The Parliamentary and Scientific Committee

INFORMATION FOR MEMBERS

From the

Parliamentary Office of Science and Technology

Briefing Note

38

December 1992

CLEAN COAL TECHNOLOGY

Due to the current review of the coal industry, the use of coal for electricity generation is under scrutiny. One factor which differentiates coal from gas and light oils is its relatively high emissions; this has spurred research to develop 'clean coal' technologies which offer increased efficiencies and reduced atmospheric pollution.

This briefing note reviews clean coal technologies and their potential in the UK and overseas.

UK POWER GENERATION

In 1990, about 35,000 MW[1] of coal-fired generating capacity supplied 68% of the UK's electricity, the remainder coming mainly from nuclear (21%) and oil (9%). This energy mix is likely to change substantially with the planned introduction of between 8,000 and 13,000 MW of gas-fired combined cycle gas turbines (CCGTs). One perceived advantage of CCGTs over current coal-fired stations, is that they produce less of the greenhouse gas carbon dioxide (CO_2), and of the acidic gases sulphur dioxide (SO_2) and nitrogen oxides (NO_x) (**Table 1**). However emerging 'clean coal' technologies (CCTs) also offer improved efficiencies and lower emissions[2].

Limits on SO_2 and NO_x emissions are set by the EC Large Combustion Plant Directive (LCPD), which requires reductions in UK SO_2 emissions (from a 1980 baseline) of 20% by 1993, 40% by 1998, and 60% by 2003; and reductions in NO_x emissions of 15% by 1993 and 30% by 1998. The directive also sets limits for SO_2 and NO_x emissions from new plant. It is to be reviewed in 1994, and many observers believe targets may be tightened. The UK is also committed to constraining its CO_2 emissions to 1990 levels by 2000.

IMPROVING CONVENTIONAL COAL STATIONS

In conventional **pulverised fuel** (PF) stations, powdered coal is burnt to raise high pressure steam to drive a turbine. About 90% of the SO_2 produced can be removed by flue gas desulphurisation (FGD). Retrofitting FGD reduces the generating efficiency by about 1 percentage point and adds an estimated 0.5p to the cost of each unit of electricity generated. The process also produces large quantities of gypsum which must be used, e.g. in plaster board, or disposed of.

Table 1 EMISSIONS OF GASEOUS POLLUTANTS FROM ELECTRICITY GENERATION (g/kWh)[1]

		Coal	Oil	Gas
Carbon Dioxide		942-1,077	887-986	448-499
Methane		3.6-4.1	0.05	2.0-5.5[2]
Acid Gases:	SO_2 (as S)	0.6[3]-6.9	6.5-7.9 (10.5)[4]	0.2
	NO_x (as N)	0.8-1.6	0.6-0.7	0.3-0.6

1 Based on kWh delivered to the consumer and including emissions during extraction (e.g. methane in coal is released during mining), transport (e.g. gas leakage from distribution pipes) and use of fuel.
2 Depends on assumptions on gas leakage in distribution (0.2 and 1%).
3 Assumes FGD
4 Sulphur emissions from bitumen-based fuel (Orimulsion).

Source: Costing the Environmental Impacts of Electricity Generation, POST, 1992.

To help meet the UK's obligations to reduce SO_2 emissions, plans to fit FGD to 12,000 MW of capacity were announced in 1989. However, the importation of low sulphur coal, and the replacement of some coal-fired stations with CCGTs have reduced this. FGD at 6,000 MW of power stations (National Power's 4,000 MW Drax station and PowerGen's 2,000 MW station at Ratcliffe-on-Soar) should begin operation in 1993/4. In other countries such as Germany, FGD has been applied routinely to new and existing plant for several years.

NO_x emissions in existing plant can be reduced by fitting 'low NO_x' burners (30-50% reductions have been achieved in UK plants). Alternatively, flue gas cleaning techniques such as selective non-catalytic reduction, or the more expensive selective catalytic reduction can be used, giving reductions of 40-50% and 80-90% respectively. It is planned to retrofit low NO_x burners to 20,000 MWe of UK coal-fired capacity, and half of this has already been completed. Selective catalytic reduction is widely used in Germany and Japan.

'CLEAN' TECHNOLOGIES

Advanced 'clean' technologies are based on **fluidised bed combustion** (FBC) and **gasification** processes; hybrid systems such as British Coal Corporation's (BCC) Topping Cycle are also under development. **Table 2** compares the efficiencies and emissions of each technology. As some CCTs are still under demonstration or

1. Power output is measured in megawatts (MW); electrical power output is indicated as MWe (megawatts electrical). 1 MW is a 1000 kilowatts (kW).

