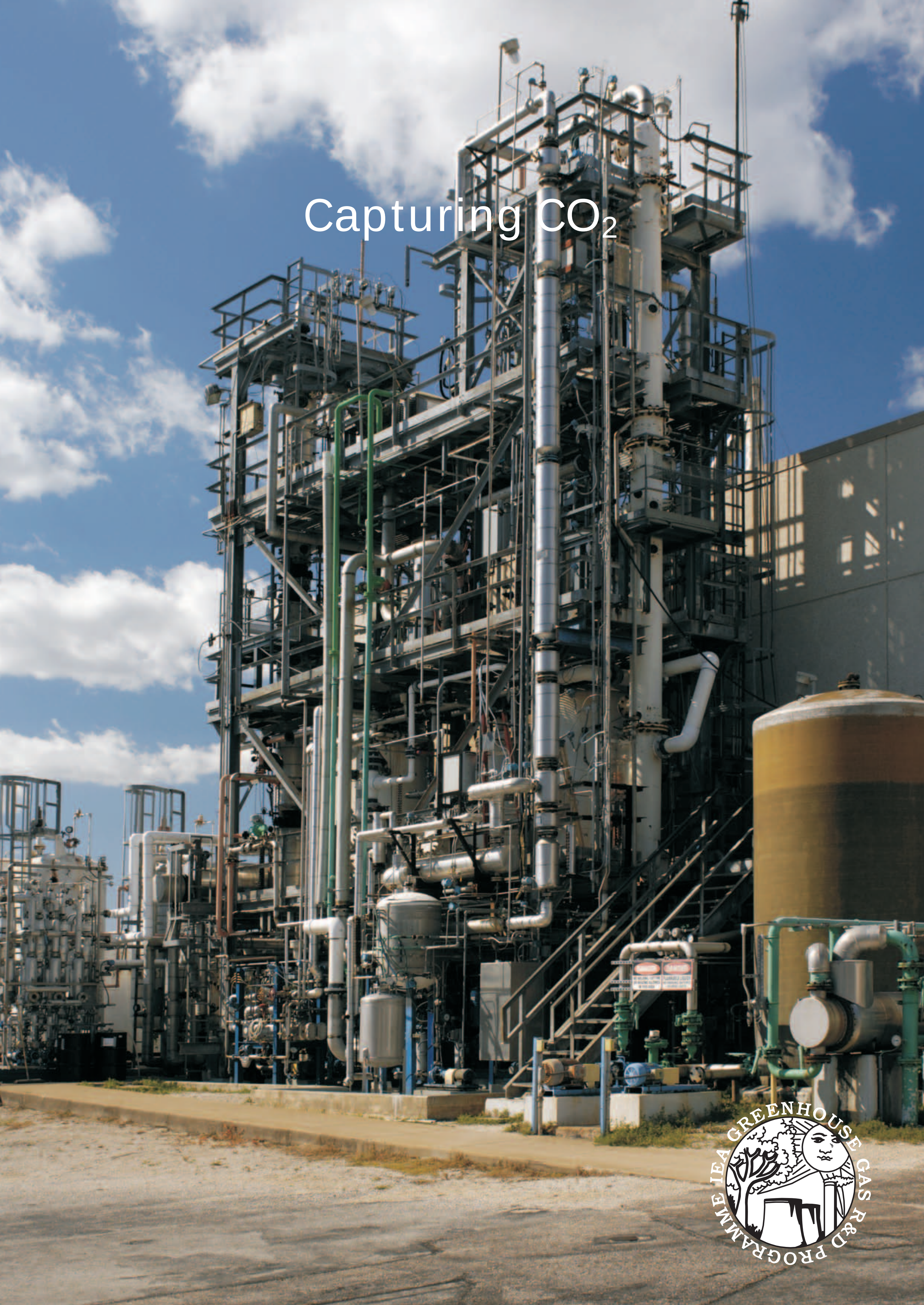
Capturing CO_2



IEA GREENHOUSE GAS R&D PROGRAMME

International Energy Agency

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Cover Pictures : CO_2 pilot plant facilities at the University of Texas at Austin. The CO_2 is captured from the flue gas by alkanolamine absorption/ stripping. The facility aims to develop an evolutionary improvement to monoethanolamine (MEA) absorption/stripping for CO_2 capture from coal-fired flue gas.

By Christopher Lewis, © Separations Research Program 2007

CONTENTS

INTRODUCTION

Emissions of greenhouse gases are expected to cause climate change. The main greenhouse gas is carbon dioxide (CO_2) and the major source of it is the combustion of fossil fuels to supply energy. Emissions can be reduced by a variety of measures, such as improving energy efficiency and developing alternative energy sources, like wind and solar power. However, a rapid move away from fossil fuels is unlikely as energy supply infrastructure has a long lifetime, and such a move could destabilise economies.

