



WORLD COAL INSTITUTE

THE COAL RESOURCE

A COMPREHENSIVE OVERVIEW OF COAL

THE COAL RESOURCE

WHERE DOES COAL COME FROM? WHAT IS IT USED FOR? IS IT USED ANYMORE?

Coal is one of the world's most important sources of energy, fuelling almost 40% of electricity worldwide. In many countries this figure is much higher: Poland relies on coal for over 94% of its electricity; South Africa for 92%; China for 77%; and Australia for 76%. Coal has been the world's fastest growing energy source in recent years – faster than gas, oil, nuclear, hydro and renewables.

Coal has played this important role for centuries – not only providing electricity, but also an essential fuel for steel and cement production, and other industrial activities.

The Coal Resource provides a comprehensive overview of coal and the role it plays in our lives. It covers how coal is formed, how it is mined, through to its use and the impact it has on our societies and natural environment. It describes coal's important role as an energy source and how coal – along with other sources of energy – will be vital in meeting the world's rapidly growing energy needs.

We hope that we will answer any questions you may have about the coal industry but if you would like further information, a number of other World Coal Institute (WCI) publications may be helpful.

- >> *The Role of Coal as an Energy Source* (2003) describes the role that coal plays in our world today and examines this role in the context of wider issues, such as increasing energy demand, energy security and environmental challenges.
- >> *Clean Coal – Building a Future through Technology* (2004) discusses how the environmental challenges facing coal – specifically the use of coal – can be overcome through the development and use of clean coal technologies.
- >> In 2001 the World Coal Institute published *Sustainable Entrepreneurship, the Way Forward for the Coal Industry* – in conjunction with the United Nations Environment Programme (UNEP) – looking at coal within the wider context of sustainable development.

Copies of all WCI publications and further information on the coal industry are available on our website: www.worldcoal.org

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SECTION ONE

WHAT IS COAL?

>> Coal is the altered remains of prehistoric vegetation that originally accumulated in swamps and peat bogs. >>



Peat



Brown Coal



Sub-bituminous



Bituminous

The build-up of silt and other sediments, together with movements in the earth's crust (known as tectonic movements) buried these swamps and peat bogs, often to great depths. With burial, the plant material was subjected to high temperatures and pressures. This caused physical and chemical changes in the vegetation, transforming it into peat and then into coal.

Coal formation began during the Carboniferous Period – known as the first coal age – which spanned 360 million to 290 million years ago.

The quality of each coal deposit is determined by temperature and pressure and by the length of time in formation, which is referred to as its 'organic maturity'. Initially the peat is converted into lignite or 'brown coal' – these are coal-types with low organic maturity. In comparison to other coals, lignite is quite soft and its colour can range from dark black to various shades of brown.

Over many more millions of years, the continuing effects of temperature and pressure produces further change in the lignite, progressively increasing its organic

maturity and transforming it into the range known as 'sub-bituminous' coals.

Further chemical and physical changes occur until these coals became harder and blacker, forming the 'bituminous' or 'hard coals'. Under the right conditions, the progressive increase in the organic maturity can continue, finally forming anthracite.

Types of Coal

The degree of change undergone by a coal as it matures from peat to anthracite – known as coalification – has an important bearing on its physical and chemical properties and is referred to as the 'rank' of the coal.

Low rank coals, such as lignite and sub-bituminous coals are typically softer, friable materials with a dull, earthy appearance. They are characterised by high moisture levels and low carbon content, and therefore a low energy content.

Higher rank coals are generally harder and stronger and often have a black, vitreous lustre. They contain more carbon, have lower moisture content, and produce more energy. Anthracite is at the top of the rank scale and

Definition

Coal is a fossil fuel. It is a combustible, sedimentary, organic rock, which is composed mainly of carbon, hydrogen and oxygen. It is formed from vegetation, which has been consolidated between other rock strata and altered by the combined effects of pressure and heat over millions of years to form coal seams.

Photographs courtesy of the Australian Coal Association

has a correspondingly higher carbon and energy content and a lower level of moisture (see diagram on page 4).

Where is Coal Found?

It has been estimated that there are over 984 billion tonnes of proven coal reserves worldwide (see definitions). This means that there is enough coal to last us over 190 years (see graph). Coal is located worldwide – it can be found on every continent in over 70 countries, with the biggest reserves in the USA, Russia, China and India.

Resource

The amount of coal that may be present in a deposit or coalfield. This does not take into account the feasibility of mining the coal economically. Not all resources are recoverable using current technology.

Reserves

Reserves can be defined in terms of proved (or measured) reserves and probable (or indicated) reserves. Probable reserves have been estimated with a lower degree of confidence than proved reserves.

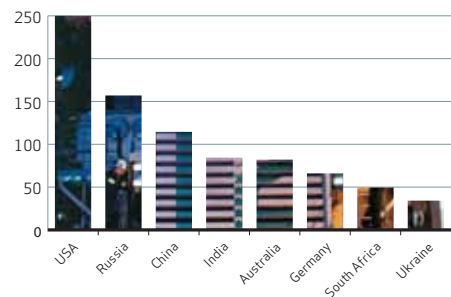
Proved Reserves

Reserves that are not only considered to be recoverable but can also be recovered economically. This means they take into account what current mining technology can achieve and the economics of recovery. Proved reserves will therefore change according to the price of coal; if the price of coal is low, proved reserves will decrease.

Source: IEA Coal Information 2004

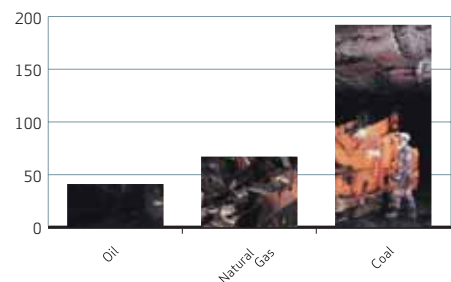
Countries with the Largest Reserves of Coal, 2003 (billion tonnes)

Source: BP 2004



Reserves-to-production Ratios, 2003 (Years)

Source: BP 2004



While it is estimated that there is enough coal to last us 190 years, this could extend still further through a number of developments, including:

- >> the discovery of new reserves through ongoing and improved exploration activities;
- >> advances in mining techniques, which will allow previously inaccessible reserves to be reached.

All fossil fuels will eventually run out and it is essential that we use them as efficiently as possible. Significant improvements continue to be made in how efficiently coal is used so that more energy can be generated from each tonne of coal produced.

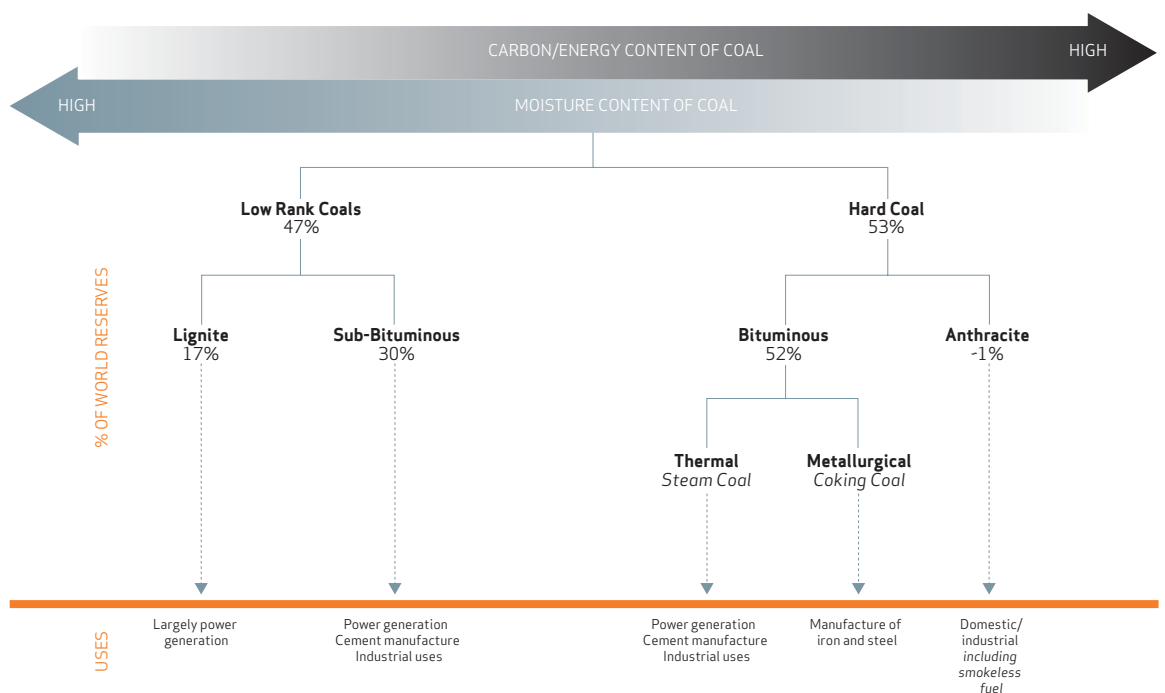
Finding Coal

Coal reserves are discovered through exploration activities. The process usually involves creating a geological map of the area, then carrying out geochemical and geophysical surveys, followed by exploration drilling. This allows an accurate picture of the area to be developed.

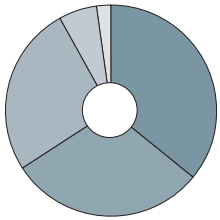
The area will only ever become a mine if it is large enough and of sufficient quality that the coal can be economically recovered. Once this has been confirmed, mining operations begin.

SECTION ONE END

Types of Coal



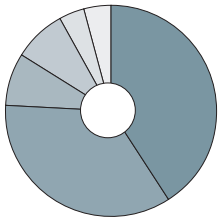
Coal Reserves Showing Regional Shares (at end of 2003)



■ Europe and Eurasia	36%
■ Asia Pacific	30%
■ North America	26%
■ Africa	6%
■ South and Central America	2%

*Middle East coal reserves less than 1% of total reserves
Source: BP 2004*

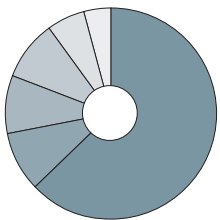
Gas Reserves Showing Regional Shares (at end of 2003)



■ Middle East	41%
■ Europe and Eurasia	35%
■ Asia Pacific	8%
■ Africa	8%
■ North America	4%
■ South and Central America	4%

Source: BP 2004

Oil Reserves Showing Regional Shares (at end of 2003)



■ Middle East	63%
■ Africa	9%
■ South and Central America	9%
■ Europe and Eurasia	9%
■ North America	6%
■ Asia Pacific	4%

Source: BP 2004



Large opencast mines can cover an area of many square kilometres and use very large pieces of equipment, such as draglines (pictured here). Photograph courtesy of Anglo Coal.

SECTION TWO

COAL MINING

>> Coal is mined by two methods – surface or ‘opencast’ mining and underground or ‘deep’ mining. >>

The choice of mining method is largely determined by the geology of the coal deposit. Underground mining currently accounts for about 60% of world coal production, although in several important coal producing countries surface mining is more common. Surface mining accounts for around 80% of production in Australia, while in the USA it is used for about 67% of production.

Underground Mining

There are two main methods of underground mining: room-and-pillar and longwall mining.

In room-and-pillar mining, coal deposits are mined by cutting a network of ‘rooms’ into the coal seam and leaving behind ‘pillars’ of coal to support the roof of the mine. These pillars can be up to 40% of the total coal in the seam – although this coal can sometimes be recovered at a later stage. This can be achieved in what is known as ‘retreat mining’ where coal is mined from the pillars as workers retreat. The roof is then allowed to collapse and the mine is abandoned.

