Carbon dioxide capture and storage: a future for coal?

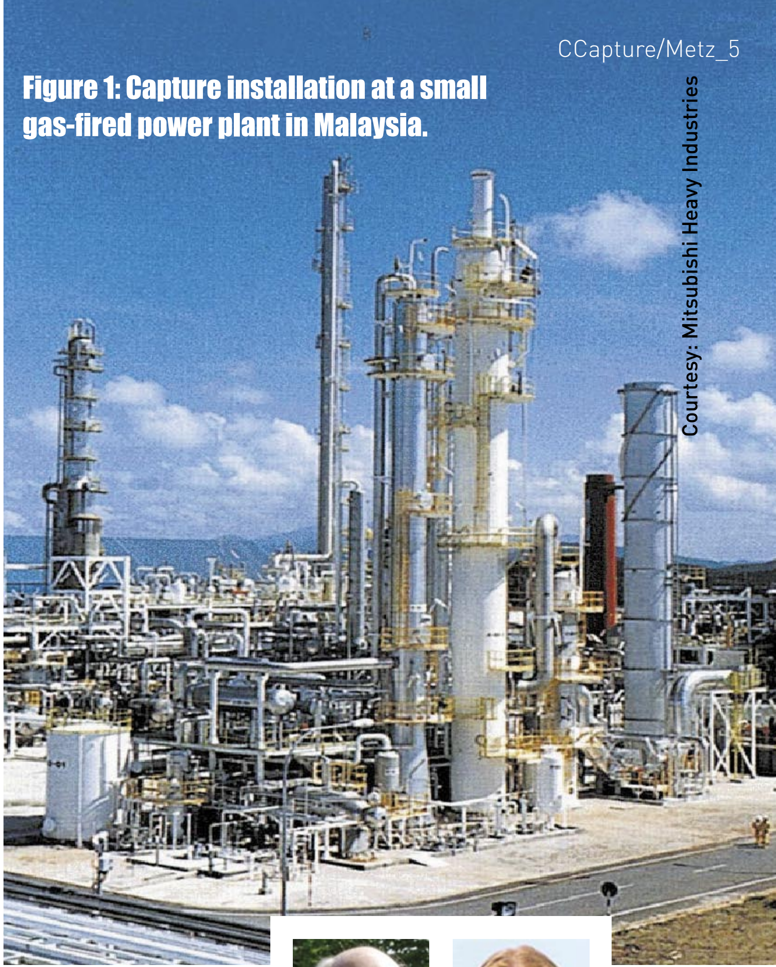

Figure 1: Capture installation at a small gas-fired power plant in Malaysia.

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Worldwide coal use is rising dramatically and will remain an important source of energy for decades to come. It provides many developing countries with an abundant and affordable energy source to fuel their energy-hungry economies, and helps raise incomes for millions of the world's poor. But the increased use of coal significantly increases greenhouse gas emissions, far beyond sustainable levels, and is a great threat to controlling climate change.

Carbon dioxide capture and storage (CCS) is a new technology which offers the only way to significantly reduce greenhouse gas emissions without denying developing countries the use of coal. Assuming sufficient policy efforts and if risks and other public concerns can be addressed, CCS could be structurally deployed on new power plants worldwide in about 10 to 15 years.

INTRODUCTION

The economies of China, India and a number of other developing countries are booming. This rapid growth improves the life of millions of people and helps to reduce poverty but energy is needed for this development. In many of the fast growing developing economies, coal is the most important energy source. In 2004, 78 per cent of electricity produced in China was generated by coal. In India this was 69 per cent, and for all of developing Asia 65 per cent. In South Africa it was 94 per cent. China, India and South Africa are responsible for about half of all world coal consumption.

With growing concern about secure energy supply and abundant coal reserves, coal use is projected to increase worldwide, resulting in increasing CO_2 emissions. However, to control climate change, a drastic reduction of CO_2 emissions is needed with coal having to make a major contribution, thereby seriously limiting its use. A new technology, CO_2 capture and storage (CCS), may come to the rescue, making it possible, in principle, to continue using coal, while drastically reducing its emissions. But the technology still needs to be applied at large scale, is not cheap and has risks that need to be controlled. Can CCS indeed provide a future for coal in a carbon constrained world?

WHAT IS CARBON DIOXIDE CAPTURE AND STORAGE?

Carbon dioxide capture and storage comprises three components: capture of CO_2 from a large point source, transport to a storage location and storage in a geological formation.