Another way to reduce emissions is to capture the CO_2 that is released from fossil fuel-fired power plants and store it underground. This is the focus of this report, as power generation accounts for about one-third of CO_2 emissions from fossil fuel use. The current leading technologies for power generation are pulverised fuel (PF) combustion steam cycles and natural gas combined cycles (NGCC). The IEA Greenhouse Gas R&D Programme (IEA GHG) has assessed the performance and costs of these power plants, both with and without the capture of CO_2. Integrated Gasification Combined Cycle (IGCC) for the gasification of coal, which was included in the assessment, may be a suitable technology from which to capture CO_2. A number of criteria were specified for all the studies to enable the results to be compared in a meaningful manner. The main specifications are listed in the Annex at the end of the report.

CO_2 can be captured by a variety of methods which are classified as post-combustion, pre-combustion and oxy-combustion. Post-combustion capture uses a solvent to capture CO_2 from the flue gas of power plants. In pre-combustion capture the fuel is reacted with air or oxygen and then with steam to produce a mixture of CO_2 and H_2. The CO_2 is removed and the hydrogen is used as the fuel. Oxy-combustion is when oxygen is used for combustion instead of air, which results in a flue gas that consists mainly of CO_2 and is potentially suitable for storage.

The next chapter describes the capture processes in more detail. The effect on the power plants of capturing the CO_2 is explained later in this report, in terms of the reduction in efficiency, the emissions of CO_2 and the extra consumption of resources by the plant. The choice of power plant and CO_2 capture method is put in context by considering some of the other factors involved, such as the choice of fuel, as well as sensitivity to the cost of fuel and the load factor. The conclusions are drawn in the final chapter.

THE POWER PLANTS AND CAPTURE PROCESSES

The three different types of capture process for CO_2 are described in this chapter.

POST-COMBUSTION CAPTURE POWER PLANTS

Post-combustion capture normally uses a solvent to capture CO_2 from the flue gas of power plants. The solvent is then regenerated. The solvents for CO_2 capture can be physical, chemical or intermediate but chemical solvents, known as amines, are most likely to be used for post-combustion capture. This is because chemical solvents are less dependent on partial pressure than physical solvents are, and the partial pressure of CO_2 in the flue gas is low, typically 4-14% by volume. However, chemical solvents require more energy (as steam) to regenerate, that is, to break the relatively strong chemical link between CO_2 and the solvent. Sterically hindered amines need less steam for regeneration.

It is likely that amines will be used for the first generation of CO_2 post-combustion capture, because of the advanced state of development of amine absorption. However, the presence of oxygen can be a problem for flue gas amine scrubbing, as it can cause degradation of some solvents and corrosion of equipment. Inhibitors can be included in the solvent to counteract the activity of oxygen. At present the process of scrubbing CO_2 with amines does not operate on the scale of power plants, but increasing the technology to this size is not considered to be a major problem.

The flue gas must contain very low levels of oxides of nitrogen and sulphur (NO_2 and SO_x) before it is scrubbed of CO_2. This is because NO_2 and SO_x react with the amine to form stable, non-regenerable salts, and so cause a steady loss of the amine. The preferred SO_x specification is usually set at between 1 and 10 ppm(v). This means that post-combustion CO_2 capture on coal fired power plants requires upstream de-NO_x and flue gas desulphurisation (FGD) facilities. The limits for NO_x can usually be met by the use of low NO_x burners with selective catalytic reduction (SCR), and the SO_x limit can be achieved by some FGD technologies.

IEA GHG has assessed two proprietory processes for the post-combustion capture of CO_2, one based on MEA and the other based on a hindered amine solvent. The hindered amine process loses less energy mainly because the solvent consumes less heat for regeneration than MEA solvents. The data presented in this report are for the hindered amine process.

Post-combustion CO_2 capture processes can be considered a current technology, although some demonstration of these technologies at large coal-fired power plants is necessary.

PRE-COMBUSTION CAPTURE POWER PLANTS

Pre-combustion capture can be used for gas turbine combined cycles. In this process, a fuel is reacted with air or oxygen to produce a fuel that contains CO and H_2. This is then reacted with steam in a shift reactor to produce a mixture of CO_2 and H_2. The CO_2 is separated and the H_2 is used as the fuel in a gas turbine combined cycle, which is the most efficient thermal cycle for power generation, currently. Pre-combustion capture can be used in natural gas or coal based plants. When the primary fuel is coal, and the key process is the gasification of the coal, it is known as an integrated gasification combined cycle (IGCC). Gasification is the partial oxidation of coal, or any fossil fuel to a gas, often known as syngas, which has H_2 and CO as its main components. Gasification can act as a bridge between coal and gas turbines, with the target of high energy efficiency and minimum emissions to the environment. However, at present, none of the existing coal-fired IGCC plants includes shift conversion with CO_2 capture.