Longwall mining involves the full extraction of coal from a section of the seam or ‘face’ using mechanical shearers. A longwall face requires

careful planning to ensure favourable geology exists throughout the section before development work begins. The coal ‘face’ can vary in length from 100-350m. Self-advancing, hydraulically-powered supports temporarily hold up the roof while coal is extracted. When coal has been extracted from the area, the roof is allowed to collapse. Over 75% of the coal in the deposit can be extracted from panels of coal that can extend 3km through the coal seam.

The main advantage of room-and-pillar mining over longwall mining is that it allows coal production to start much more quickly, using mobile machinery that costs under \$5 million (longwall mining machinery can cost \$50 million).

The choice of mining technique is site specific but always based on economic considerations; differences even within a single mine can lead to both methods being used.

Surface Mining

Surface mining – also known as opencast or opencut mining – is only economic when the coal seam is near the surface. This method recovers a higher proportion of the coal

deposit than underground mining as all coal seams are exploited – 90% or more of the coal can be recovered. Large opencast mines can cover an area of many square kilometres and use very large pieces of equipment, including: draglines, which remove the overburden; power shovels; large trucks, which transport overburden and coal; bucket wheel excavators; and conveyors.

Definition

Overburden is the layer of soil and rocks (strata) between the coal seams and the surface.

The overburden of soil and rock is first broken up by explosives; it is then removed by draglines or by shovel and truck. Once the coal seam is exposed, it is drilled, fractured and systematically mined in strips. The coal is then loaded on to large trucks or conveyors for transport to either the coal preparation plant or direct to where it will be used.

Coal Preparation

Coal straight from the ground, known as run-of-mine (ROM) coal, often contains unwanted impurities such as rock and dirt and comes in a mixture of different-sized fragments. However, coal users need coal of a consistent quality. Coal preparation – also known as coal beneficiation or coal washing – refers to the treatment of ROM coal to ensure a consistent quality and to enhance its suitability for particular end-uses.

The treatment depends on the properties of the coal and its intended use. It may require only simple crushing or it may need to go through a complex treatment process to reduce impurities.

To remove impurities, the raw run-of-mine coal is crushed and then separated into various size fractions. Larger material is usually treated using 'dense medium separation'. In this

process, the coal is separated from other impurities by being floated in a tank containing a liquid of specific gravity, usually a suspension of finely ground magnetite. As the coal is lighter, it floats and can be separated off, while heavier rock and other impurities sink and are removed as waste.

The smaller size fractions are treated in a number of ways, usually based on differences in mass, such as in centrifuges. A centrifuge is a machine which turns a container around very quickly, causing solids and liquids inside it to separate. Alternative methods use the different surface properties of coal and waste. In 'froth flotation', coal particles are removed in a froth produced by blowing air into a water bath containing chemical reagents. The bubbles attract the coal but not the waste and are skimmed off to recover the coal fines. Recent technological developments have helped increase the recovery of ultra fine coal material.



Longwall mining involves the full extraction of coal from a section of the seam using mechanical shearers.

Photograph courtesy of Joy Mining Machinery.

Definition

DWT – Deadweight Tonnes which refers to the deadweight capacity of a ship, including its cargo, bunker fuel, fresh water, stores etc.

Underground Mining Operations

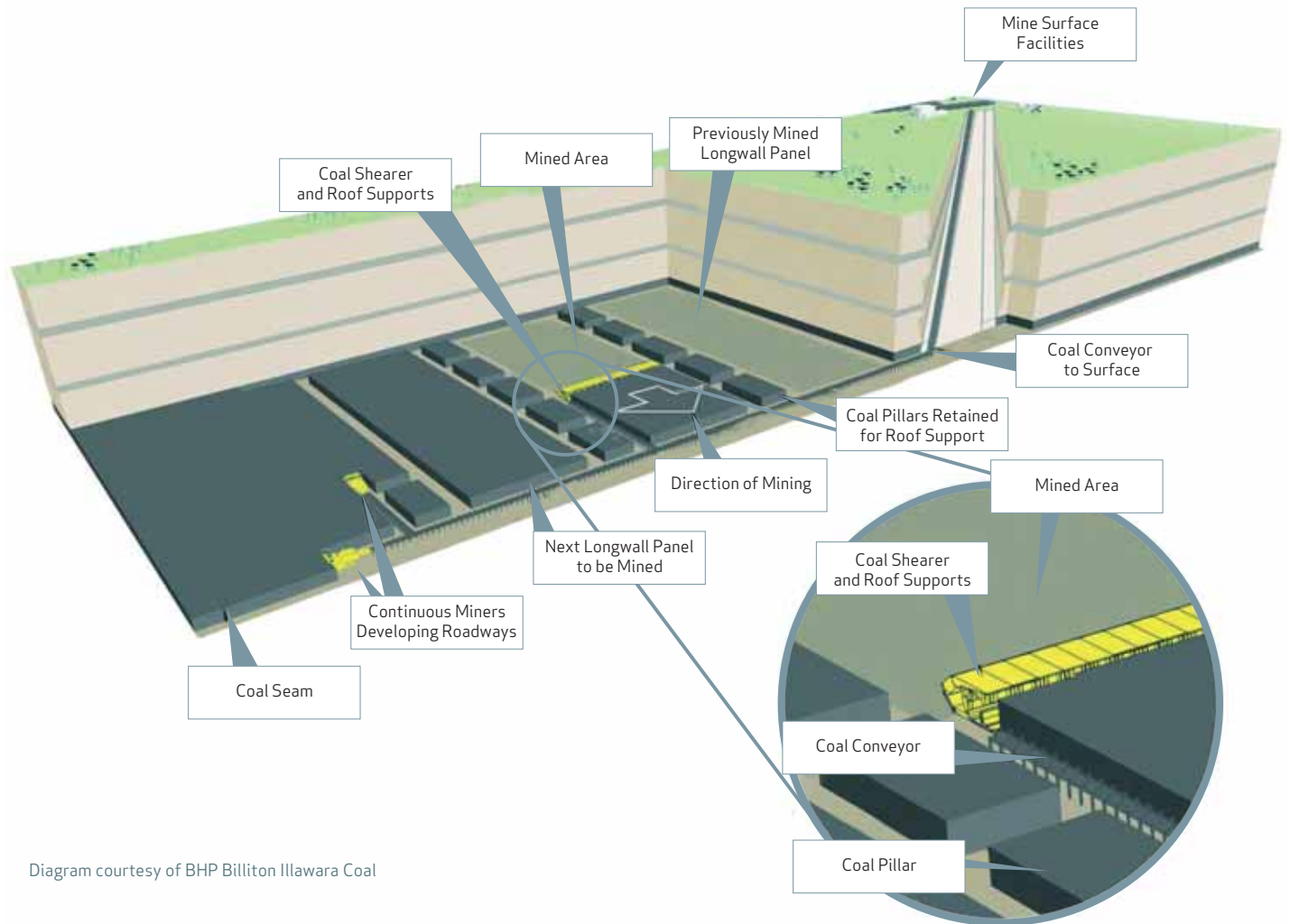
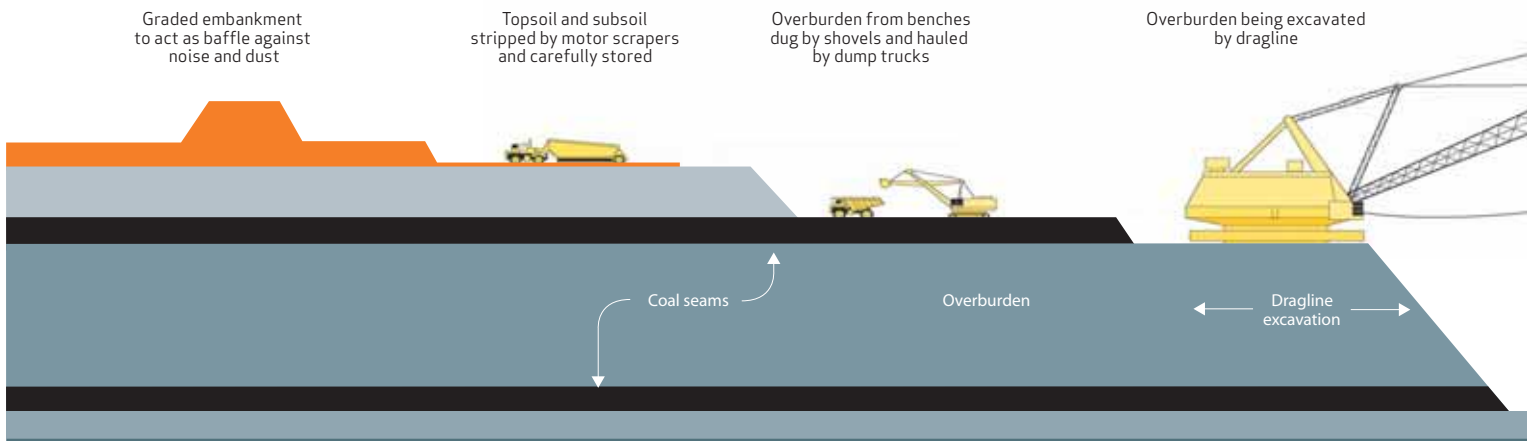


Diagram courtesy of BHP Billiton Illawara Coal

Coal Transportation

The way that coal is transported to where it will be used depends on the distance to be covered. Coal is generally transported by conveyor or truck over short distances. Trains and barges are used for longer distances within domestic markets, or alternatively coal can be mixed with water to form a coal slurry and transported through a pipeline.

Ships are commonly used for international transportation, in sizes ranging from Handymax (40-60,000 DWT), Panamax (about 60-80,000 DWT) to large Capesize vessels (about 80,000+ DWT). Around 700 million tonnes (Mt) of coal was traded internationally in 2003 and around 90% of this was seaborne trade. Coal transportation can be very expensive – in some instances it accounts for up to 70% of the delivered cost of coal.



Surface Coal Mining Operations and Mine Rehabilitation



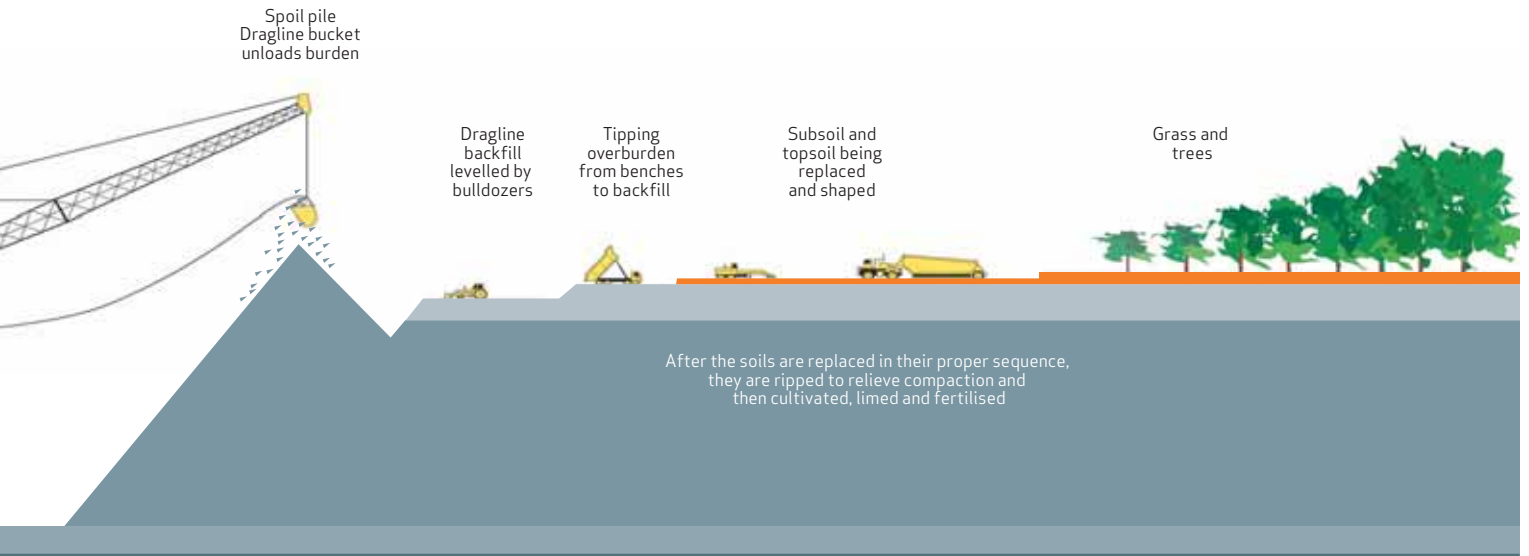
Froth flotation cells at Goedehoop Colliery are used for fine coal beneficiation. Photograph courtesy of Anglo Coal.

