits; storage (i.e. operating) permits; operational and post-closure obligations; and also two detailed annexes in which specific criteria for site characterisation and monitoring requirements are laid out.

According to the EU-CCS directive of 17 December 2008 (Article 12), injection streams must consist "*overwhelmingly*" of CO_2. Other substances may be present if they are incidental to the capture process, or added exclusively for monitoring purposes (e.g. wastes). New installations will also be subject to industrial emissions regulations and to environmental impact assessments before authorisation. Article 12 of the CCS directive allows the European Commission to adopt guidelines on the composition of CO_2 streams.

While leakage is not explicitly prohibited by the new directive, storage sites may only be selected "*if under the proposed conditions of use there is no significant risk of leakage, and if no significant environmental or health risks exist*" (Article 4). Storage site operators are required to carry out a monitoring regime until site handover to, inter alia, detect any significant irregularities and CO_2 leakages, and to update assessment of the safety and integrity of the storage complex in the short- and long-term (Article 13). If leaks occur and result in emissions being released into the atmosphere or water columns, the operator must surrender a corresponding number of ETS allowances until corrective measures have been taken, in accordance to the ETS Directive[37]. Liability for other types of damage, e.g. local damage, will be covered by the existing Environment Liability Directive 2004/35.

After storage sites have closed (Article 17), the ownership and liabilities may be transferred to the competent national authority under certain conditions (Article 18). This shall be after a minimum period of twenty years unless the "*available evidence that the stored CO_2 will be completely and permanently contained*" convinces competent authorities to agree an earlier transfer. As there is no automatic transfer of a site, there is an incentive for operators to maintain high standards of site selection, operation and monitoring in order to eventually achieve this.

Intellectual Property Rights (IPR) framework for CCS initiatives

The development of CCS will both use existing IPR and generate new IPR. China is seeking to exploit the export potential of CCS so the ability to control new IPR arising from the various demonstration projects is a priority for Chinese companies. At the same time, China is looking for support from other governments and companies, who will want reassurances that any existing IPR is protected and that they have access to any new IPR that has been developed.

It is clear that there are concerns in Europe about the robustness of China's IPR regime and a sense that CCS cooperation with China could damage Europe's competitiveness. While some of these concerns are unfounded they could present a significant obstacle to future cooperation.[38] What is needed is an IPR framework that gives confidence to industrial partners about IPR protection and enforcement. This will require the development of contractual agreements between business and government and may also require government-to-

[37] Directive 2003/87/EC, OJ L 275, 25.10.2003
[38] E3G (2008), pp 92-94

government MoUs to provide additional protection and enhanced knowledge sharing.

A key objective of this framework will be to establish what each party contributes to the venture and how the benefits (and risks) of failure will be shared out. CCS demonstrations in China will most likely take the form of joint-ventures involving government and industry partners on both sides, and the legal issues will be complex. There are, however, a number of core models that can be used for this form of joint venture. In the UK, for example, a set of model research collaboration contracts, also known as Lambert Model Agreements, were established to provide a voluntary and workable framework for universities and sponsor companies around IPR ownership[39].

Projects funded by the EU and individual Member States are subject to State Aid Reviews by the European Commission, which always include conditions on IPR sharing. For example, documents issued by the UK's Department for Business, Enterprise and Regulatory Reform (BERR) as part of its competitive tender for a CCS demonstration project contain the following conditions:

"The Project Developer will not be required to assign any of the Project IPR to BERR or a third party. However, the Project Developer will be required to commit to granting access to, and providing for the dissemination of, information and Project IPR in order to further BERR's aim of facilitating the deployment of CCS in the UK, Europe and internationally."

"Final bids will be evaluated on plans for the dissemination of commercial and technical information, know-how and show-how internationally, provision of access to Project information for production of reports and publicity materials."

Similar language is likely to be needed in any external projects to which the EU contributes funds.

In addition to specific contracts governing a particular project, additional IPR protection can be given by government-to-government agreements. These provide companies with direct access to a government-to-government dispute resolution process rather than having to go through local courts in the first instance. The Chinese government has already signed MoUs on IPR with a number of countries:[40]

- A China-USA MoU on the Protection of Intellectual Property was signed in 1992 and a framework for regular consultation mechanism on IP was established in 2000. This paved the way for the creation in 2004 of the Intellectual Property Protection Working Group of the Joint Commission of Commerce and Trade (JCCT) of China and the US;
- The EU and China established an IPR working group in 2005 and recently signed an updated action plan;[41]
- China has established bilateral or triangular dialogues and cooperation mechanisms on IP with Japan and South Korea, including annual

[39] http://www.innovation.gov.uk/lambertagreements/index.asp?lvl1=1&lvl2=0&lvl3=0&lvl4=0
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meetings since 2001 between the commissioners of the respective patent offices (Trilateral Policy Dialogue Meetings).