2. CO_2 emissions from coal will always be higher than gas due to the high carbon content of coal; the carbon to energy ratio of coal is almost twice that of gas.

Table 2 COMPARISON OF EFFICIENCIES AND EMISSIONS

Technology	Generating Efficiency*	SO_2 Removal %	NO_x Emissions mg/m³
PF + FGD +low NO_x burners	38-39	90	500-650
CFBC	39-40	90	100-300
PFBC	41-43	90	150-300
IGCC	43-44	99	120-300
BCC Topping cycle	46-47	90	150-300
LCPD limits (for high sulphur fuel)		90	650

* Based on lower heating value

development, it is difficult to estimate the cost of plant accurately. However, it is thought that these technologies have the potential to generate electricity at a cost (up to 20%) less than that of a new PF plant equipped with FGD and low NO_x burners.

In fluidised bed combustion, a stream of air from the bottom of the combustion chamber 'fluidises' a mixture of coal and crushed limestone. More than 90% of SO_2 can be captured by the limestone, and lower operating temperatures than in PF plant inhibit NO_x formation. FBC can use a wide range of coals, including lignite, and other fuels, e.g. refuse or sewage sludge. The end product of combustion is a mixed waste of ash and gypsum which must be disposed of. FBC may operate either at normal (atmospheric) pressure - e.g. **circulating fluidised bed combustion** (CFBC), or under pressure, **pressurised fluidised bed combustion** (PFBC).

There are about 200 **CFBC** units (mainly used for cogeneration of electricity and heat) in operation worldwide, including four at industrial sites in Britain. The technology is commercially proven for plant of up to 150 MWe capacity, and several larger demonstration plants are already planned (e.g. Electricité de France are constructing a 250 MWe plant). BCC and East Midlands Electricity planned to build a 150 MWe power station at Bilsthorpe minehead, but a request for 20% of the cost from the Government was turned down in 1990. The project failed to get EC funding, and has not gone ahead.

In **PFBC**, coal is burnt at pressures of 10 to 20 atmospheres, and, as well as using heat from the bed to raise steam, the hot pressurised combustion gas is fed into a gas turbine, raising the generating efficiency. Much pioneering work on PFBC was undertaken by BCC at Grimethorpe (see Box), but its leading proponent is now a Swedish firm (ABB Carbon) from which BCC receives royalties for some parts of the design. There is about one year's operating experience from four 80 MWe units in Sweden, Spain and the US, and more power stations, including larger 330 MWe units are planned in the US, Japan and Eastern Europe.

Integrated gasification combined cycle (IGCC) units convert coal to gas by reacting it with steam and oxygen (or air) in a gasifier. The gas is cleaned to remove sulphur compounds and other impurities (more than 99% of sulphur can be recovered and sold), and then fed into a gas turbine. The hot turbine exhaust can generate extra power in a steam turbine - combined cycle operation. Combined cycle gas turbines could be converted from natural gas to coal-derived gas in the future by adding a coal gasifier and gas clean-up, but it would be necessary to take account of space and other requirements at the planning stage.

Several gasifier systems have been developed worldwide, and several demonstration plants are in operation or under construction. British Gas (BG), in conjunction with the German firm, Lurgi, successfully demonstrated a gasifier at Westfield, Fife, which was used to power a 25 MWe gas turbine. The process produces an inert slag which may be used, e.g. as roadfill, or must be disposed of. BG have now closed the site and are trying to market the process. A design study, partially funded by the (then) Department of Energy (DEn), of a 300 MWe power station based on the BG/Lurgi gasifier was completed in March 1992, and has led to a proposal for a UK demonstration project (see Issues). Shell will begin operating a 250 MWe demonstration plant for a Dutch electricity utility at Buggenum in late 1993, and a demonstration project, partly funded by the EC and based on German IGCC technology is beginning in Spain. Several IGCC projects are planned in the US, where funding is available from the US Government's Clean Coal Technology programme.

Hybrid combined cycle systems will combine the best features of gasification and combustion-based cycles. Some of the coal is converted to a hot fuel gas to be burned in a gas turbine, and the remaining char is burnt in a fluidised bed to raise steam for a conventional steam turbine. BCC have been developing such a system (the BCC Topping Cycle) since the late 1980s at Grimethorpe and the Coal Research Establishment (see **Box**). As with FBC, the end product is a mixture of ash and gypsum which must be disposed of. Pilot plants have been built for other hybrid systems in the US and Germany, and there are plans for demonstration projects. Predicted advances in gas turbine technology will improve the efficiency of both IGCC and hybrid systems.