Measures are taken at every stage of coal transportation and storage to minimise environmental impacts (see Section 5 for more information on coal and the environment).

Safety at Coal Mines

The coal industry takes the issue of safety very seriously. Coal mining deep underground involves a higher safety risk than coal mined in opencast pits. However, modern coal mines have rigorous safety procedures, health and safety standards and worker education and training, which have led to significant improvements in safety levels in both underground and opencast mining (see graph on page 11 for a comparison of safety levels in US coal mining compared to other industry sectors).

There are still problems within the industry. The majority of coal mine accidents and fatalities occur in China. Most accidents are in small scale town and village mines, often illegally operated, where mining techniques are labour intensive and use very basic equipment. The Chinese government is taking steps to improve safety levels, including the forced



closure of small-scale mines and those that fail to meet safety standards.

Coal Mining & the Wider Community

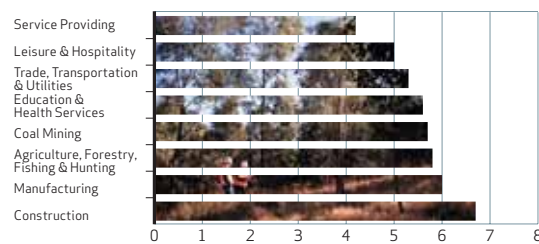
Coal mining generally takes place in rural areas where mining and the associated industries are usually one of, if not, the largest employers in the area. It is estimated that coal employs over 7 million people worldwide, 90% of whom are in developing countries.

Not only does coal mining directly employ millions worldwide, it generates income and employment in other regional industries that are dependent on coal mining. These industries provide goods and services into coal mining, such as fuel, electricity, and equipment, or are dependent on expenditure from employees of coal mines.

Large-scale coal mines provide a significant source of local income in the form of wages, community programmes and inputs into production in the local economy.

Injury Rates in Selected US Industries, 2003
(per 100 full-time employees)

Source: Bureau of Labor Statistics, US Department of Labor



However, mining and energy extraction can sometimes lead to land use conflicts and difficulties in relationships with neighbours and local communities. Many conflicts over land use can be resolved by highlighting that mining is only a temporary land use. Mine rehabilitation means that the land can be used once again for other purposes after mine closure.



Coal is traded internationally, with coal shipped huge distances by sea to reach markets. Photograph courtesy of Ports Corporation of Queensland

SECTION THREE

THE GLOBAL COAL MARKET

» Coal is a global industry, with coal mined commercially in over 50 countries and coal used in over 70. »

Major Coal Importers, 2003 (Mt)

Japan	162
Republic of Korea	72
Chinese Taipei	54
Germany	35
UK	32
Russia	24
India	24
USA	23
Netherlands	22
Spain	22

Source: IEA Coal Information 2004

The world currently consumes over 4050 Mt of coal. Coal is used by a variety of sectors – including power generation, iron and steel production, cement manufacturing and as a liquid fuel. The majority of coal is either utilised in power generation – steam coal or lignite – or iron and steel production – coking coal.

Coal Production

Over 4030 Mt of coal is currently produced – a 38% increase over the past 20 years. Coal production has grown fastest in Asia, while Europe has actually seen a decline in production.

The largest coal producing countries are not confined to one region – the top five producers are China, the USA, India, Australia and South Africa. Much of global coal production is used in the country in which it was produced, only around 18% of hard coal production is destined for the international coal market.

Global coal production is expected to reach 7 billion tonnes in 2030 – with China accounting for around half the increase over this period. Steam coal production is projected to have reached around 5.2 billion tonnes; coking coal 624 million tonnes; and brown coal 1.2 billion tonnes.

Coal Consumption

Coal plays a vital role in power generation and this role is set to continue. Coal currently fuels 39% of the world's electricity and this proportion is expected to remain at similar levels over the next 30 years.

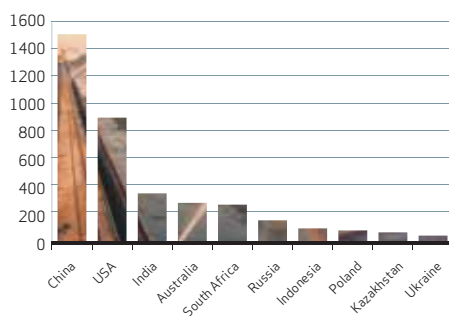
Consumption of steam coal is projected to grow by 1.5% per year over the period 2002-2030. Lignite, also used in power generation, will grow by 1% per year. Demand for coking coal in iron and steel production is set to increase by 0.9% per year over this period.

The biggest market for coal is Asia, which currently accounts for 54% of global coal consumption – although China is responsible for a significant proportion of this. Many countries do not have natural energy resources sufficient to cover their energy needs, and therefore need to import energy to help meet their requirements. Japan, Chinese Taipei and Korea, for example, import significant quantities of steam coal for electricity generation and coking coal for steel production.

It is not just a lack of indigenous coal supplies that prompts countries to import coal but also the importance of obtaining specific types of coal. Major coal producers such as China, the

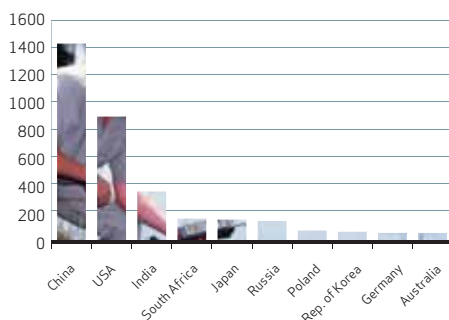
Top Ten Coal Producing Countries Worldwide, 2003 (Mt)

Source: IEA 2004



Top Ten Coal Consumers Worldwide, 2003 (Mt)

Source: IEA 2004



Definition

OECD is the Organisation for Economic Cooperation and Development. It is a group of 30 member countries who are committed to democratic government and the market economy.

USA and India, for example, also import quantities of coal for quality and logistical reasons.

Coal will continue to play a key role in the world's energy mix, with demand in certain regions set to grow rapidly. Growth in both the steam and coking coal markets will be strongest in developing Asian countries, where demand for electricity and the need for steel in construction, car production, and demands for household appliances will increase as incomes rise.

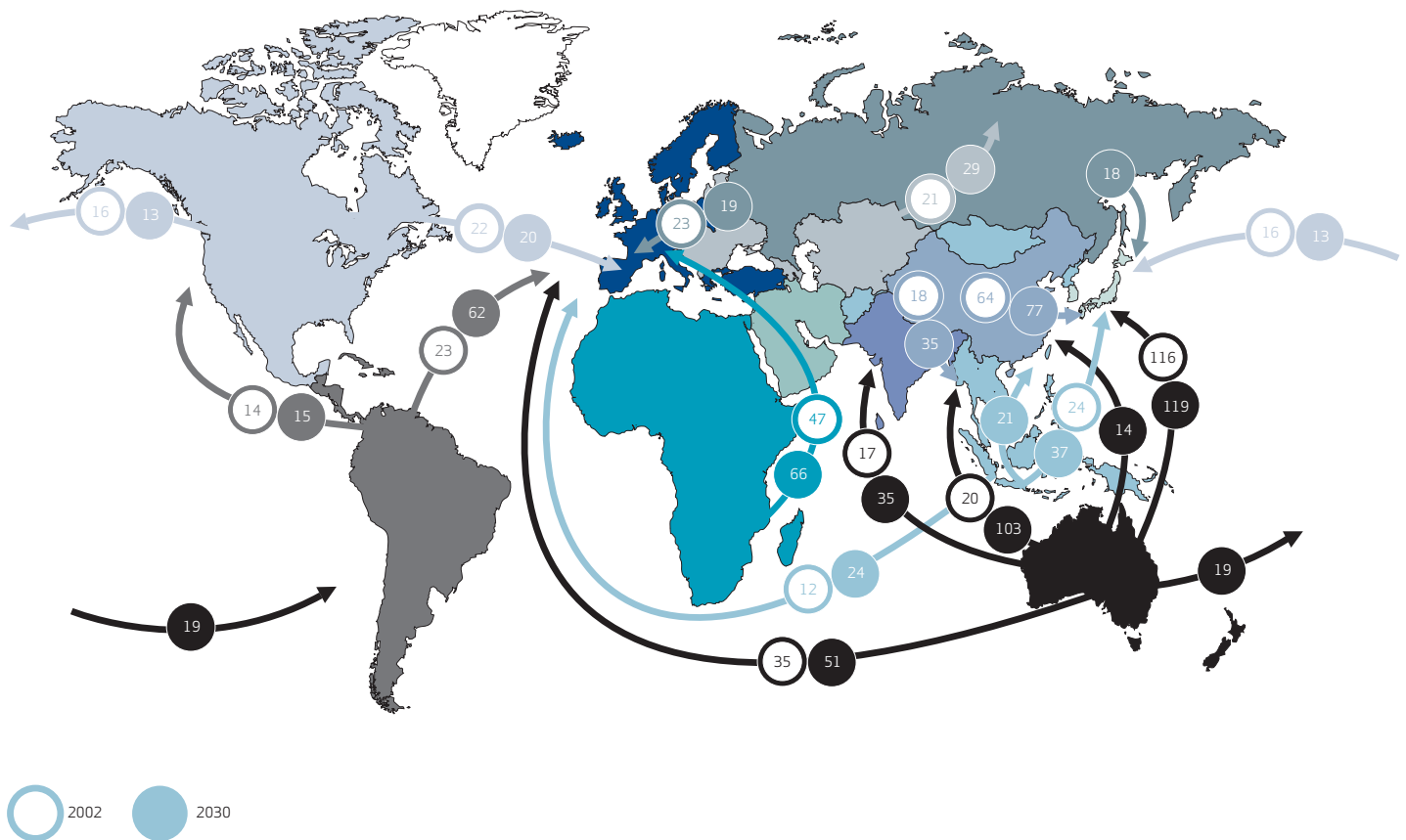
Coal Trade

Coal is traded all over the world, with coal shipped huge distances by sea to reach markets.

Over the last twenty years, seaborne trade in steam coal has increased on average by about 8% each year, while seaborne coking coal trade has increased by 2% a year. Overall international trade in coal reached 718 Mt in 2003; while this is a significant amount of coal it still only accounts for about 18% of total coal consumed.

Transportation costs account for a large share of the total delivered price of coal, therefore international trade in steam coal is effectively divided into two regional markets – the Atlantic and the Pacific. The Atlantic market is made up of importing countries in Western Europe, notably the UK, Germany and Spain. The Pacific market consists of developing and OECD Asian importers, notably Japan, Korea and Chinese Taipei. The Pacific market currently accounts for about 60% of world steam coal trade. Markets tend to overlap when coal prices are high and supplies plentiful. South Africa is a natural point of convergence between the two markets.

