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COAL INDUSTRY ADVISORY BOARD
Meeting with IEA Governing Board, Wednesday 10 December 2003
Background Paper

Clean Coal Technologies

Clean coal technologies (CCTs) have an important role to play over the coming decades to minimise the environmental impact of the substantial coal use that is forecast. This briefing paper focuses primarily on the technologies to reduce sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and carbon dioxide (CO_2).

CCT projects have demonstrated technologies in four key areas: environmental control technologies applicable to conventional plants, advanced power generation, coal processing and industrial applications.

Environmental control technologies at conventional plants

These technologies were developed to remove or prevent the formation of SO_2, NO_x and particulates when coal is burned to generate electricity at conventional, coal-fired power stations where the coal is pulverised to a fine powder before being burned in a boiler to raise steam for a steam turbine.

Flue gas desulphurisation to remove >90% of the SO_2, typically using a wet limestone slurry, is widely adopted and capital costs have halved over the last decade. Many NO_x reduction technologies are employed at commercial plants: low-NO_x burners, over-fire air, reburn, non-catalytic reduction techniques and, to meet the most demanding standards, selective catalytic reduction.

The efficiency of conventional coal-fired power station designs continues to improve with each new project, such that CO_2 emissions from new plants are 15-25% less than many older plants. The latest supercritical steam designs are reducing CO_2 emission by a further 10% or more, and are the preferred technology choice in many countries.

Development programmes for ultra-supercritical technology aim to improve coal-fired generation efficiency to above 50% (*i.e.* comparable to gas-fired generation). The scale of these programmes means that they are very unlikely to proceed without government encouragement and support. This would be justified by the potential carbon savings that would result from world-wide application, yet governments in some of the most developed countries still hesitate to support development of the technology.

Advanced power generation

Advanced, coal-fired power generation technologies offer an alternative approach to the conventional technologies discussed above. As always, the aim is to achieve high thermal efficiency and hence reduced CO_2 emissions, very low pollutant emissions, few solid wastes requiring disposal, and improved economics. The two main technologies are:

- Fluidised-Bed Combustion (FBC)
- Integrated Gasification Combined Cycle (IGCC)

FBC reduces emissions of SO_2 and NO_x by the controlled combustion of crushed coal in a bed fluidised with jets of air. Sulphur released from the coal as SO_2 is captured by a sorbent (*e.g.* limestone) injected into the combustion chamber along with the coal. Around 90% of the sulphur can be removed as a solid compound with the ash. FBCs operate at a much lower temperature than conventional pulverised coal boilers, greatly reducing the amount of thermal NO_x formed. The relatively simple FBC is particularly suited to poorer quality fuels and is widely used in developing countries.

IGCC systems involve gasification of coal, cleaning the gas produced, and combusting it in a gas turbine generator to produce electricity. Residual heat in the exhaust gas from the gas turbine is recovered in a heat recovery boiler as steam, which can be used to produce additional electricity in a steam turbine generator. IGCC systems are among the cleanest and most efficient of the emerging clean coal technologies: sulphur, nitrogen compounds, and particulates are removed before the gas is burned in the gas turbine and thermal efficiencies of over 50% are likely in the future.

In the gasifier, sulphur from the coal forms hydrogen sulphide (H_2S) which is readily removed by commercially available processes. Sulphur removal can exceed 99.9% and by-products are saleable sulphur or sulphuric acid. High levels of nitrogen removal are also possible. Some of the coal's nitrogen is converted to ammonia (NH_3) which can be almost totally removed by established chemical processes, thus limiting the formation of fuel-NO_x. Thermal-NO_x formation in the gas turbine is limited by staged combustion or by adding moisture or nitrogen to control flame temperature.

Coal processing for clean fuels

A variety of technologies are available to produce clean liquid fuels having high energy density and low sulphur. The largest example is in South Africa where almost 40 million tonnes of low grade coal is gasified and processed into high quality synfuels, including transport fuels, using the Fischer-Tropsch process.

Industrial applications

This category includes iron-making, with coal replacing a proportion of the more expensive coke traditionally used in blast furnaces. It also includes processes to remove SO_2 and other pollutants from the flue gases produced during cement manufacture.

CO_2 capture and hydrogen production

To properly address the climate change issue will require the capture and storage of CO_2 emissions from all fossil fuel use. There is much research work in progress to examine and further develop the many technologies that are already available to capture CO_2 from coal use. Amine scrubbing of the flue gases from conventional coal-fired plant uses equipment that is similar to existing FGD, but would be very expensive today and significantly reduce power generation efficiency. Engineering refinements and eventual commercialisation should see costs fall substantially and the efficiency penalty largely compensated for by the technology advances discussed above. Capture of CO_2 from IGCC plant has particular attractions, not least because it is already demonstrated at an appropriate scale for power generation. It would also allow the production of carbon-free hydrogen from coal: a clean transport fuel for the future.

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Research, development and demonstration in liberalised markets

Liberalisation of energy industries is creating intense cost-reduction pressures on all companies – coal, oil, natural gas and electricity companies are merging into larger business entities that are investing less in research. Government programmes must therefore be designed to encourage cost-competitive solutions to the environmental challenges society faces. Deregulation and a growing environmental awareness are creating new markets for energy concepts that use natural gas, coal, and biomass fuels to generate a mix of products that include electricity, liquid fuels and chemicals, with virtually zero environmental impact when CO_2 is captured. Without major expenditure by governments into these so-called Zero Emission Technologies (ZET), it is very doubtful whether the objectives of the UNFCCC can be met. The coal industry is fully supportive of the growing collaboration between groups engaged in ZET development, notably from the USA, Canada, Australia, Japan and Europe.