Capture of CO_2

Point sources need to be large to make it economically attractive to capture CO_2. Examples of such sources include power plants and natural gas production wells, see Table 1. Capture can occur by separating CO_2 from flue gases or natural gas, eg through chemical absorption or membrane technology. CO_2 can also be captured before combustion by first gasifying and treating coal. A capture installation for a large CO_2 source is the size of a small chemical factory, see Figure 1, and the energy use of capture and compression is substantial, leading to lower power plant efficiencies if CCS is applied.

The capture step is by far the most costly component of CCS and research is underway to find more efficient capture processes. Although there are no full scale power plants with CO_2 capture facilities yet, several are planned and no major technological challenges are expected. Some CO_2 sources, such as existing hydrogen production facilities (in refineries and fertiliser plants) and gas recovery operations already provide a pure CO_2 stream, considerably reducing costs of CO_2 capture.

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Transportation and storage of CO_2

Transport of CO_2 to the storage location is expected to occur through pipelines. Carbon dioxide transport in pipelines is already employed on a large scale in the US and Canada to transport CO_2 used in enhanced oil recovery operations. For long distance (more than 1,000 km) and overseas transportation, shipping is an option.

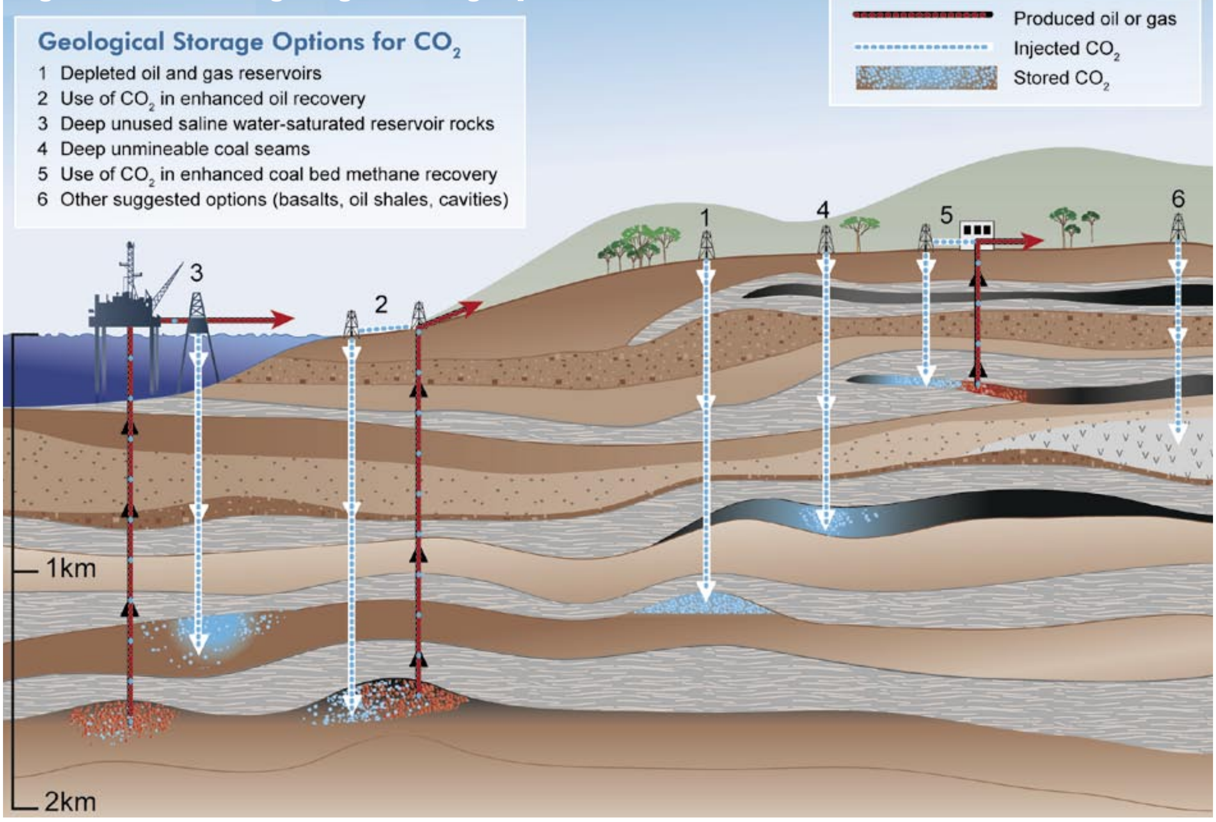
For underground storage, CO_2 could be injected in oil or gas reservoirs, deep saline formations or coal beds, Figure 2. Depleted oil or gas reservoirs have the advantage that the reservoir has contained oil and gas for a very long time, providing some guarantee for

Table 1: An overview of global stationary CO_2 point sources larger than 0.1 million tonnes (Mt) of CO_2/yr.