Major Inter-Regional Coal Trade Flows, 2002-2030 (Mt)

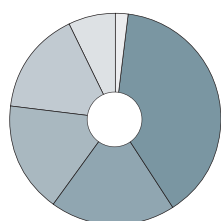


Source: IEA 2004

Australia is the world's largest coal exporter; exporting over 207 Mt of hard coal in 2003, out of its total production of 274 Mt. Coal is one of Australia's most valuable export commodities. Although almost three-quarters of Australia's exports go to the Asian market, Australian coals are used all over the world, including Europe, the Americas and Africa.

International coking coal trade is limited. Australia is also the largest supplier of coking coal, accounting for 51% of world exports. The USA and Canada are significant exporters and China is emerging as an important supplier. Coking coal is more expensive than steam coal, which means that Australia is able to afford the high freight rates involved in exporting coking coal worldwide.

Total World Electricity Generation (% by Fuel, 2002)

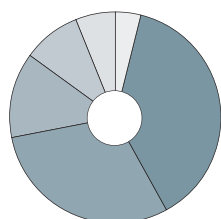


Coal	39%
Gas	19%
Nuclear	17%
Hydro	16%
Oil	7%
Other*	2%

* Other includes solar, wind, combustible renewables, geothermal and waste

Source: IEA 2004

Total World Electricity Generation (% by Fuel, projected for 2030)



Coal	38%
Gas	30%
Hydro	13%
Nuclear	9%
Other*	6%
Oil	4%

* Other includes solar, wind, combustible renewables, geothermal and waste

Source: IEA 2004

Energy Security

Minimising the risk of disruptions to our energy supplies is ever more important – whether they are caused by accident, political intervention, terrorism or industrial disputes. Coal has an important role to play at a time when we are increasingly concerned with issues relating to energy security.

The global coal market is large and diverse, with many different producers and consumers from every continent. Coal supplies do not come from one specific area, which would make consumers dependent on the security of supplies and stability of only one region. They are spread out worldwide and coal is traded internationally.

Many countries rely on domestic supplies of coal for their energy needs – such as China, the USA, India, Australia and South Africa. Others import coal from a variety of countries: in 2003 the UK, for example, imported coal from Australia, Colombia, Poland, Russia, South Africa, and the USA, as well as smaller amounts from a number of other countries and its own domestic supplies.

Coal therefore has an important role to play in maintaining the security of the global energy mix.

- >> Coal reserves are very large and will be available for the foreseeable future without raising geopolitical or safety issues.
- >> Coal is readily available from a wide variety of sources in a well-supplied worldwide market.
- >> Coal can be easily stored at power stations and stocks can be drawn on in emergencies.

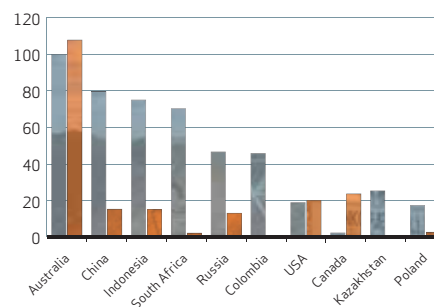
- >> Coal-based power is not dependent on the weather and can be used as a backup for wind and hydropower.
- >> Coal does not need high pressure pipelines or dedicated supply routes.
- >> Coal supply routes do not need to be protected at enormous expense.

These features help to facilitate efficient and competitive energy markets and help to stabilise energy prices through inter-fuel competition.

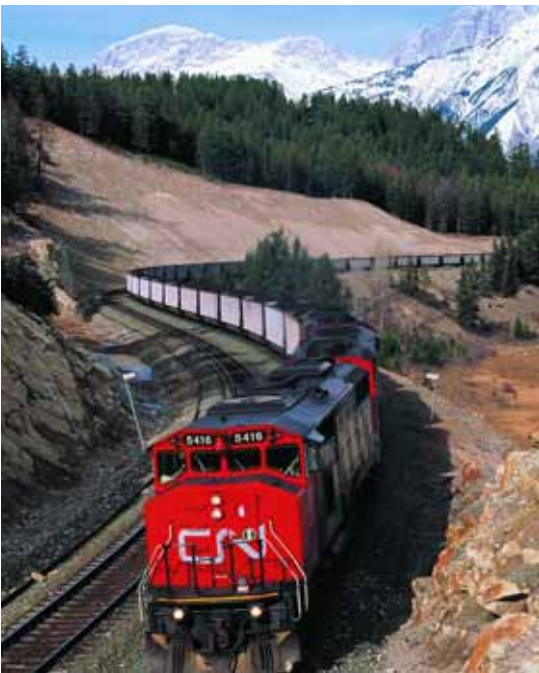
Major Coal Exporters, 2003 (Mt)

■ Steam
■ Coking

Source: IEA 2004



SECTION THREE END



Minimising the risk of disruption to our energy supplies is ever more important. Coal supply routes do not need to be protected at enormous expense.

Photograph courtesy of CN.



Coal currently supplies 39% of the world's electricity. The availability of low cost supplies of coal has been vital to achieving high rates of electrification worldwide. Photograph courtesy of Vattenfall.

SECTION FOUR

HOW IS COAL USED?

» Coal has many important uses worldwide. The most significant uses are in electricity generation, steel production, cement manufacturing and other industrial processes, and as a liquid fuel. »

Definition

Primary Energy is all energy consumed by end-users. This includes the energy used to generate electricity, but does not include the electricity itself.

History of Coal Use

Coal has a very long and varied history. Some historians believe that coal was first used commercially in China. There are reports that a mine in northeastern China provided coal for smelting copper and for casting coins around 1000 BC. One of the earliest known references to coal was made by the Greek philosopher and scientist Aristotle, who referred to a charcoal like rock. Coal cinders found among Roman ruins in England indicate that the Romans used energy from coal before AD 400. Chronicles from the Middle Ages provide the first evidence of coal mining in Europe and even of an international trade as sea coal from exposed coal seams on the English coast was gathered and exported to Belgium.

It was during the Industrial Revolution in the 18th and 19th centuries that demand for coal surged. The great improvement of the steam engine by James Watt, patented in 1769, was largely responsible for the growth in coal use. The history of coal mining and use is inextricably linked with that of the Industrial Revolution – iron and steel production, rail transportation and steamships.

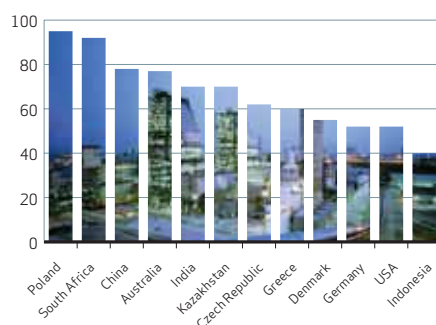
Coal was also used to produce gas for gas lights in many cities, which was called ‘town gas’. This process of coal gasification saw the growth in gas lights across metropolitan areas at the beginning of the 19th century, particularly in London. The use of coal gas in street lighting was eventually replaced with the emergence of the modern electric era.

With the development of electric power in the 19th century, coal’s future became closely tied to electricity generation. The first practical coal-fired electric generating station, developed by Thomas Edison, went into operation in New York City in 1882, supplying electricity for household lights.

Oil finally overtook coal as the largest source of primary energy in the 1960s, with the huge growth in the transportation sector. Coal still plays a vital role in the world’s primary energy mix, providing 23.5% of global primary energy needs in 2002, 39% of the world’s electricity, more than double the next largest source, and an essential input into 64% of the world’s steel production.

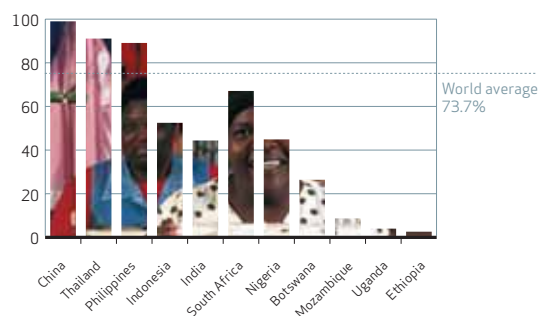
Percentage of Electricity Generated from Coal in Selected Countries (mixture of 2003 & 2002 data)

Source: IEA 2004



Electrification Rates for Selected Developing World Countries, 2002 (%)

Source: IEA 2004



How is Coal Converted into Electricity?

Modern life is unimaginable without electricity. It lights houses, buildings, streets, provides domestic and industrial heat, and powers most equipment used in homes, offices and machinery in factories. Improving access to electricity worldwide is a key factor in alleviating poverty. It is staggering to think that 1.6 billion people worldwide, or 27% of the world's population, do not have access to electricity.

Steam coal, also known as thermal coal, is used in power stations to generate electricity. The earliest conventional coal-fired power stations used lump coal which was burnt on a grate in boilers to raise steam. Nowadays, the coal is first milled to a fine powder, which increases the surface area and allows it to burn more quickly. In these pulverised coal combustion (PCC) systems, the powdered coal is blown into the combustion chamber of a boiler where it is burnt at high temperature. The hot gases and heat energy produced converts water – in tubes lining the boiler – into steam.

The high pressure steam is passed into a turbine containing thousands of propeller-like blades. The steam pushes these blades causing the turbine shaft to rotate at high speed. A generator is mounted at one end of the turbine shaft and consists of carefully wound wire coils. Electricity is generated when these are rapidly rotated in a strong magnetic field. After passing through the turbine, the steam is condensed and returned to the boiler to be heated once again (see diagram on page 21).

The electricity generated is transformed into the higher voltages – up to 400,000 volts –

used for economic, efficient transmission via power line grids. When it nears the point of consumption, such as our homes, the electricity is transformed down to the safer 100-250 voltage systems used in the domestic market.

Modern PCC technology is well-developed and accounts for over 90% of coal-fired capacity worldwide. Improvements continue to be made in conventional PCC power station design and new combustion techniques are being developed. These developments allow more electricity to be produced from less coal – this is known as improving the thermal efficiency of the power station. More details on these technologies and how they enhance the environmental performance of coal-fired power stations can be found in Section 5.

Importance of Electricity Worldwide

Access to energy, and specifically electricity, is a driving force behind economic and social development. Dependable and affordable access to electricity is essential for improving public health, providing modern information and education services, and saving people from subsistence tasks, such as gathering fuel. Around 2.4 billion people rely on primitive biomass fuels – such as wood, dung and crop residues – for cooking and heating. Improving access to electricity and allowing people to move away from the combustion of fuels in household fires would have a significant health impact. The World Health Organisation has estimated that smoke from burning solid fuels indoors is responsible for 1.6 million deaths each year in the world's poorest countries.

Improving access to energy also supports economic development:

Top Five Coking Coal Producers (Mt)

China	159
Australia	112
Russia	55
USA	40
Canada	23

Source: IEA 2004

World Crude Steel Production (Mt)

1970	595
1975	644
1980	717
1985	719
1990	770
1995	752
1996	750
1997	799
1998	777
1999	789
2000	848
2001	850
2002	902
2003	965

Source: IISI

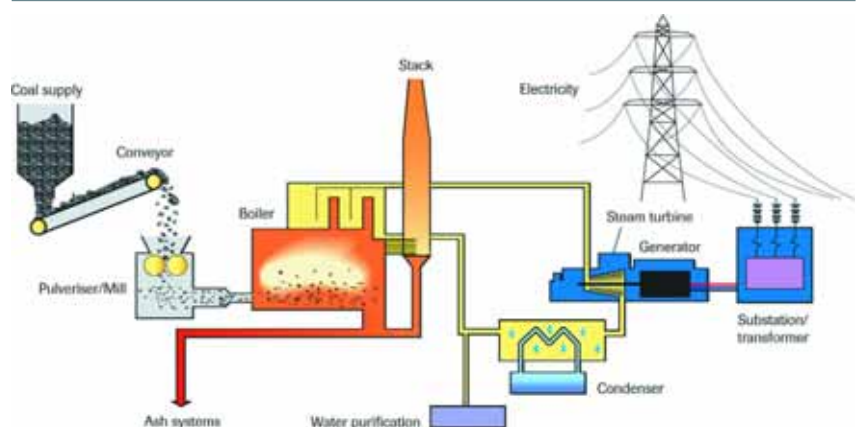
>> Labour that would otherwise be spent collecting fuel is freed for more productive use, such as in agricultural and manufacturing industries. This increases household income, labour supply and the productive capacity of developing economies.