Other technologies under development[3] include the integration of coal gasifiers with **fuel cells**, and **magnetohydrodynamics**. Both technologies offer potential efficiencies of over 50%, but are about 20 years away from market availability for power generation. Research into improving the environmental performance of coal also continues e.g. the removal of sulphur

3. Another use of coal is *liquefaction* - the production of liquid petroleum products directly from coal. The UK has a technical lead with a 2.5 tonne per day pilot plant at Point of Ayr. Liquefaction is unlikely to become economic unless current oil prices double.

BOX THE GRIMETHORPE TEST FACILITY

1977-1984 International Energy Agency (IEA) PFBC Programme. An 80 MW PFBC test facility, then the largest in the world, was built next to Grimethorpe Colliery, and a test programme successfully completed. The £60M programme was funded equally by the UK, US and West Germany; 70% of the UK contribution came from the Government and 30% from BCC.

1985-89 Joint PFBC Programme. BCC and the Central Electricity Generating Board (CEGB) jointly funded a £28M programme to resolve the remaining problems identified in the IEA project. The US Electric Power Research Institute and the US Department of Energy provided £8M for work on hot gas clean up systems and the combustion of coal slurry. In 1987 the CEGB, whose policy was to obtain increased efficiency by scaling up PF plant, left the project.

1990-1993 Topping Cycle Development. BCC promoted the Topping Cycle and experienced some difficulty with funding the project. The UK DEn was asked for £16M of the £27.5M cost of work required at Grimethorpe, but required BCC to find industrial sponsorship. Ahlstrom Corporation of Finland were initially willing to provide £5M, but then withdrew; and the DEn provided funding for the first year until another industrial partner (GEC Alsthom) was found. The DTI who took over from the DEn is now supplying £11.6M over three years; other funders are BCC, PowerGen, the EC, and the US Electric Power Research Institute.

Experimental work at Grimethorpe finished in March 1992 and the facility was shut down and is now being dismantled. Analysis of the results and complementary work at BCC's Coal Research Establishment will be completed in 1993.

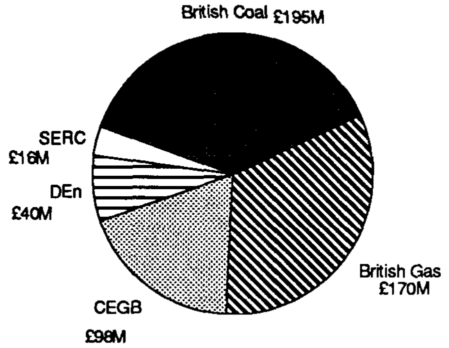
from coal prior to combustion, but the commercial feasibility of the various possibilities is still unproven.

CURRENT ISSUES

Clean coal technologies offer improved generating efficiencies and reduced gaseous pollution, and could allow the use of coals with a higher sulphur content (including many British coals) under tightening environmental standards. Many thus see a potential market for CCTs both in the UK, where there will be a shortfall of capacity sometime between 2000 to 2010 caused by the retirement of existing coal-fired plant, and abroad, e.g. in Eastern Europe, China and India.

The UK has substantial expertise in CCT and is at the forefront of development in areas such as the Topping Cycle and the BG/Lurgi gasifier. However, decisions taken now about future R&D and CCT demonstration will determine whether UK technology is available for use in both the home and export market.

Figure 1 UK FUNDING OF CLEAN COAL TECHNOLOGY 1980/81 to 1990/91*



* Total of £519M at 1990/91 prices

Research and Development

A breakdown of public sector funding of clean coal technology over the last 10 years (£519M at 1990/91 prices) is shown in **Figure 1**. Historically, the largest funder has been BCC, who had a statutory duty to undertake research *'necessary to secure the future of the industry'*, although the CEGB and BG also supported a wide range of research on coal-fired generation and gasification prior to privatisation. Only 8% of funding came directly from the DEn.

Many independent experts are concerned about the future of long-term strategic R&D in a privatised energy industry, and believe the generators are tending to fund only the minimum R&D necessary to become an informed buyer. Thus since privatisation, overall R&D spending by the CEGB's successors has fallen by 50%, and spending on CCT has fallen from an average of £10M per annum by the CEGB to £2.7M in 1990/91 (£1.5M by National Power and £1.2M by PowerGen). BCC's funding of R&D on coal use has also contracted (partly as a result of objectives set by the Government) from £31.1M in 1986/7 to £12.8M in 1991/92 (all at 1991 prices). Given the experience of the CEGB, many expect that the proposed privatisation of BCC will lead to further cuts in long-term strategic research.