IEA GHG has assessed plants based on two types of gasifier:

- A slurry feed gasifier, in which the gas product is cooled by quenching with water; and
- A dry feed gasifier, in which the gas product is cooled in a heat recovery boiler.

In the slurry feed IGCC plant without CO_2 capture, the coal is ground and slurried with water and then pumped to the gasifier vessels where it reacts with oxygen. The products from gasification are quenched with water, the saturated gas is cooled, and condensed water and minor impurities are removed. The sulphur compounds are removed from the gas by passing it through a reactor and feeding it to a Selexol acid gas removal (AGR) plant. Selexol is a physical solvent. The clean fuel gas is fed to the gas turbine combined cycle plant.

However, in the case of the IGCC with CO_2 capture, the gas from the gasifier is fed to a CO_2-shift converter prior to cooling and the Selexol unit removes CO_2 as well as sulphur compounds. The Selexol is regenerated to produce separate CO_2 and sulphur compound streams. The CO_2 stream is compressed and dried for transport by pipeline. The removal rate of CO_2 is over 90%, which means that an overall CO_2 capture rate of 85% can be achieved.

In the dry feed gasifier plant without capture of CO_2, the coal is dried, ground and then fed to the gasifier vessels. The gasifier product gas is quenched, cooled and is then fed to a dry particulate removal unit. Some of the gas is recycled as quench gas and the remainder is scrubbed with water, reheated, the COS is removed and it is fed to an MDEA solvent acid removal plant. The clean fuel gas is fed to the gas turbine combined cycle plant. The configuration of the plant with CO_2 capture is the same except that the COS removal process is replaced by a two-stage shift converter and H_2S and CO_2 are separated in a Selexol AGR unit.

OXY-COMBUSTION CAPTURE POWER PLANTS

Oxy-combustion is the term for when a fossil fuel is combusted with nearly pure oxygen and recycled flue gas or CO_2 and water/steam to produce a flue gas consisting essentially of CO_2 and water. It may have potential as part of a system for capturing and storing CO_2 as the nitrogen concentration in the flue gas is much lower than when air is used for firing. So the CO_2 can be stored with less downstream processing.

The PF oxy-combustion plant uses the same steam conditions as the other post-combustion capture plant. A large amount of oxygen is required for combustion, which is obtained from an air separation unit.The flue gas from oxy-combustion is compressed and chilled to separate out nitrogen, oxygen and other impurities. The resulting CO_2 concentration is typically 95mol% or more.

The EU NO_x emission limits can be met with just the firing system of the boiler with staged combustion and low temperature at the furnace exit. The NO_x and SO_x will be converted to acid and condensed from the CO_2 stream, so SCR and FGD units may not be needed.

Oxy-combustion is at a relatively early stage of development but integrated pilot plants are being built and plans to build commercial power plants are also at an advanced stage.

PERFORMANCE OF THE POWER PLANTS

The principle aim of this comparison is to evaluate the effect of CO_2 capture on different power plant technologies. To this end, the plant performances, investment and production costs and environmental impact were examined.

POWER PLANT EFFICIENCY

The thermal efficiencies of the power plants with and without CO_2 capture are compared in Table 1, based on information from studies carried out by IEA GHG. The natural gas fired plants have the highest thermal efficiency (about 55-56%) of the plants without capture of CO_2. The efficiency is calculated on a lower heating value (LHV) basis. The PF and the dry feed IGCC have a similar net efficiency (43.1-44.0%). The slurry feed IGCC plant has the lowest efficiency at 38%. This is largely because there is a lower efficiency of conversion of coal to fuel gas in the slurry feed gasifier.

Table 1 Power Plant Thermal Efficiencies

Fuel	Power Generation Technology	CO_2 Capture Technology	Net Efficiency[a] % (LHV)
Coal	Pulverised fuel	None	44.0
		Post-combustion	35.3
		Oxy-combustion	35.4
	IGCC, dry feed	None	43.1
		Pre-combustion	34.5
	IGCC, slurry feed	None	38.0
		Pre-combustion	31.5
Gas	Gas turbine combined cycle	None	55.6
		Post-combustion	49.6
		Oxy-combustion	44.7

a. HHV efficiencies of the coal-fired plants are 0.956 times the LHV efficiencies. HHV efficiencies of the gas-fired plants are 0.904 times the LHV efficiencies

Capturing CO_2 requires energy and thus reduces the thermal efficiency of the plants. The NGCC plants still have the highest efficiency at 44.71-49.6% and the efficiency reduction for the capture of CO_2 is only 6.0-10.9 percentage points. The efficiencies of the dry feed IGCC, oxy-combustion and post-combustion coal-fired plants are similar, at 34.5-35.4%. The efficiency reductions for CO_2 capture on the same plant are 8.6-8.7 percentage points. Although the slurry feed IGCC plant with capture has the lowest efficiency at 31.5%, it also has the lowest efficiency reduction compared to the same type of coal fired plant without capture, at 6.5 percentage points.