>> The intensive collection of biomass for fuel for household consumption in many cases degrades the productivity of agricultural land – through desertification (by removing trees) or through depriving soil of nutrients (by collecting animal waste).

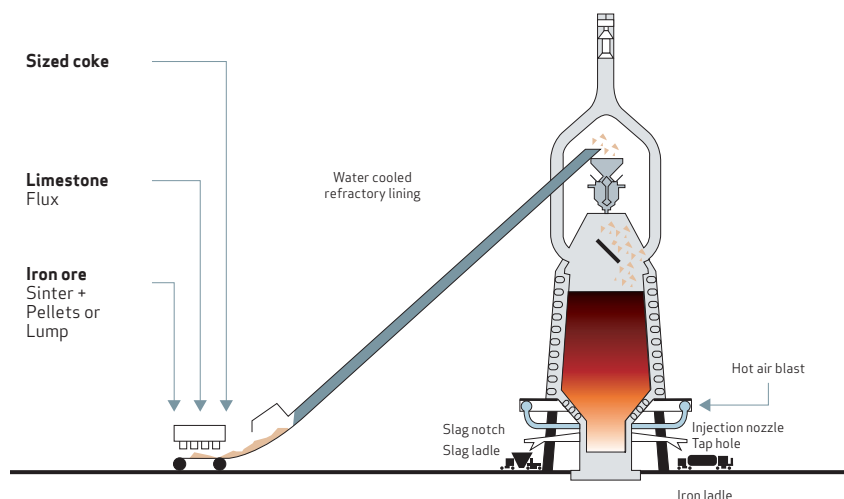
>> Inefficient combustion of unconventional fuels, especially in households without flues, creates health complications. Moving households towards modern energy sources, such as electricity, improves health and productivity.

>> The provision of household electricity provides for the use of modern appliances – such as washing machines – and lighting which improves the productivity of home labour and frees time.

Converting Coal to Electricity



Coal Use in Steel Production



Coal currently supplies 39% of the world's electricity. In many countries this role is much higher. The availability of low-cost supplies of coal in both developed and developing countries has been vital to achieving high rates of electrification. In China, for example, 700 million people have been connected to the electricity system over the past 15 years. The country is now 99% electrified, with around 77% of the electricity produced in coal-fired power stations.

Coal in Iron & Steel Production

Steel is essential to everyday life – cars, trains, buildings, ships, bridges, refrigerators, medical equipment, for example, are all made with steel. It is vital for the machines which make nearly every product we use today.

Coal is essential for iron and steel production; some 64% of steel production worldwide comes from iron made in blast furnaces which use coal. World crude steel production was 965 million tonnes in 2003, using around 543 Mt of coal.

Raw Materials

A blast furnace uses iron ore, coke (made from specialist coking coals) and small quantities of limestone. Some furnaces use cheaper steam coal – known as pulverised coal injection (PCI) – in order to save costs.

Iron ore is a mineral containing iron oxides. Commercial ores usually have an iron content of at least 58%. Iron ore is mined in around 50 countries – the seven largest producers account for about 75% of world production. Around 98% of iron ore is used in steel making.

Coke is made from coking coals, which have certain physical properties that cause them to soften, liquefy and then resolidify into hard but porous lumps when heated in the absence of air. Coking coals must also have low sulphur and phosphorous contents and, being relatively scarce, are more expensive than the steam coals used in electricity generation.

The coking coal is crushed and washed. It is then 'purified' or 'carbonised' in a series of coke ovens, known as batteries. During this process, by-products are removed and coke is produced.

Blast Furnace

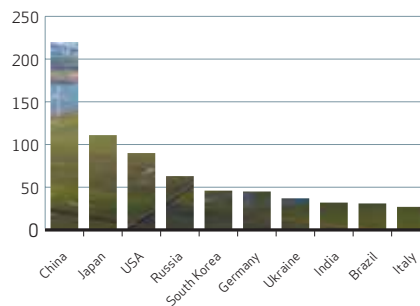
The raw materials – iron ore, coke and fluxes (minerals such as limestone which are used to collect impurities) – are fed into the top of the blast furnace. Air is heated to about 1200°C and is blown into the furnace through nozzles in the lower section. The air causes the coke to burn producing carbon monoxide, which creates the chemical reaction. The iron ore is reduced to molten iron by removing the oxygen. A tap at the bottom of the furnace is periodically opened and molten iron and slag is drained.

It is taken to a basic oxygen furnace (BOF) where steel scrap and more limestone are added and 99% pure oxygen is blown onto the mixture. The reaction with the oxygen raises the temperature up to 1700°C, oxidises the impurities, and leaves almost pure liquid steel. Around 0.63 tonnes (630 kg) of coke produces 1 tonne (1000 kg) of steel.

Basic oxygen furnaces currently produce about 64% of the world's steel. A further 33% of steel is produced in electric arc furnaces (EAF). EAFs are used to produce new steel from scrap metal. If scrap steel is readily available, this method is lower cost than the traditional blast furnace. The electric arc furnace is charged with scrap steel and iron. Electrodes are placed in the furnace and when power is applied they produce an arc of electricity. The energy from the arc raises the temperature to 1600°C, melting the scrap

Top Ten Steel Producing Countries, 2003 (Mt)

Source: IISI



and producing molten steel. Much of the electricity used in EAF is produced from coal.

Developments in the steel industry have enabled 'pulverised coal injection' technology to be used. This allows coal to be injected directly into the blast furnace. A wide variety of coals can be used in PCI, including steam coal.

Steel is 100% recyclable, with some 383 Mt of recycled steel used in 2003 and around 400 Mt used in 2004. The BOF process uses up to 30% recycled steel and around 90-100% is used in EAF production. By-products from iron and steel making can also be recycled - slag, for example, can be solidified, crushed, and used in soil mix, road surfaces and cement.

Coal Liquefaction

In a number of countries coal is converted into a liquid fuel – a process known as liquefaction. The liquid fuel can be refined to produce transport fuels and other oil products, such as plastics and solvents. There are two key methods of liquefaction:

- >> direct coal liquefaction – where coal is converted to liquid fuel in a single process;
- >> indirect coal liquefaction – where coal is first gasified and then converted to liquid.

In this way, coal can act as a substitute for crude oil, a valuable role in a world ever more concerned with energy security. The cost effectiveness of coal liquefaction depends to a large extent on the world oil price with which, in an open market economy, it has to compete. If the oil price is high, coal liquefaction becomes more competitive.

There have been instances in the past where the isolation of a country from reliable, secure sources of crude oil has forced the large-scale production of liquid fuels from coal. Germany produced substantial amounts of coal-derived fuels during the Second World War, as did embargoed South Africa between the mid-1950s and 1980s. South Africa continues large-scale production of liquid fuels to the present day.

The only commercial-scale coal liquefaction process currently in operation worldwide is the indirect Sasol (Fischer-Tropsch) process. South Africa leads the world in coal liquefaction technologies – it has seen the most research and development (R&D) in indirect coal liquefaction and currently supplies about a third of its domestic liquid fuel requirements from coal. China is also

experiencing growth in coal liquefaction as a way of utilising the country's enormous reserves of coal and lessening dependence on imported oil.

Coal and Cement

Cement is critical to the construction industry – mixed with water, and gravel it forms concrete, the basic building element in modern society. More than 1350 million tonnes of cement are used globally every year.

Cement is made from a mixture of calcium carbonate (generally in the form of limestone), silica, iron oxide and alumina. A high-temperature kiln, often fuelled by coal, heats the raw materials to a partial melt at 1450°C, transforming them chemically and physically into a substance known as clinker. This grey pebble-like material is comprised of special compounds that give cement its binding properties. Clinker is mixed with gypsum and ground to a fine powder to make cement.

Coal is used as an energy source in cement production. Large amounts of energy are required to produce cement. Kilns usually burn coal in the form of powder and consume around 450g of coal for about 900g of cement produced. Coal is likely to remain an important input for the global cement industry for many years to come.

Coal combustion products (CCPs) can also play an important role in concrete production. CCPs are the by-products generated from burning coal in coal-fired power plants. These by-products include fly ash, bottom ash, boiler slag and flue gas desulphurisation gypsum. Fly ash, for example, can be used to replace or supplement cement in concrete. Recycling coal combustion products in this way is beneficial

to the environment, acting as a replacement for primary raw materials.

Other Uses of Coal

Other important users of coal include alumina refineries, paper manufacturers, and the chemical and pharmaceutical industries. Several chemical products can be produced from the by-products of coal. Refined coal tar is used in the manufacture of chemicals, such as creosote oil, naphthalene, phenol, and benzene. Ammonia gas recovered from coke ovens is used to manufacture ammonia salts, nitric acid and agricultural fertilisers. Thousands of different products have coal or coal by-products as components: soap, aspirins, solvents, dyes, plastics and fibres, such as rayon and nylon.

Coal is also an essential ingredient in the production of specialist products:

- >> Activated carbon - used in filters for water and air purification and in kidney dialysis machines.
- >> Carbon fibre – an extremely strong but light weight reinforcement material used in construction, mountain bikes and tennis rackets.
- >> Silicon metal – used to produce silicones and silanes, which are in turn used to make lubricants, water repellents, resins, cosmetics, hair shampoos and toothpastes.



Technologies continue to be developed to improve the environmental performance of coal fired power stations – the Nordjyllandsværket coal fired power station in Denmark has an efficiency level of 47%. Photograph courtesy of Elsam. Photographer Gert Jensen.



The Ulan coal mine in Australia includes the innovative Bobadeen Irrigation Scheme, which uses surplus mine water to irrigate 242 hectares of land specially planted with perennial pastures and is maintained at an optimal level by beef cattle. Photo courtesy of Xstrata Coal

SECTION FIVE

COAL AND THE ENVIRONMENT

>> Our consumption of energy can have a significant impact on the environment. Minimising the negative impacts of human activities on the natural environment – including energy use – is a key global priority. >>

However, it is important to balance concerns for the environment alongside the priorities of economic and social development. ‘Sustainable development’ encapsulates all three areas and has been defined as: “...development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

While coal makes an important contribution to economic and social development worldwide, its environmental impact has been a challenge.

Coal Mining & the Environment

Coal mining – particularly surface mining – requires large areas of land to be temporarily disturbed. This raises a number of environmental challenges, including soil erosion, dust, noise and water pollution, and impacts on local biodiversity. Steps are taken in modern mining operations to minimise these impacts. Good planning and environmental management minimises the impact of mining on the environment and helps to preserve biodiversity.

Land Disturbance

In best practice, studies of the immediate environment are carried out several years

before a coal mine opens in order to define the existing conditions and to identify sensitivities and potential problems. The studies look at the impact of mining on surface and ground water, soils, local land use, and native vegetation and wildlife populations (see koala case study on page 30). Computer simulations can be undertaken to model impacts on the local environment. The findings are then reviewed as part of the process leading to the award of a mining permit by the relevant government authorities.

Mine Subsidence

A problem that can be associated with underground coal mining is subsidence, whereby the ground level lowers as a result of coal having been mined beneath. Any land use activity that could place public or private property or valuable landscapes at risk is clearly a concern.

A thorough understanding of subsidence patterns in a particular region allows the effects of underground mining on the surface to be quantified. This ensures the safe, maximum recovery of a coal resource, while providing protection to other land uses.