Many, including the (former) Commons Energy Committee, feel that the Government should accept increased responsibility for long-term R&D which is beyond the timescale of the market, yet in the national interest. They point out that current DTI funding of CCT (£4.65M, 3.5% of the energy R&D budget in 1991/92) is low compared with Government R&D funding in other countries with a privatised coal industry - $49M in Germany, $182M in Japan, $593M in US (10%, 6% and 23% of 1991 energy R&D budgets respectively). It is also much less than UK R&D expenditure on other generation technologies e.g. £94M for nuclear power. Some have suggested that such R&D budgets could be funded by a levy on energy producers; others believe that the privatised industries should be made, possibly by the regulators, to undertake a share of long-term research. Others,however, consider that the unwillingness of a private energy industry to fund long-term R&D indicates that short-term R&D is sufficient.

The Energy Committee and others have advocated a long-term R&D strategy by the Government. This would act as a signal of government commitment to the industry, and would provide greater continuity in long-term projects. The stop-start effect of the current regime can be seen at Grimethorpe, where uncertainty over future funding has already led to the transfer of technology and experienced staff to Sweden. In May 1991, the Coal Task Force (a group of industrialists and academics set up by the DEn) presented the DEn with a ten year strategy for coal R&D, costing an estimated £380 to £820M. The DTI has yet to respond, although it is likely to do so as part of the current coal review.

One specific issue concerns the future of BCC's Coal Research Establishment (CRE), a centre of international excellence, which at present carries out both market support activities and longer term research activities for BCC. In 1991/92, 60% of CRE's £14M budget came from BCC, and the majority of the remainder from the EC. Maintenance of its pilot plant and engineering facilities would be dependent on a privatised coal industry continuing to support long-term strategic research, and/or increased future project support by DTI.

Demonstration

The next logical step in the commercialisation of UK CCT is widely viewed as a demonstration of IGCC and/or BCC's Topping Cycle. The IGCC Industrial Working Group (a consortium of BCC, BG, PowerGen, National Power and British power engineering companies) submitted a proposal for a 300 MWe demonstration plant, based on the BG/Lurgi gasifier, to the DTI in May 1992. It has asked for a grant of around £200M towards estimated costs of £350M, or alternatively suggests that the project is supported by a subsidy for each unit of electricity generated. This could be raised through a small (probably less than 1%) 'environmental and technical' levy on electricity generated - analogous to the Non-Fossil Fuel Obligation which was introduced to subsidise electricity produced from nuclear and renewable sources. The DTI is currently considering the working group's proposal.

In the case of the Topping Cycle, BCC has developed components of the system, and is seeking Government funding for continuing development of the technology. A Working Party set up by the DTI has reviewed the technology and looked at the development of a project; the DTI is considering its report.

Demonstration plants are already in operation or under construction in other European countries, the US and Japan. Independent experts and industry believe that unless the UK embarks on demonstration projects very soon, UK technologies will not be commercially proven by 2000, when new UK generating capacity will be needed. Domestic operating experience is also crucial if UK manufacturers are to compete in the export market.

Demonstration projects are unlikely to proceed without some public funding for a number of reasons - their high capital cost, the need to compete with pool price electricity, the timescales involved (7 to 8 years) which are long relative to the shorter term R&D objectives of the UK privatised generating and fuel industries, and the weakened state of the UK manufacturing industry. Demonstration plants in other countries have all had government support (up to 50% in cases such as the US Clean Coal Programme), and many believe UK projects should receive similar support. The DTI aims to maintain an overall ratio of 1:4 between DTI and external contributions (from industry and other funding agencies) in the projects supported by its current coal R&D programme.

The EC THERMIE programme offers up to 40% of costs in demonstration projects and in the UK contributes to the Point of Ayr liquefaction programme and to work on the Topping Cycle. However, BCC failed to obtain support for its Bilsthorpe CFBC project, and some, including the Energy Committee, have queried whether this is a consequence of the UK Government's lack of support for CCT demonstration. Furthermore, they point out that the UK did not respond to a call for proposals for IGCC demonstration projects and is not involved in the successful Spanish project. The Government points out that EC support is not dependent on support by national governments (additional national support is limited by a 49% cap on public sector funding), and that under THERMIE rules, proposals must come from industry not the Government.

Some experts also believe that a low level of interest by many of the UK power engineering companies has been a contributing factor in the slow commercialisation of CCT in the UK. However, others point out that there has been no guarantee of a home market for such companies - the CEGB was committed to very large PF stations, and under current conditions the power generators appear committed to CCGTs, for new capacity.

FURTHER READING

Additional details and background information are available from POST, 2 Little Smith St., London SW1P 3DL, tel: (071)-222-2688.