(IPCC Special Report on CCS, based on The International Energy Agency's Greenhouse Gas R&D Programme)

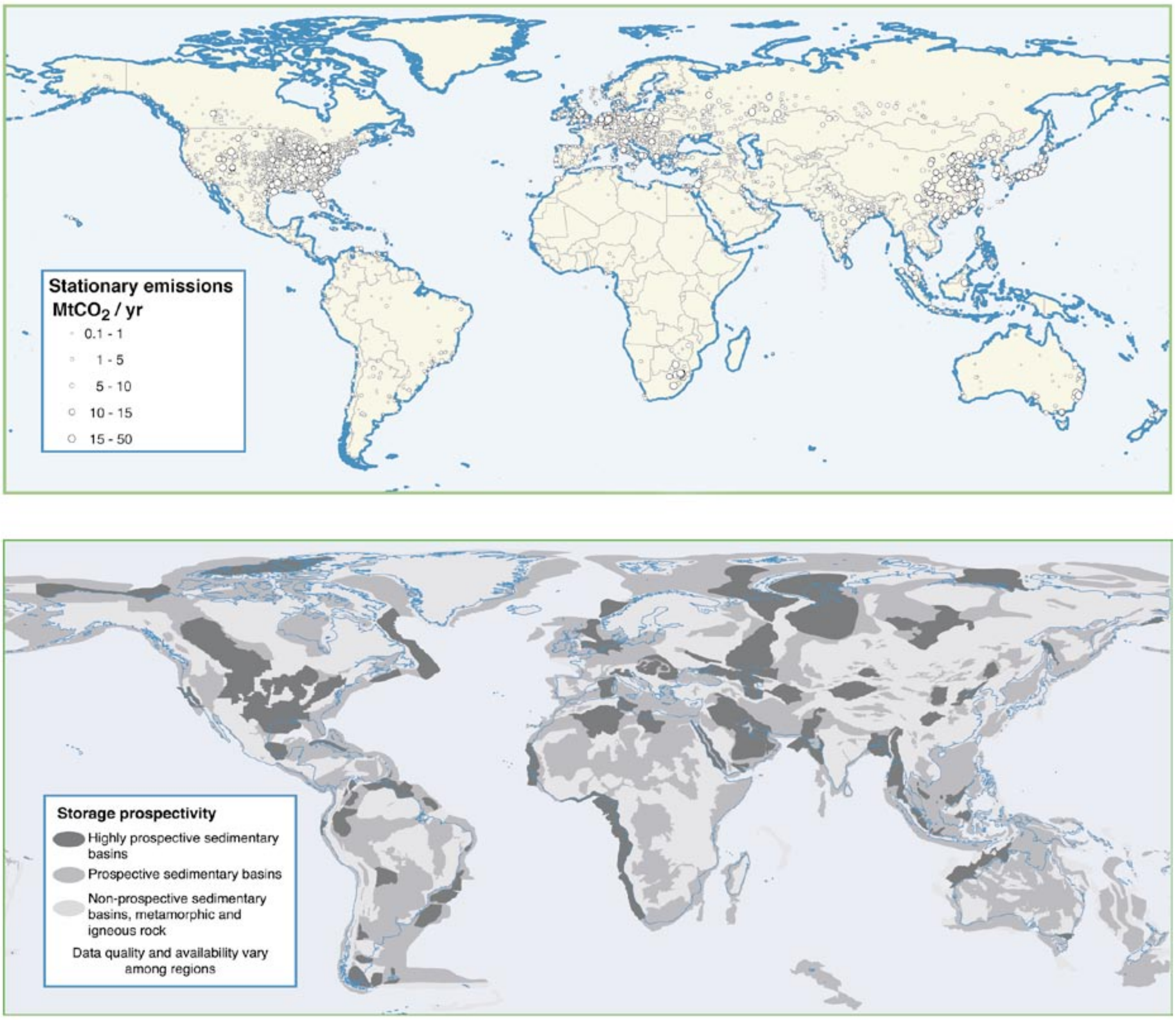
Process	Number of sources	Emissions ($MtCO_2$/yr)
Fossil fuels		
Power	4,942	10,539
Cement production	1,175	932
Refineries	638	798
Iron and steel industry	269	646
Petrochemical industry	470	379
Oil and gas processing	N/A	50
Other sources	90	33
Biomass		
Bioethanol and bioenergy	303	91
Total	**7,887**	**13,466**

Figure 2: Overview of geological storage options.