There are a number of factors which contribute to the efficiency reductions for CO_2 capture, and they vary depending on the fuel and technology used for combustion. The factors and the effect they have on plant efficiency are summarised in Figure 1. It shows that the major source of energy reduction for post-combustion capture is the use of low pressure steam to regenerate the solvent used to capture CO_2. The natural gas fired plants with post-combustion capture of CO_2 have a smaller reduction in efficiency. This is because there is less CO_2 to be captured as natural gas has a lower carbon content per unit of energy than coal.

Figure 1 also shows that the IGCC plants with CO_2 capture lose less energy than the PF plants with CO_2 capture. This is because the CO_2 partial pressure is higher in the IGCC plants and so a less energy intensive physical solvent scrubbing process can be used. In the post-combustion capture plants the feed gas is close to atmospheric pressure and the concentration of CO_2 is lower, so a more energy intensive chemical solvent is required. In addition, the IGCC plants require less energy for CO_2 compression as some of the CO_2 is recovered at raised pressure.

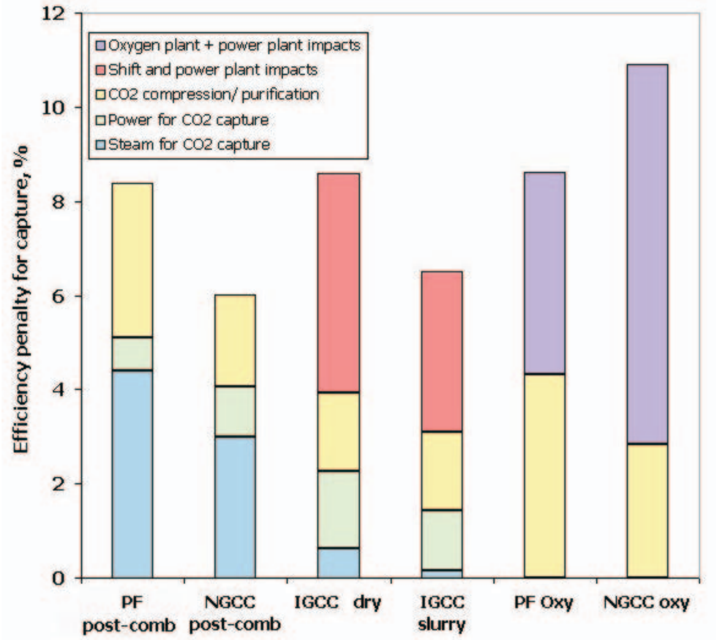

Figure 1 Breakdown of efficiency penalty for CO_2 capture

However, the IGCC plants have some of their own sources of energy loss. For example, the fuel gas is passed through shift reactors prior to the removal of CO_2, and the shift reactions are exothermic. Although most of the exothermic heat is recovered in steam generators, it means that energy bypasses the gas turbine and is fed directly into the steam cycle, which has a lower efficiency. The dry feed IGCC plant has a higher overall energy loss than the slurry feed plant because the raw fuel gas has a higher concentration of CO and so more shift conversion is needed. In addition, there is a requirement to add steam to the shift converter feed. Shift conversion and CO_2 separation also has an impact on the performance of the gas turbine combined cycle. Over half of the efficiency reduction caused by CO_2 capture in IGCC plants is the result of energy losses due to shift conversion and changes in the performance of the gas turbine combined cycle.

The oxy-combustion plant loses efficiency because of the electricity used by the oxygen production unit. This is slightly offset by smaller losses in the main power generation units such as not requiring an FGD plant. A higher volume of gas is fed to the CO_2 compressors due to the presence of impurities. Additional compression is necessary to drive the separation unit, which removes these impurities. The oxy-combustion NGCC plant uses less energy than the coal-fired one, but the reduction in efficiency is much greater. The amount of oxygen required per MW of fuel is about 15% lower for the NGCC plant, but the oxygen is produced at high pressure for feeding to the gas turbine. The result is higher overall energy consumption.

EMISSIONS OF CO_2

The amount of CO_2 emitted, captured or avoided by the power plants is shown in Table 2. The quantity of CO_2 avoided is the emissions per kWh of a plant with CO_2 capture, compared to the emissions of a baseline plant that does not capture CO_2. The baseline plant is that which would be displaced by a plant with CO_2 capture, so it may or may not be the same technology as that which displaces it. Three types of baseline plant are given in Table 2: the same type of power generation technology as that with CO_2 capture; a PF plant; and an NGCC plant.