The Moura mine was the first operation in Australia to establish a commercial coal mine methane business alongside its coal mining operations. The project has the potential to make overall GHG emissions savings equivalent to 2.8 million tonnes of CO₂ per annum. Photograph courtesy of Anglo Coal Australia.

Water Pollution

Acid mine drainage (AMD) is metal-rich water formed from the chemical reaction between water and rocks containing sulphur-bearing minerals. The runoff formed is usually acidic and frequently comes from areas where ore- or coal mining activities have exposed rocks containing pyrite, a sulphur-bearing mineral. However, metal-rich drainage can also occur in mineralised areas that have not been mined.

AMD is formed when the pyrite reacts with air and water to form sulphuric acid and dissolved iron. This acid run-off dissolves heavy metals such as copper, lead and mercury into ground and surface water.

There are mine management methods that can minimise the problem of AMD, and effective mine design can keep water away from acid-generating materials and help prevent AMD occurring. AMD can be treated actively or passively. Active treatment involves installing a water treatment plant, where the AMD is first dosed with lime to neutralise the acid and then passed through settling tanks to remove the sediment and particulate metals. Passive treatment aims to develop a self-operating

system that can treat the effluent without constant human intervention.

Dust & Noise Pollution

During mining operations, the impact of air and noise pollution on workers and local communities can be minimised by modern mine planning techniques and specialised equipment. Dust at mining operations can be caused by trucks being driven on unsealed roads, coal crushing operations, drilling operations and wind blowing over areas disturbed by mining.

Dust levels can be controlled by spraying water on roads, stockpiles and conveyors. Other steps can also be taken, including fitting drills with dust collection systems and purchasing additional land surrounding the mine to act as a buffer zone between the mine and its neighbours. Trees planted in these buffer zones can also minimise the visual impact of mining operations on local communities. Noise can be controlled through the careful selection of equipment and insulation and sound enclosures around machinery. In best practice, each site has noise and vibration monitoring equipment installed, so that noise levels can be measured to ensure the mine is within specified limits.

Rehabilitation

Coal mining is only a temporary use of land, so it is vital that rehabilitation of land takes place once mining operations have ceased. In best practice a detailed rehabilitation or reclamation plan is designed and approved for each coal mine, covering the period from the start of operations until well after mining has finished. Land reclamation is an integral part of modern mining operations around the world and the cost of rehabilitating the land once mining has ceased is factored into the mine's operating costs.

Mine reclamation activities are undertaken gradually – with the shaping and contouring of spoil piles, replacement of topsoil, seeding with grasses and planting of trees taking place on the mined-out areas. Care is taken to relocate streams, wildlife, and other valuable resources.

Reclaimed land can have many uses, including agriculture, forestry, wildlife habitation and recreation.

Using Methane from Coal Mines

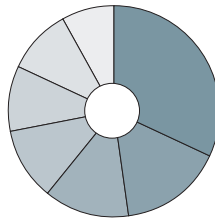
Methane (CH₄) is a gas formed as part of the process of coal formation. It is released from the coal seam and the surrounding disturbed strata during mining operations.

Methane is a potent greenhouse gas – it is estimated to account for 18% of the overall global warming effect arising from human activities (CO₂ is estimated to contribute 50%). While coal is not the only source of methane emissions – production of rice in wet paddy fields and other agricultural activities are major emitters – methane from coal seams can be utilised rather than released to the atmosphere with a significant environmental benefit.

Coal mine methane (CMM) is methane released from coal seams during coal mining. Coalbed methane (CBM) is methane trapped within coal seams that have not, or will not, be mined.

Methane is highly explosive and has to be drained during mining operations to keep working conditions safe. At active underground mines, large-scale ventilation systems move massive quantities of air through the mine, keeping the mine safe but also releasing methane into the atmosphere at very low concentrations. Some active and

Major Sources of Methane Emissions



■ Livestock	32%
■ Oil and Natural Gas	16%
■ Solid Waste	13%
■ Rice	11%
■ Waste Water	10%
■ Other	10%
■ Coal	8%

Source: US EPA

abandoned mines produce methane from degasification systems, also known as gas drainage systems, which use wells to recover methane.

As well as improving safety at coal mines, the use of CMM improves the environmental performance of a coal mining operation and can have a commercial benefit. Coal mine methane has a variety of uses, including on-site or off-site electricity production, use in industrial processes and fuel for cofiring boilers.

Coalbed methane can be extracted by drilling into and mechanically fracturing unworked coal seams. While the CBM is utilised, the coal itself remains unmined.

Coal Use & the Environment

Global consumption of energy raises a number of environmental concerns. For coal, the release of pollutants, such as oxides of sulphur and nitrogen (SO_x and NO_x), and particulate and trace elements, such as mercury, have been a challenge. Technologies have been developed and deployed to minimise these emissions.



ENVIRONMENTAL MANAGEMENT

KOALA VENTURE

Environmental management and rehabilitation at coal mines does not simply mean protecting the natural vegetation – it also includes protecting the wildlife at the mine. At the Blair Athol opencast coal mine in Queensland, Australia, this means taking care of the native koala population.

The Koala Venture project between Rio Tinto Coal Australia – operators of the mine – and the University of Queensland began when the mine management approached the university for help on how to minimise the impact of its mining operations on the colony of koalas on the land.

The project aims to manage the koala population, their safety and security

on the Blair Athol mine lease and adjacent areas. The koalas feeding and roosting habits are monitored to improve rehabilitation practices, while their health and reproductive status are studied to ensure that the population of koala is maintained.

In order to advance operations at the opencast mine, vegetation that includes koala habitat must be cleared. A two-stage tree clearing procedure is used to minimise disruption to the koalas. This process involves leaving some of the trees used by koalas for several months, while removing the remainder. Research has shown that the koalas will then voluntarily tend to move into the rehabilitated areas featuring their preferred trees or into adjacent undisturbed areas.

The Koala Venture is the first ever study undertaken of the breeding ecology of free-ranging koalas using DNA testing and has made some important breakthroughs in the understanding of how koalas breed.

Information gathered at the Blair Athol mine has been incorporated into the National Strategy for the Conservation of the Koala in Australia.

More information on the Koala Venture can be found at www.koalaventure.com

A more recent challenge has been that of carbon dioxide emissions (CO₂). The release of CO₂ into the atmosphere from human activities – often referred to as anthropogenic emissions – has been linked to global warming. The combustion of fossil fuels is a major source of anthropogenic emissions worldwide. While the use of oil in the transportation sector is the major source of energy-related CO₂ emissions, coal is also a significant source. As a result, the industry has been researching and developing technological options to meet this new environmental challenge.

Technological Response

Clean coal technologies (CCTs) are a range of technological options which improve the environmental performance of coal. These technologies reduce emissions, reduce waste, and increase the amount of energy gained from each tonne of coal.

Different technologies suit different types of coal and tackle different environmental problems. The choice of technologies can also depend on a country's level of economic development. More expensive, highly advanced technologies may not be suitable in developing countries, for example, where cheaper readily-available options can have a larger and more affordable environmental benefit.

Reducing Particulate Emissions

Emissions of particulates, such as ash, have been one of the more visible side-effects of coal combustion in the past. They can impact local visibility, cause dust problems and affect people's respiratory systems. Technologies are available to reduce and, in some cases, almost eliminate particulate emissions.

Coal Cleaning

Coal cleaning, also known as coal beneficiation or coal preparation, increases the heating value and the quality of the coal by lowering levels of sulphur and mineral matter (see Section 2 for a description of coal preparation techniques). The ash content of coal can be reduced by over 50%, helping to cut waste from coal combustion. This is particularly important in countries where coal is transported long distances prior to use, since it improves the economics of transportation by removing most of the non-combustible material. Coal cleaning can also improve the efficiency of coal-fired power stations, which leads to a reduction in emissions of carbon dioxide.

Electrostatic Precipitators & Fabric Filters

Particulates from coal combustion can be controlled by electrostatic precipitators (ESP) and fabric filters. Both can remove over 99.5% of particulate emissions and are widely applied in both developed and developing countries. In electrostatic precipitators, particulate-laden flue gases pass between collecting plates, where an electrical field creates a charge on the particles. This attracts the particles towards the collecting plates, where they accumulate and can be disposed of.

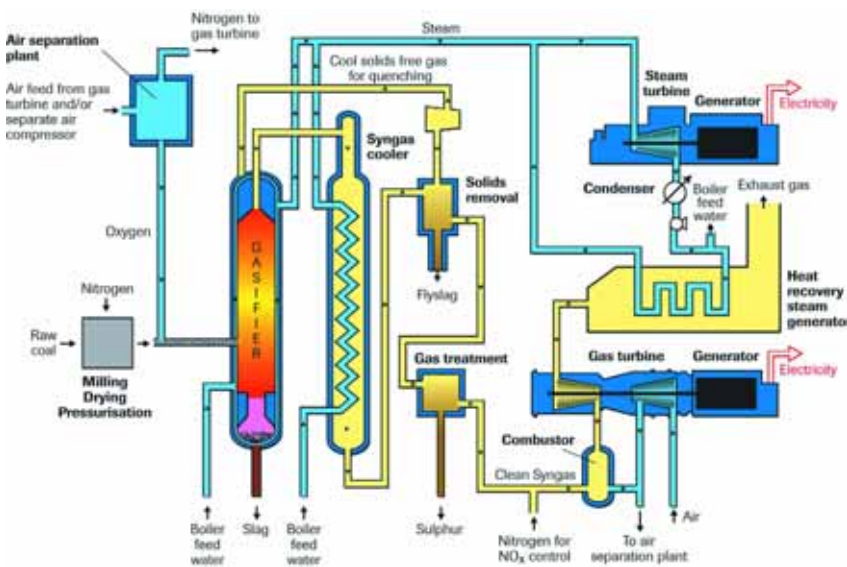
Fabric filters, also known as 'baghouses', are an alternative approach and collect particles from the flue gas on a tightly woven fabric primarily by sieving.

The use of particulate control equipment has a major impact on the environmental performance of coal-fired power stations. At the Lethabo power station in South Africa,

Definition

Carbon dioxide is a colourless, odourless, incombustible gas formed during decomposition, combustion and respiration.

An Integrated Gasification Combined Cycle Unit



electrostatic precipitators remove 99.8% of fly ash, some of which is sold to the cement industry. For Eskom, the plant operator, the use of ESPs has had a major impact on the environmental performance of its power stations. Between 1988 and 2003, it reduced particulate emissions by almost 85% while power generated increased by over 56%.

Preventing Acid Rain

Acid rain came to global attention during the latter part of the last century, when acidification of lakes and tree damage in parts of Europe and North America was discovered.

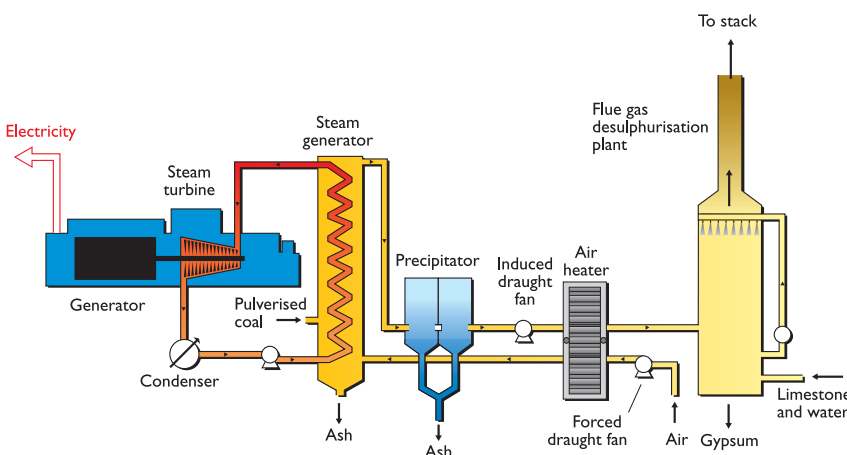
Acid rain was attributed to a number of factors, including acid drainage from deforested areas and emissions from fossil fuel combustion in transportation and power stations.