Courtesy: CO2CRC

Figure 3: Worldwide CO_2 point sources (top) and prospective storage locations (bottom).



Courtesy: IEA Greenhouse Gas R&D Programme and Geosciences Australia.

storage permanence if old abandoned wells can be controlled. The injection of CO_2, a technique already commonly used by the oil and gas industry, can also enhance oil and gas recovery in almost-depleted reservoirs, reducing costs.

Probably the largest potential for CO_2 storage is in deep, saline water-bearing formations, with several large CO_2 injection projects currently being implemented, such as the Sleipner project in Norway. The feasibility of CO_2 storage in coal beds, with or without the recovery of coal bed methane, depends strongly on the permeability of the reservoir. Although small trials are happening, the potential of this storage option is likely to be limited.

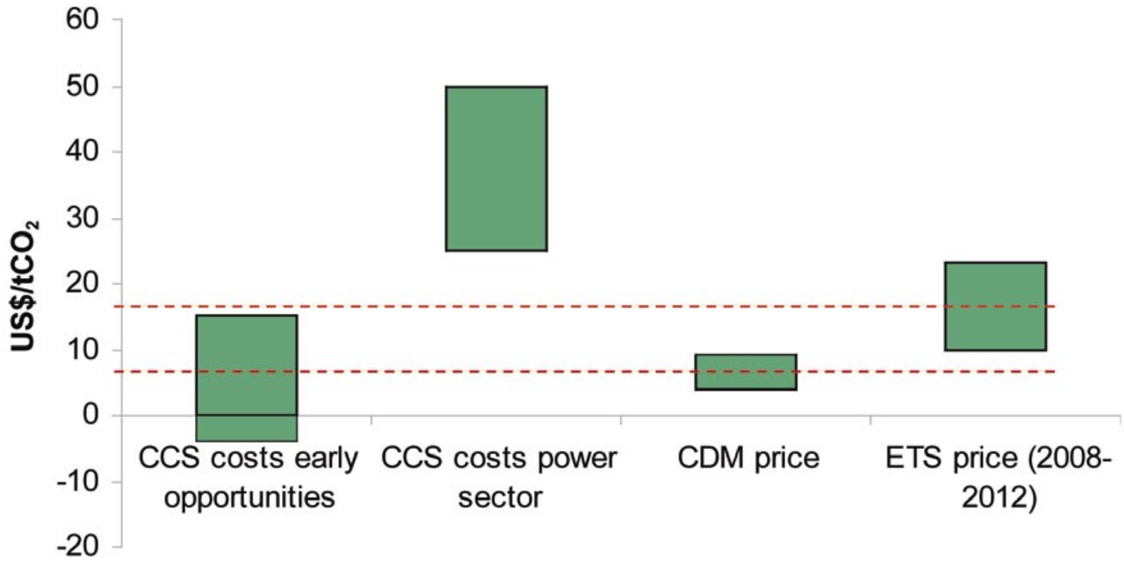
Possibilities of capture and storage of CO_2 can be found all over the world and most point sources of CO_2 are within reasonable distance from promising storage locations, see Figure 3. Current knowledge also reveals that the overall capacity of geological storage is sufficient to store the CO_2 that is likely available to be captured. For some countries or regions, however, the situation may be less advantageous because of the lack of suitable underground formations.

> **“Possibilities of capture and storage can be found all over the world. Current knowledge reveals that the overall capacity of geological storage is sufficient to store the CO_2 available for capture.”**

ECONOMIC ASPECTS OF CCS

Adding CCS to a coal-fired power plant is not cheap. According to the Intergovernmental Panel on Climate Change (IPCC) Special Report it adds US$1-5 cents

Figure 4: Comparison of costs of CCS for early opportunities and in the power sector, with price levels for CDM and ETS based carbon credits.



per kWh to the costs of electricity, depending on the technology applied and the local circumstances. For industrial customers who pay prices close to production costs this could mean a 25-100 per cent increase. Even for households normally paying a higher price, this is a substantial rise. Only a substantial carbon price increase through policy intervention could change the picture, enabling CCS to become economically attractive. According to the IPCC, carbon prices would have to be US$25-30per tonne CO_2 to see CCS deployed at a significant level.

> **“Public perception studies on CCS show that the general public is reluctant rather than enthusiastic about CCS, and that ‘not in my back yard’ feelings play a role.”**

Several industrialised countries committed to emission reductions under the Kyoto Protocol are establishing a price on carbon emissions. The most extensive scheme is the European Union Emissions Trading Scheme (ETS). Carbon prices in the ETS have fluctuated heavily over the past two years, showing extremely low prices of US$5 and peaking occasionally around US$40 per tonne of CO_2. The current 2008 – 2012 forward price is about US$25 per tonne. In addition to the ETS, the Kyoto Protocol's Clean Development Mechanism (CDM) has established a carbon price in developing countries. These CO_2 prices are substantially lower, currently between US$5 and US$15 per tonne. CCS is currently waiting approval as a project activity under the CDM, which is an issue of considerable controversy and diverging political views in the climate negotiations.