Table 2 CO_2 emissions data

Fuel	Power generation technology	CO_2 capture technology	CO_2 emissions g/kWh	CO_2 captured g/kWh	CO_2 avoided g/kWh		
					Same techn-ology baseline	PF base line	NG CC base line
Coal	PF	None	743	—	—	—	—
		Post-comb	92	832	651	651	287
		Oxy	84	831	659	659	295
	IGCC	None	763	—	—	—	—
	(dry)	Pre-comb	142	809	621	601	237
	IGCC	None	833	—	—	—	—
	(slurry)	Pre-comb	152	851	681	591	227
Gas	NGCC	None	379	—	—	—	—
		Post-comb	63	362	316	680	316
		Oxy	12	403	367	731	367

The addition of CO_2 capture technology reduces the thermal efficiency of the power plant, which increases the production of CO_2. For this reason, when plants of the same power generation technology are compared, the amount of emissions avoided are lower than the amounts captured. However, in some circumstances plants with CO_2 capture may displace old, inefficient plants which would increase the amount of CO_2 avoided, beyond that shown in Table 2.

The post-combustion and pre-combustion CO_2 capture plants collect 85-90% of the CO_2, and the oxy-combustion plants 90-97%, as shown in Table 2. These results are not necessarily the technical limits or economic optima. More work is required to find the effects of percentage CO_2 capture on costs and efficiency for all the technologies.

Each technology produces a CO_2 of a different purity. If a high purity CO_2 is required, this may influence the decision as to which technology is selected.

CONSUMPTION OF RESOURCES AND OTHER EMISSIONS

CO_2 capture affects the consumption of raw materials, the quantities of waste and the emissions to the atmosphere per unit of electricity output. The reduction in thermal efficiency increases the consumption of raw materials. In addition, there is a need for some make-up solvent for post and pre combustion capture.

Post-combustion CO_2 capture plants use more solvent and produce more solvent residue than IGCC plants. Hindered amine is a more advanced solvent than MEA, thus less is required and less waste is produced.

Emissions of sulphur oxides to the atmosphere are expected to reduce, but emissions of NOx are expected to increase, exept for oxy-combustion.

From an environmental perspective, the optimum technology for coal-fired power generation will depend on the relative importance given to the consumption of different resources and the environmental impacts of different types of wastes and emissions.

CAPITAL COSTS AND COST OF ELECTRICITY GENERATION

The capital costs and costs of electricity generation for each technology are shown in Figures 2 and 3, but they are subject to a number of uncertainties including the fact that the capture technologies being considered have not yet operated in full scale commercial plants. Fluctuations in currency exchange rates and the market for plant, materials and fuel add more uncertainty.

However, Figures 2 and 3 do show that the capital costs and costs of electricity generation for the PF post-combustion capture, oxyfuel and dry feed IGCC plants are similar. The slurry feed IGCC plant has capital costs that are about 20% lower and the cost of electricity generation is 10% lower. However, all the studies are based on assumptions about plant performance and availability, and have yet to be demonstrated. In addition, costs can vary for different coals and plant locations. All the technologies considered have scope for improvement, so the relative costs could change in the future.