9 Opportunities for progress in 2009

The cost of building a CCS demonstration plant in China is estimated to be between €300 million - €500 million, depending on the level of ambition. China and the EU have been working together since 2005 to explore the potential for CCS demonstration in China and decisions are expected this year on the way forward. While Europe has earmarked funding for 10-12 CCS demonstration projects and aims to have them up and running by 2015, the EU financing mechanism agreed in December 2008 excludes projects in third countries such as China. Alternative financing options need to be found if Europe is serious about accelerating CCS demonstration in China and other developing countries.

UNFCCC and multilateral financing mechanisms

China is a significant beneficiary of projects financed through the Clean Development Mechanism (CDM) of the Kyoto Protocol. However CCS projects are currently ineligible for CDM financing. The EU and others would like to change this but it is being blocked by other developing countries. Even if CCS were to be allowed in the CDM, prices are unlikely to be high enough to enable CCS in the power sector.

The World Bank has established a portfolio of Climate Investment Funds (CIF) including the Clean Technology Fund and the Strategic Climate Fund. These are defined as an interim measure to support low carbon development plans pending decisions at the UNFCCC Conference in Copenhagen on a post-2012 international climate agreement. In September 2008 donors pledged contributions to the CIF amounting to over US$6.1 billion, some of which could potentially support CCS demonstration in China. However donors have yet to deliver on these pledges and there is strong opposition in some quarters to World Bank financing of coal-related projects in developing countries.

In the context of the global climate negotiations, China and other developing countries have made ambitious proposals on the technology and financing aspects of a post-2012 agreement. The EU has yet to agree a clear vision of its own but recognises that developed countries will need to provide substantial support (finance, technology, capacity building) to developing countries to enable them to achieve “substantial deviation” of their emissions below the business-as-usual growth trajectory. Further ideas on potential financing mechanisms are set out in a Communication released in January 2009 by the European Commission – although this has been criticised by developing countries and civil society organisations for its lack of detail.[42]

A recent report by E3G recommends an enhanced Technology Cooperation Mechanism as part of the post-2012 agreement including Technology Action Plans for CCS and other key technologies.[43] To implement the Technology Action

[42] Europa (28 January 2009) *Climate Change: Commission Sets Out Proposals for Global Pact on Climate Change at Copenhagen*
http://europa.eu/rapid/pressReleasesAction.do?reference=IP/09/141
[43] E3G (2008)

Plans the post-2012 agreement would establish a new Global Innovation and Diffusion Fund. This fund could integrate existing activity (e.g. the World Bank Climate Investment Funds) through two windows:

- Research, Development and Demonstration (RD&D) Window: This would be responsible for the development of new technologies with a focus on applied research and demonstration to push new technologies down the innovation chain, adapt them for use in developing countries and address orphan innovation areas;
- Technology Diffusion Window: This would be responsible for broader uptake of new technologies including direct financing; patent buy-outs; and capacity building to ensure developing countries have the supporting systems necessary to use new technologies.

In addition the report recommends a *"Protect and Share"* agreement for IPR and licensing. This would involve government-to-government commitments of the kind discussed in the previous section to encourage joint-ventures and public-private partnerships. Support would be made available under the Fund to strengthen IPR protection measures in developing countries, consistent with their existing international commitments under WIPO and WTO. Enhanced IPR protection would be balanced by a Framework Agreement for the accelerated sharing and licensing of low-carbon technology to ensure rapid diffusion.

Other European financing possibilities

Reaching agreement on new UNFCCC arrangements is an immense challenge, especially in the current economic climate, and any new financing mechanisms are unlikely to take effect until 2013. Other sources of funding will therefore be needed to drive progress in the meantime. The World Bank's CIF is one option; the European Investment Bank is another (€3 billion low carbon window for Asia including a €500 million China Climate Change Framework Loan). Both offer concessional loans rather than grants so may not offer a complete solution. Some Member States (e.g. UK) may be prepared to make bilateral contributions to CCS but it is unclear whether the amounts involved would be adequate.

The European Commission is in the process of developing a Communication on *'Financing CCS and other clean carbon technologies in emerging and developing countries.'* This will make recommendations on how to disburse the €60m allocated by for clean coal technology transfer under the Commission's ENRTP (Environment and Natural Resources Thematic Programme). The current thinking is to establish a public-private partnership based on the SICAV model (French acronym meaning "Investment Company with Variable Capital"). Some of the funding is likely to go to other developing countries (e.g. South Africa).