Oxides of sulphur (SO_x) and nitrogen (NO_x) are emitted to varying degrees during the combustion of fossil fuels. These gases react chemically with water vapour and other substances in the atmosphere to form acids, which are then deposited in rainfall.

Steps have been taken to significantly reduce SO_x and NO_x emissions from coal-fired power stations. Certain approaches also have the additional benefit of reducing other emissions, such as mercury.

Sulphur is present in coal as an impurity and reacts with air when coal is burned to form SO_x. In contrast, NO_x is formed when any fossil fuel is burned. In many circumstances, the use of low sulphur coal is the most economical way to control sulphur dioxide. An alternative approach has been the development of flue gas desulphurisation (FGD) systems for use in coal-fired power stations.

A Flue Gas Desulphurisation System



FGD systems are sometimes referred to as 'scrubbers' and can remove as much as 99% of SO_x emissions. In the USA, for example, sulphur emissions from coal-fired power plants decreased by 61% between 1980 and 2000 – even though coal use by utilities increased by 74%.

Oxides of nitrogen can contribute to the development of smog as well as acid rain. NO_x emissions from coal combustion can be reduced by the use of 'low NO_x' burners, improving burner design and applying technologies that treat NO_x in the exhaust gas stream. Selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) technologies can reduce NO_x emissions by around 80-90% by treating the NO_x post-combustion.

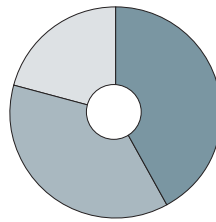
Fluidised bed combustion (FBC) is a high efficiency, advanced technological approach to reducing both NO_x and SO_x emissions. FBC is able to achieve reductions of 90% or more. In FBC systems, coal is burned in a bed of heated particles suspended in flowing air. At high air velocities, the bed acts as a fluid resulting in the rapid mixing of the particles. This fluidising action allows complete coal combustion at relatively low temperatures.

Reducing Carbon Dioxide Emissions

A major environmental challenge facing the world today is the risk of 'global warming'.

Naturally occurring gases in the atmosphere help to regulate the earth's temperature by trapping other radiation - this is known as the greenhouse effect (see diagram on page 36). Human activities, such as the combustion of fossil fuels, produce additional greenhouse gases (GHG) which accumulate in the atmosphere. Scientists believe that the build-

CO₂ Emissions from Fossil Fuels



Oil	41%
Coal	38%
Gas	21%

Source: IEA 2004

up of these gases is causing an enhanced greenhouse effect, which could cause global warming and climate change.

The major greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

Coal is one of many sources of greenhouse gas emissions generated by human activities and the industry is committed to minimising its emissions.

Greenhouse gases associated with coal include methane, carbon dioxide (CO₂) and nitrous oxide (N₂O). Methane is released from deep coal mining (see earlier section). CO₂ and N₂O are released when coal is used in electricity generation or industrial processes, such as steel production and cement manufacture.

Combustion Efficiency

An important step in reducing CO₂ emissions from coal combustion has been improvements in the thermal efficiencies of coal-fired power stations. Thermal efficiency is a measure of the overall fuel conversion efficiency for the electricity generation process. The higher the efficiency levels, the greater the energy being produced from the fuel.

The global average thermal efficiency of coal-fired power stations is around 30%, with the OECD average at around 38%. In comparison, China has an average thermal efficiency of all its installed coal-fired capacity of some 27% (though newer stations with significantly improved efficiencies are increasingly being installed).

New 'supercritical' technology allows coal-fired power plants to achieve overall thermal efficiencies of 43-45%. These higher levels are possible because supercritical plants operate at higher steam temperatures and pressures than conventional plants. Ultrasupercritical power plants can achieve efficiency levels of up to 50% by operating at even higher temperatures and pressures. More than 400 supercritical plants are operating worldwide, including a number in developing countries.

An alternative approach is to produce a gas from coal – this is achieved in integrated gasification combined cycle (IGCC) systems. In IGCC, coal is not combusted directly but reacted with oxygen and steam to produce a 'syngas' composed mainly of hydrogen and

carbon monoxide. This syngas is cleaned of impurities and then burnt in a gas turbine to generate electricity and to produce steam for a steam power cycle.

IGCC systems operate at high efficiencies, typically in the mid-40s but plant designs offering close to 50% efficiencies are available. They also remove 95-99% of NO_x and SO_x emissions. Work is being undertaken to make further gains in efficiency levels, with the prospect of net efficiencies of 56% in the future. There are around 160 IGCC plants worldwide.

IGCC systems also offer future potential for hydrogen production linked with carbon capture and storage technologies (described in more detail in the next section).

Carbon Capture & Storage

An important factor in the future use of coal will be the level to which CO₂ emissions can be reduced. Much has been done to achieve this, such as the improvements in efficiency levels. One of the most promising options for the future is carbon capture and storage (CCS).

The Coal-fired Route to CO₂ Reductions

Up to 5% CO₂ Reductions

Coal Upgrading

Includes coal washing/drying, briquetting. Widespread use throughout the world.

Up to 22% CO₂ Reductions

Efficiency Improvements of Existing Plant

Conventional coal-fired subcritical generation has improved significantly in its efficiency (38-40%) so reducing emissions. Supercritical and ultrasupercritical plants offer even higher efficiencies (already up to 45%). Improved efficiency subcritical plants operate around the world. Supercritical and ultrasupercritical plants operate successfully in Japan, USA, Europe, Russia and China.

Up to 25% CO₂ Reductions

Advanced Technologies

Very high efficiencies and low emissions from innovative technologies such as integrated gasification combined cycle (IGCC), pressurised fluidised bed combustion (PFBC) and in the future integrated gasification fuel cells (IGFC). IGCC and PFBC operational in USA, Japan and Europe, IGFC at R&D stage.

Up to 99% CO₂ Reductions

Zero Emissions

Carbon capture and storage. Significant international R&D efforts ongoing. FutureGen project aims to have demonstration plant operational within 10 years.

Carbon capture and storage technologies allow emissions of carbon dioxide to be stripped out of the exhaust stream from coal combustion or gasification and disposed of in such a way that they do not enter the atmosphere.

Technologies that allow CO₂ to be captured from emission streams have been used for many years to produce pure CO₂ for use in the food processing and chemicals industry. Petroleum companies often separate CO₂ from natural gas before it is transported to market by pipeline. Some have even started permanently storing CO₂ deep underground in saline aquifers.

While further development is needed to demonstrate the viability of separating out CO₂ from high volume, low CO₂ concentration flue gases from coal-fired power stations, carbon capture is a realistic option for the future.

Once the CO₂ has been captured, it is essential that it can be safely and permanently stored. There are a number of storage options at various stages of development and application.

Carbon dioxide can be injected into the earth's subsurface, a technique known as geological storage. This technology allows large quantities of CO₂ to be permanently stored and is the most comprehensively studied storage option. As long as the site is carefully chosen, the CO₂ can be stored for very long periods of time and monitored to ensure there is no leakage.

Depleted oil and gas reservoirs are an important option for geological storage. Latest estimates suggest that depleted oilfields have a total capacity of some 126 Gigatonnes (Gt) of CO₂. Depleted natural gas reservoirs have a considerably larger storage capacity of some 800 Gt of CO₂. Unmineable

Underground Storage Options for CO₂

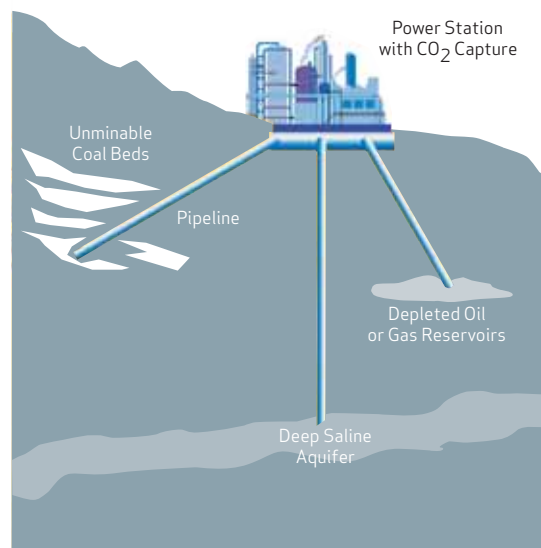


Diagram courtesy of IEA GHG R&D Programme

coal beds are estimated to have a storage capacity of some 150 Gt of CO₂.

Large amounts of CO₂ can also be stored in deep saline water-saturated reservoir rocks, allowing countries to store their CO₂ emissions for many hundreds of years. Firm estimates of the CO₂ storage capacity in deep saline formations have not yet been fully developed, though it has been estimated that it could range between 400 and 10,000 Gt. There are a number of projects demonstrating the effectiveness of CO₂ storage in saline aquifers. The Norwegian company Statoil is undertaking a project at the Sleipner field located in the Norwegian section of the North Sea. The Nagaoka project, started in Japan in 2002, is a smaller-scale, five-year project researching and demonstrating the potential of CO₂ storage in on-shore and off-shore aquifers.

The Greenhouse Effect

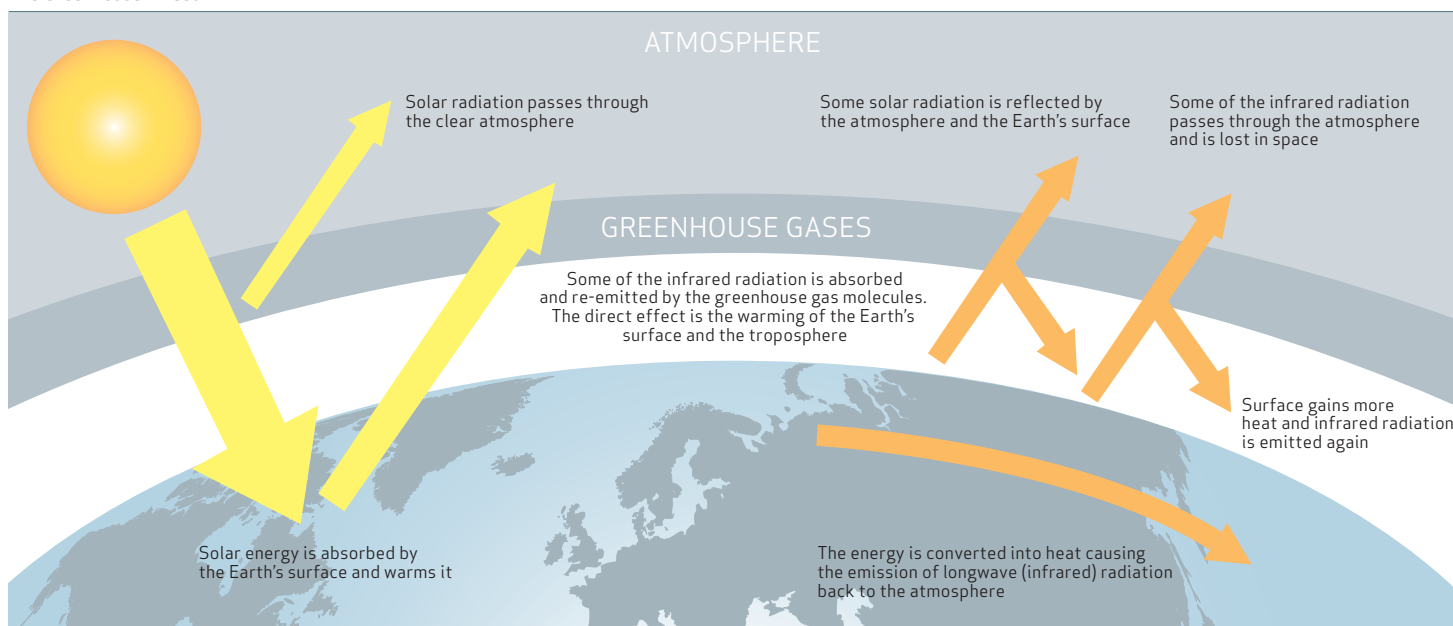


Diagram courtesy of the Intergovernmental Panel on Climate Change

The storage of CO₂ can also have an economic benefit by allowing increased production of oil and coalbed methane. These techniques are referred to as enhanced oil recovery (EOR) and enhanced coalbed methane recovery (ECBM). The CO₂ can be used to 'push' oil out of underground strata and is already widely used in the oil industry. The Weyburn Enhanced Oil Recovery project uses CO₂ from a lignite-fired power station in the USA and transports it through a 205 mile pipeline to the Weyburn oilfield in Canada to boost oil production. Around 5000 tonnes or 2.7 m³ of CO₂ per day are injected into the oilfield, an amount which would otherwise have been released into the atmosphere.