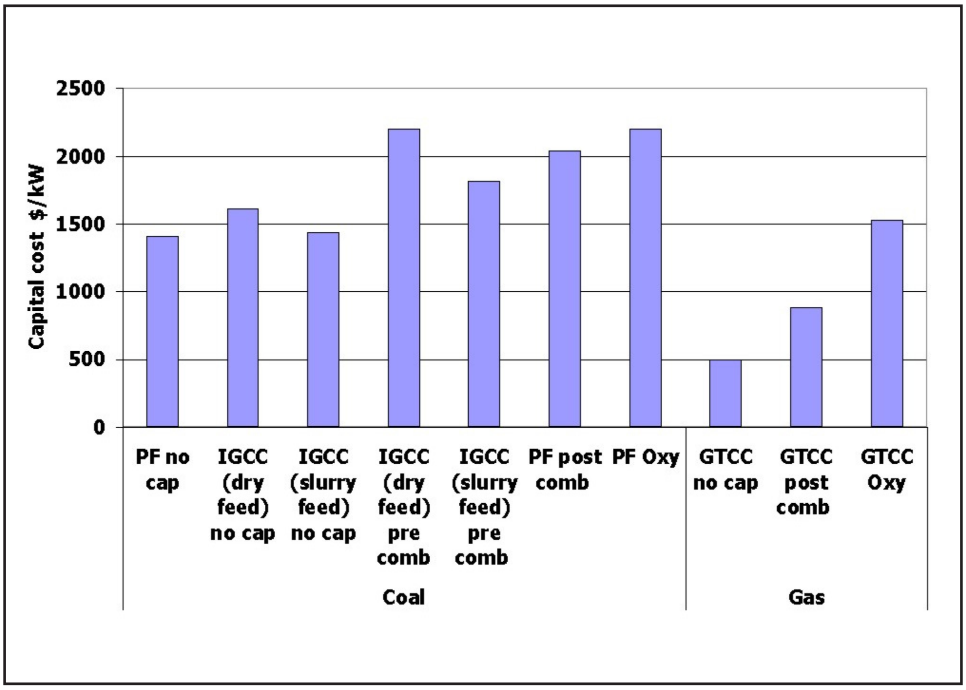

Figure 2 Power outputs and capital costs

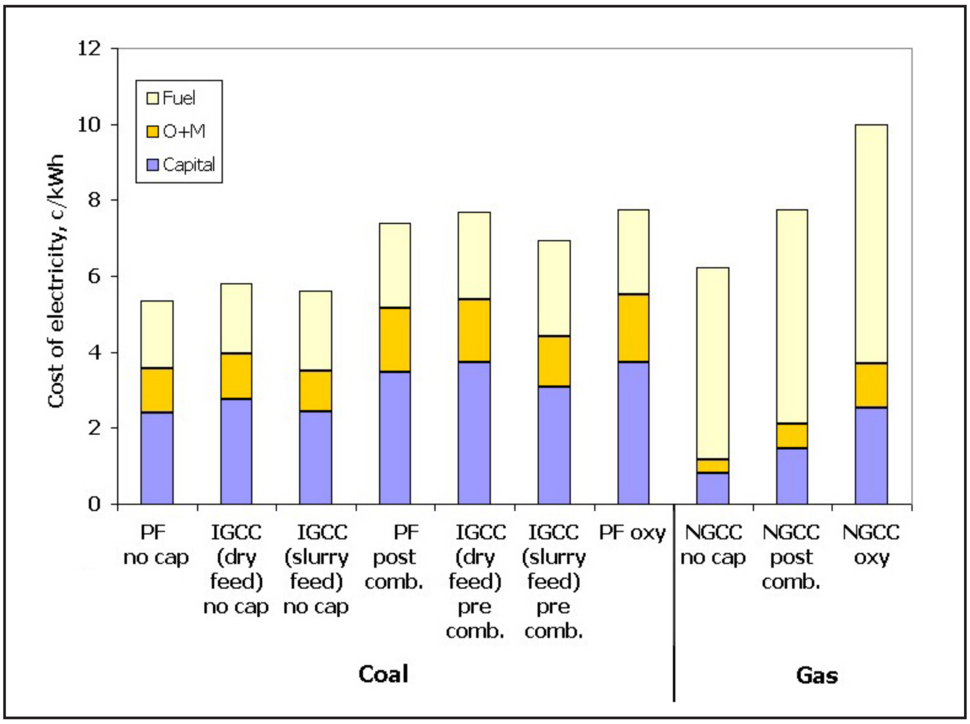

Figure 3 Cost of electricity

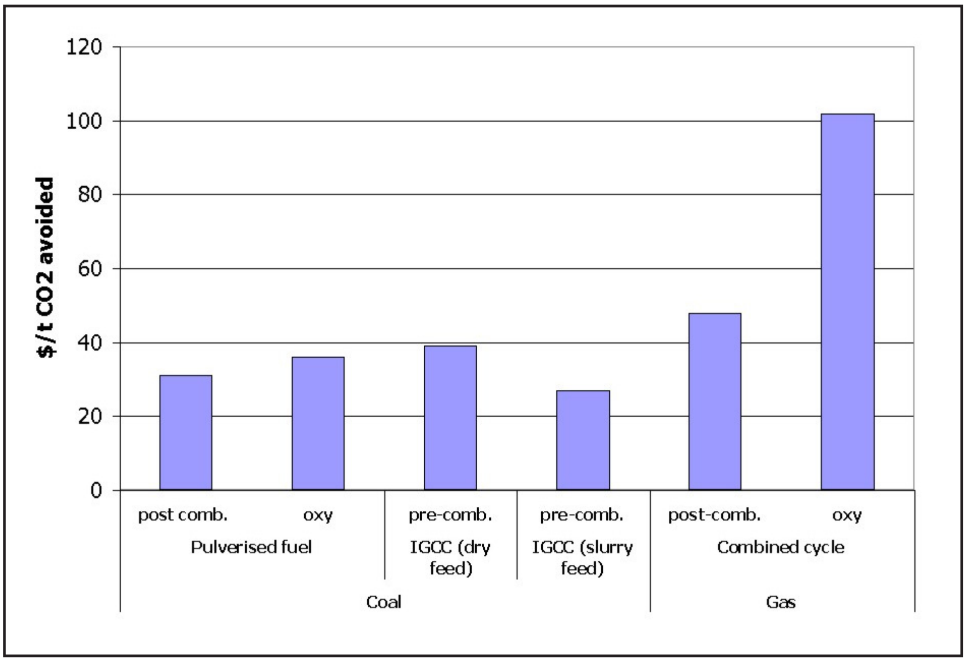

Figure 4 Cost of CO_2 avoided

SENSITIVITY TO COST OF FUEL

The cost of a major input, that is the fuel, feed into the cost of power generation. The price of fuel varies with location and time. For example, in a region where fuel is cheap to produce and the access to international markets is not easy, the price may be lower than internationally traded prices. Figures 3 and 4 are based on a coal price of $2.2/GJ and a gas price of $7.8/GJ (LHV basis). The effects of different fuel prices can be easily seen by scaling the fuel cost bar in Figure 3. The costs in Figures 3 and 4 do include the costs of CO_2 compression to a pressure of 11MPa but exclude transport and storage.

SENSITIVITY TO THE LOAD FACTOR

Figures 3 and 4 use cost data for base load plants, operating at a load factor of 85%. In the short term, power plants with CO_2 capture and storage are likely to operate at base load. This will maximise the use made of CO_2 capture and repay the investment more swiftly. However, in the longer term this may change. The need to reduce emissions of CO_2 may lead to a large increase in the use of renewables, such as wind and solar energy, which have low marginal operating costs and so will generally operate whenever they can in preference to other types of generating plant. As a result, other plants on the grid will have to operate at lower annual load factors to meet peak demands. The ability of power plants with a CO_2 capture facility to operate in this way will need to be assessed.

Table 3 shows a simple projection of the effects of load factor on the costs of electricity produced by NGCC and pulverised coal plants with post combustion CO_2 capture. At lower load factors the cost of electricity increases less for NGCC than for coal fired power plants. This is because the fixed costs of NGCCs are lower than those of coal-fired power plants. Plants with CO_2 capture are expected to work better in power grids containing substantial proportions of renewable energy than technologies that are more capital intensive and less flexible, such as nuclear power.

Table 3 Sensitivity of cost to load factor

Fuel	Capture	60% Load Factor (c/kWh)	$/t CO_2 avoided	35% Load Factor (c/kWh)	$/t CO_2 avoided