At the same time, the Commission is preparing a more ambitious communication on *Low Carbon Financing* focusing on implementation of the EU's Strategic Energy Technology (SET) Plan. This has a strong focus on Europe's domestic decarbonisation agenda and is not expected to provide any immediate solutions to the urgent need for funding CCS demonstration in developing countries. It is likely to be published around May 2009.

Possible G8 CCS Initiative

In June 2008 G8 Energy Minsters agreed to collaborate to launch 20 large-scale CCS demonstration projects worldwide by 2010 and to help accelerate demonstration activities in developing countries. This could provide the basis for an initiative under the Italian G8 Presidency to inject momentum into global CCS cooperation. A G8 initiative could include:

- A programme of action to implement the 20 CCS demonstration plants. The EU has committed funds for 10-12 plants. The US, Canada, Japan and Russia could commit to provide funding for at least 8 further plants.
- Agreement on additional coordinated funding for at least 3 CCS demonstration plants in developing countries, targeted to incentivise action in China, India, Indonesia, South Africa and others. This work could be administered through the Asia Pacific Partnership on Clean Development and Climate (APP) and would build on the NZEC cooperation on CCS between the EU and China.
- The 20+3 projects could share performance criteria and knowledge in a reciprocal manner, as proposed by the Zero Emissions Platform (ZEP) for the EU demonstration projects. This would aim to accelerate the commercial deployment of CCS by 2020.
- The G8 could agree a discussion framework to accelerate cooperative research, development and demonstration for low carbon technology, providing for G8 joint initiatives with developing countries beyond narrow "technology transfer", and matching financial incentives to a strengthened regime of IPR. The G77 and China have embraced the concept of "Technology Action Programmes". It is important that the G8, as originators of 80% of global technology (as measured by patents), have a joint position on these issues in advance of UNFCCC's COP15 in Copenhagen.

An initiative of this kind would help build trust with developing countries in advance of Copenhagen by showing the G8 moving from aspiration to implementation on a major area of low carbon technology. It could also be pursued as part of the technology discussions within the new Major Economies Forum (MEF) on Energy and Climate launched recently by US President Obama.[44]

[44] The Major Economies Forum (MEF) brings together Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, the United Kingdom, and the United States. Denmark also attends in its capacity as the current Chair of the UN climate negotiations. The first meeting of MEF leaders will be held in July the day after the G8 Summit in Italy.

10 Conclusions

- China is committed to tackling climate change and has developed a strong suite of policies to improve energy efficiency and boost investment in renewables.
- Coal will remain at the centre of China's energy system at least for some decades. Early development and deployment of CCS is essential if China is to play a meaningful role in global emissions reduction.
- CCS should be seen as one component of an ambitious overall clean energy strategy that also includes energy efficiency and renewables. It is not a substitute for these other measures.
- There appears to be enough storage capacity in China to store the majority of China's CO_2 emissions from large point sources. However, more site-specific work is needed to develop this understanding.
- China needs to develop regulations governing all aspects of CCS before the roll-out of the technology. The regulations being developed in the EU and elsewhere can provide useful guidelines for the Chinese government.
- Initially, the development of CCS in China – and other developing countries - will require international cooperation in terms of funding, technical expertise and capacity building. This will require the development of a global framework for technology transfer and in particular a resolution to the issues around IPR.
- The EU has earmarked funding for 10-12 CCS demonstration plants but the money will not be available for projects in third countries such as China. This leaves major question marks over future EU-China cooperation on CCS. Current exploratory work is due to conclude in late 2009 but China is unlikely to be willing to move towards full demonstration without a stronger commitment from the EU.
- From a climate security perspective the EU has an interest in early and ambitious CCS demonstration in China, but this will come at a price. The EU needs to be clear on what it wants to achieve and what it is willing to fund. Options range from small-scale technology development to a bigger investment in laying foundations for wider roll-out of CCS in China.
- The Italian G8 or the US-led MEF could offer an opportunity to drive forward CCS demonstration in China and other developing countries, leveraging the resources of the US, Japan, Canada and other international partners. This would help build confidence ahead of the UNFCCC Conference in Copenhagen in December.

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Germanwatch

Following the motto "Observing, Analysing, Acting", Germanwatch has been actively promoting North-South equity and the preservation of livelihoods since 1991. In doing so, we focus on the politics and economics of the North with their worldwide consequences. The situation of marginalised people in the South is the starting point of our work. Together with our members and supporters as well as with other actors in civil society we intend to represent a strong lobby for sustainable development. We endeavour to approach our aims by advocating fair trade relations, responsible financial markets, compliance with human rights, and the prevention of dangerous climate change.

Germanwatch is funded by membership fees, donations, grants from the "Stiftung Zukunftsfähigkeit" (Foundation for Sustainability), and by grants from a number of other public and private donors.

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E3G is an independent, non-profit European organisation operating in the public interest to accelerate the global transition to sustainable development.

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