Given the cost and limited incentives, it is not surprising that CCS has yet to be applied commercially at coal-fired power plants, see Figure 4, either in industrialised countries, or in developing countries with emerging economies. Although the economics of CCS look better for some other industrial sectors, particularly sources with pure CO_2 emissions, an incentive is still required to make it happen.

PUBLIC AND PRIVATE VIEWS ON CCS

Even if the costs are acceptable to society, risks of CO_2 leakage play a significant role in public perception of CCS. According to the IPCC, risks of CO_2 storage can be comparable to similar operations if appropriate governmental regulation regarding site selection and characterisation, monitoring and remediation is in place. Two major international marine treaties, the OSPAR and London Conventions, have recently reached agreement on such regulation, providing a useful precedent for other national and international policymaking. Regulation is also currently under development in the EU and Australia.

Despite this progress, public perception studies on CCS show that the general public is reluctant rather than enthusiastic about CCS, and that 'not in my back yard' feelings play a role. Education, transparent procedures and rule making, and public consultation seem essential to allow for public acceptance of CCS. Environmental organisations can play a role if they recognise the need for CCS, but they also see permanence of CO_2 storage as an uncertainty, and are mindful that CCS might become a replacement for, rather than a supplement to, energy efficiency and renewable energy.

Industry has generally welcomed the possibility of CCS rather than moving away from fossil fuels altogether. As early as 1996, the Norwegian oil company Statoil pioneered CCS in the Sleipner project, responding to a high CO_2 tax on offshore operations. BP operates a CCS project in In Salah, Algeria, and has announced several others in the US and Australia. Coal companies such as AngloCoal, formerly rejecting any climate policy, are lobbying for CCS. Coal, gas and even biomass-using electricity companies in Europe are announcing demonstration after demonstration. The private sector all over the world sees CCS as a major way to achieve extensive emissions reductions.

THE WAY FORWARD

What are the prospects for CCS application in the future? This depends strongly on the question of when a carbon price of US$25-30 per tonne CO_2 will be reached. Uncertainty about future carbon prices and heavy price fluctuation most likely play a role in the hesitating position of industry. Most CCS projects depend on government subsidies and will take at least another 10 to 15 years before CCS could become standard for coal-fired power plants in Europe.

What does that mean for the rapidly-rising CO_2 emissions form coal-fired power plants in emerging economies? Given their pressing economic development needs it is unlikely they can commit to stringent climate change policies any time soon. And unless CDM carbon prices skyrocket and CCS is approved under the CDM, it will not be sufficient to cover the costs of CCS in the power sector.

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There are, however, prospects for CCS when considered in a broader context. China, for example, is rapidly becoming one of the main suppliers of modern ‘supercritical’ coal-fired power plants. It is already building such plants in large numbers and is moving to the most advanced technology: integrated coal gasification systems. This technology has much lower air pollutant emissions and is the cheapest when it comes to adding CCS, possibly even through retrofitting. China could, with appropriate additional investment made available, eg through cooperation such as the zero carbon power consortium of China, the EU and the UK, become a leader in coal gasification-based CCS power plants, in conjunction with major international corporations.

CONCLUSION

Carbon dioxide capture and storage provides possibilities to make fossil fuels, and coal in particular, part of the solution to climate change. However, this will not happen automatically. Governments in industrialised countries and emerging economies alike should develop regulations to ensure that CO_2 storage occurs safely and permanently, with adequate financial incentives for CCS deployment at coal-fired power plants put in place.

Authors

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Heleen de Coninck is an atmospheric chemist and environmental scientist and works as a researcher at the Energy Research Centre of the Netherlands (ECN). Since joining ECN in 2001, she has worked on several issues, including rural electrification, the Clean Development Mechanism, CCS, and emissions trading. She was the coordinator of the IPCC Special Report on CCS and is currently pursuing a PhD with the VU University of Amsterdam on post-2012 climate policy.

Organisation

The Netherlands Environmental Assessment Agency is providing scientifically based information to national and international governmental bodies. It covers all aspects of environmentally sustainable development, environment and nature protection. The Energy Research Centre of the Netherlands carries out independent research on the application of energy technologies in all aspects of the energy system and provides energy policy advice to national and international governments.
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