Coal	None	6.7		10.1	
	Post-combustion	9.3	40	14.2	63
Gas	None	6.7		7.8	
	Post-combustion	8.6	59	10.5	85

COSTS OF TRANSPORT AND STORAGE OF CO_2

The costs of transporting and storing CO_2 are influenced largely by local conditions. For example, if the CO_2 is used for EOR, the extra oil recovered can be worth more than the cost of the CO_2. However, if CO_2 capture and storage is used widely, the CO_2 may be stored in disused hydrocarbon fields or deep saline formations, and so no revenue would be generated. It is thought that the average costs of CO_2 transport and storage may be range from about 4-12$/t, depending on the injection technology and the properties of the storage reservoir.

A cost of 10 $/t$CO_2$ stored increases the cost of electricity production by about 0.8 c/kWh for coal-fired power plants and by about 0.4 c/kWh for gas-fired plants. The cost is greater for coal-fired plants because more than twice as much CO_2 is captured per kWh of net electricity.

OTHER FACTORS THAT INFLUENCE THE CHOICE OF TECHNOLOGY

The choice of power plant technology and CO_2 capture method will depend on many factors besides cost and efficiency, as has already been indicated. The focus of this section is on some of these other influences.

COAL COMPOSITION

The cost and performance of power plants depends on the coal composition. The data in this report are based on a bituminous coal described in the Annex. If low rank coal is the fuel selected, this will have a major impact on the power generation technology and the CO_2 capture process. The low rank coals are sub-bituminous, lignite and brown coal. They have relatively high moisture and oxygen contents and low heating values. Low rank coal accounts for almost half of the world's proven recoverable coal reserves on a mass basis and 30% of coal production. About 60% of the low rank coal reserves are sub-bituminous and the rest is lignite. The slurry feed IGCC technology evaluated by IEA GHG is not suitable for lignite because the water content of the slurry would be excessive. Studies by IEA GHG and others indicate that post combustion capture and oxy-combustion become more competitive relative to IGCC for lower rank coals. The coal sulphur content and the ash content and composition can also have a major impact on the relative merits of technologies.

OTHER FACTORS

The studies that have been discussed assessed some of the main criteria that would affect a utility's choice of power generation and CO_2 capture technology. There are, of course, a range of other criteria to be considered, including:

- the operating flexibility of the plant and its compatibility with future grid requirements;
- the risks of underperformance;
- various health and safety issues;
- the availability and diversity of equipment and technology suppliers;
- the compatibility of the new system with utilities' operating experience; and
- the potential for future improvements.

These additional criteria are being studied by the IEA GHG.

DISCUSSION AND CONCLUSIONS

Coal-fired power plants have increased steadily in efficiency and emissions reduction. A state of the art coal-fired power plant operates at an efficiency of around 45% and can incorporate the following facilities to reduce emissions:

- the catalytic removal of NO_x;
- ESP or bag filtration for the separation of particulates;
- capture of SO_x with wet or dry scrubbing; and
- the removal of mercury and heavy metals.

In this report the emphasis is on the reduction of CO_2 emissions. Technologies are available to reduce these by around 90%. The cost of power generation with CO_2 capture depends on a range of technical and economic factors, including the extremely variable cost of fuel. However, the cost of power generation, with CO_2 capture included, is estimated to be around 7-8 c/kWh (US), based on typical current European fuel prices.

PF combustion and NGCC are the most widely used power generation technologies and IGCC technology is being demonstrated in commercial scale plants.

CO_2 produced by the combustion of coal or gas can be captured in different ways:

- post-combustion using a formulated amine solvent;
- pre-combustion for gasification processes, using selective regenerative chemical and physical solvents; and
- oxy-combustion.

Post-combustion processes are unproven on the large scale required by the power industry. Questions remain about the rate of solvent deterioration. Capital and energy demands are high. Thus, technological developments are desirable, and are likely to happen if the pressure to capture CO_2 increases.

Pre-combustion CO_2 capture processes are more proven but the basic power generation process (IGCC) is less well proven than PF. The main issues are the integration, operability and reliability of plants. The processes also consume large amounts of capital and energy. So again, improvements are sought.

The third route to capture CO_2 is by oxy-combustion. Oxy-combustion development is in the early stages. There is interest in oxy-combustion as it enables power to be produced, with nearly zero emissions of greenhouse gases. However, the cost of oxygen production in sufficient quantity is a major penalty.

IEA GHG studies have found that the thermal efficiencies of power plants with CO_2 capture, based on the leading technologies are 32-35% (LHV) for bituminous coal-fired plants and 45-50% for natural gas combined cycle plants. The studies considered in this report have assessed some of the main general criteria which affect a utility's choice of power generation and CO_2 capture technology. But local circumstances and utilities' preferences will also influence the choice of power generation and CO_2 capture technology.

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2006/1 CO_2 Capture in Low Rank Coal Power Plants. January 2006

2006/8 CO_2 Capture as a Factor in Power Station Investment Decisions. May 2006

ANNEX

The capture techniques were studied for the IEA GHG by a number of leading engineering contractors and developers:

- post-combustion capture was studied by Fluor, in collaboration with Mitsui Babcock and Alstom, and by MHI;
- pre-combustion capture was studied by Foster Wheeler, with data from gasification and gas treating vendors; and
- oxy-combustion was studied by Mitsui Babcock, in collaboration with Air Products and Alstom.

The technical and economic specifications for the power plant used in the assessments are listed below.

TECHNICAL CRITERIA

Coal feed	Australian bituminous coal	
	Ash	12.2% as received
	Moisture	9.5% as received
	Carbon	82.5% dry ash free
	Hydrogen	5.6% dry ash free
	Oxygen	9.0% dry ash free
	Nitrogen	1.8% dry ash free
	Sulphur	1.1% dry ash free
	Chlorine	0.03% dry ash free
	LHV	25.87 MJ/kg as received
Natural gas	Southern Norwegian North Sea	
	Methane	83.9 vol%
	Ethane	9.2 vol%
	Propane	3.3 vol%
	Butane+	1.4 vol%
	CO_2	1.8 vol%
	N_2	0.4 vol%
Plant location	Netherlands coastal site	
	Average air temperature	9°C
	Average sea water temperature	12°C
CO_2 output pressure	11 MPa	

ECONOMIC CRITERIA

DCF rate	10% per year, excluding inflation
Plant operating life	25 years
Plant construction	3 years
Load factor	85%
Coal price	2.2 $/GJ (LHV)
Natural gas price	7.8 $/GJ (LHV)

The CO_2 is compressed to 11 MPa, as listed above. At this pressure it is a dense phase liquid which can be transported. However, the means of transport of the CO_2 and the nature of the storage reservoir will determine the amount of compression needed for the CO_2. It could be pumped to a higher pressure if required, with little impact on the plant performance and cost. It could also be liquefied for transport by ship if required.

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