ECBM allows CO₂ to be stored in unmineable coal seams and improves the production of coalbed methane as a valuable by-product.

Carbon capture and storage offers the potential for the large-scale CO₂ reductions needed to stabilise atmospheric concentrations of CO₂.

Coal & Renewable Energy

The continued development and deployment of renewable energy will play an important role in improving the environmental performance of future energy production. However, there are a number of significant practical and economic barriers that limit the projected rate of growth of renewable energy.

Renewable energy can be intermittent or unpredictable and 'site-dependent', which means they are only available at specific locations. Wind energy, for example, depends on whether and how strongly the wind is blowing and even the best wind farms do not normally operate for more than about one-third of the time. Many forms of biomass are

seasonal and can be difficult to transport. Coal-fired electricity can help support the growth of renewable energy by balancing out their intermittencies in power supply. Coal can provide convenient, cheap base-load power while renewables can be used to meet peak demand. The economics and efficiency of biomass renewables can also be improved by co-firing with coal.

While clean coal technologies are improving the environmental performance of coal-fired power stations, its role as an affordable and readily available energy source offers wider environmental benefits by supporting the development of renewables.

Overcoming Environmental Impacts

The environmental impact of our energy consumption is a concern for us all. Limiting the negative effects of coal production and use is a priority for the coal industry and one which has been the focus of research, development and investment. Much has been achieved – technologies have been developed and are widely used to limit particulate emissions, NOx and SOx and trace elements. Improvements in the efficiency of coal combustion have already achieved significant reductions in carbon dioxide emissions. The wider use of technologies to improve the environmental performance of coal will be essential, particularly in developing countries where coal use is set to markedly increase.

Technological innovation and advancement, such as carbon capture and storage, offers many future prospects for tackling CO₂ emissions from coal use in the future.

The UNFCCC & GHG Emissions

The United Nations Framework Convention on Climate Change (UNFCCC) sets an overall framework for intergovernmental efforts to tackle climate change. It opened for signature at the Earth Summit in Rio de Janeiro in 1992 and entered into force in 1994. Under the Convention, governments:

- >> Gather and share information on GHG emissions, national policies and best practices.
- >> Launch national strategies for addressing GHG emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries.
- >> Cooperate in preparing for adaptation to the impacts of climate change.

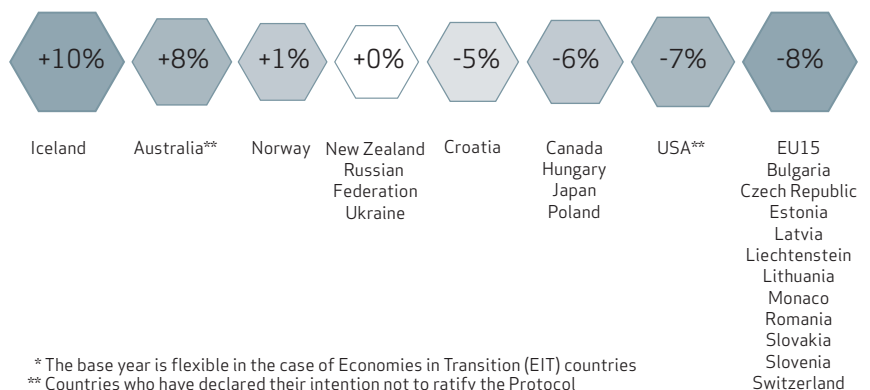
Countries that are parties to the UNFCCC meet annually at the Conference of the Parties (COP). It was at COP3, held in Kyoto in 1997, that countries negotiated the Kyoto Protocol, which set legally-binding targets for emissions reductions.

The Kyoto Protocol entered into force in February 2005. At that time there were 128 countries who were Parties to the Protocol, 30 of whom are developed countries with emissions targets. Both Australia and the USA have refused to ratify the Protocol but are undertaking their own domestic measures to stabilise GHG emissions.

Kyoto sets targets for industrialised countries “with a view to reducing their overall emissions of such gases by at least 5% below existing 1990 levels, in the commitment period 2008-2012”.

Kyoto covers emissions of the six main greenhouse gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆). Rather than placing a specific target on each of the gases, the overall emissions targets for all six is combined and translated into ‘CO₂ equivalents’, used to produce a single figure.

Kyoto Protocol Emissions Targets (1990* to 2008/2012)



* The base year is flexible in the case of Economies in Transition (EIT) countries
 ** Countries who have declared their intention not to ratify the Protocol



Access to energy, and specifically electricity, is a driving force behind economic and social development. Photograph courtesy of Anglo Coal.

SECTION SIX

MEETING FUTURE ENERGY DEMAND

>> The global energy system faces many challenges in this century. It will have to continue to supply secure and affordable energy in the face of growing demand. At the same time society expects cleaner energy and less pollution, with an increasing emphasis on environmental sustainability. >>

Over the next 30 years, it is estimated that global energy demand will increase by almost 60%. Two thirds of the increase will come from developing countries – by 2030 they will account for almost half of total energy demand.

However, many of the world's poorest people will still be deprived of modern energy in 30 years time. Electrification rates in developing countries will rise from 66% in 2002 to 78% in 2030 but the total number of people without electricity will fall only slightly, from 1.6 billion to just under 1.4 billion in 2030 due to population growth (see map on page 40).

Energy is vital to human development. It is impossible to operate a factory, to run a shop, deliver goods to consumers, or grow crops, for example, without some form of energy. Access to modern energy services not only contributes to economic growth and household incomes but also to the improved quality of life that comes with better education and health services. Unless access to energy is improved, many of the world's poorest countries will remain trapped in a circle of poverty, social instability and under-development.

If we are to significantly improve access to energy worldwide – and maintain a secure energy system – all forms of energy will be needed. This includes coal, gas, oil, nuclear, hydro and renewables.

The Role of Coal

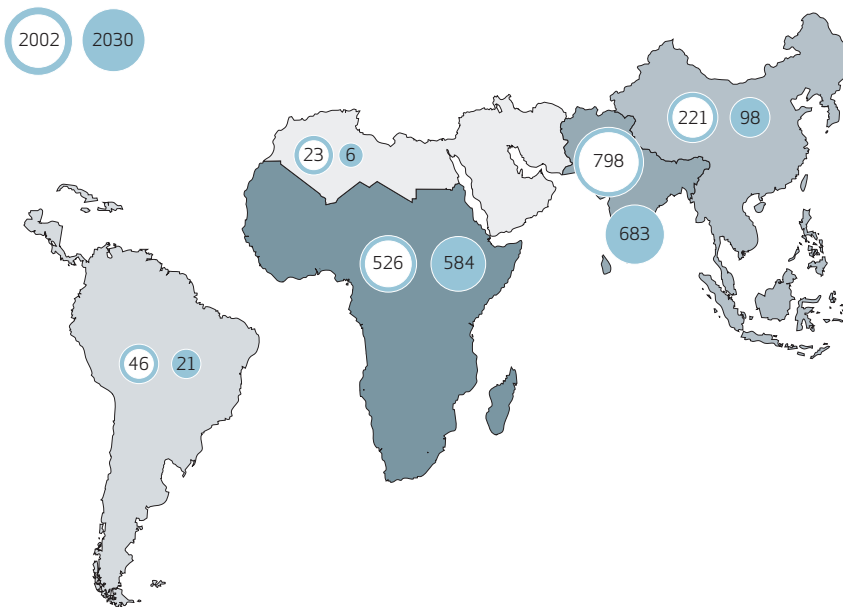
As the most important fuel for electricity generation and a vital input into steel production, coal will have a major role to play in meeting future energy needs.

During the past two years, the use of coal has grown at a faster rate than for any other fuel, rising by almost 7% in 2003. Demand in China grew by 15%, in Russia by 7%, in Japan by 5% and in the USA by 2.6%.

Demand for coal and its vital role in the world's energy system is set to continue. Asian countries will see the most increase in the use of coal, with China and India alone accounting for 68% of the increase.

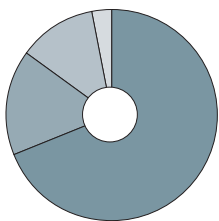
Coal will continue to play a vital role in electricity generation worldwide – while it currently supplies 39% of the world's electricity, this figure will only drop one percentage point over the next three decades.

Number of People Without Electricity in the Developing World (millions)



Source: IEA 2004

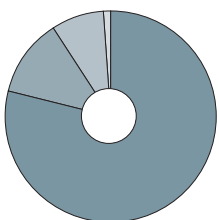
World Coal Demand by Sector - 2002



Power Generation	69%
Industry	16%
Other	12%
Residential	3%

Source: IEA 2004

World Coal Demand by Sector - 2030



Power Generation	79%
Industry	12%
Other	8%
Residential	1%

Source: IEA 2004

With the availability of abundant, affordable and geographically disperse reserves, coal has a vital role to play in a world where reliable supplies of affordable energy will be essential to global development.

Making Further Environmental Gains

Technological innovation will allow demand for coal to be met without an unacceptable environmental impact.

The wider deployment of clean coal technologies will have a significant impact on the environmental performance of coal in both developed and developing countries. It has been suggested, for example, that if the efficiency of the world's coal-fired power stations was improved to the level of Germany's coal-fired power stations, the reduction in CO₂ emissions would be greater than will be achieved under the Kyoto Protocol.

In the longer term, carbon capture and storage offers the potential for significant reductions in CO₂ emissions from coal consumption, nearing almost zero-emissions.

Research and development is focusing on increasingly innovative ways of generating energy. One important option for the longer term is the move towards hydrogen-based energy systems, in which hydrogen is used to produce electricity from gas turbines and, ultimately, fuel cells. Fuel cells use electrochemical reactions between hydrogen and oxygen instead of a combustion process to produce electricity.

Hydrogen does not occur naturally in usable quantities; it would have to be manufactured. Fossil fuels are one probable source. Coal, with the biggest and most widespread reserves of

World Coal Demand (Mt)				
	2002		2030	
	Million Tonnes	Coal's Share of Electricity Generation (%)	Million Tonnes	Coal's Share of Electricity Generation (%)
OECD North America	1051	46	1222	40
OECD Europe	822	29	816	24
OECD Pacific	364	36	423	29
OECD	2237	38	2461	33
Russia	220	19	244	15
Other Transition Economies	249	27	340	18
Transition Economies	469	22	584	16
China	1308	77	2402	72
East Asia	160	28	456	49
South Asia	396	60	773	54
Latin America	30	4	66	5
Middle East	15	6	23	5
Africa	174	47	264	29
Developing Countries	2085	45	3984	47
World	4791	39	7029	38

Source: IEA 2004

any fossil fuel, is a prime candidate to provide hydrogen – via coal gasification – in the quantities needed.

Until recently, the energy intensive nature of the processes involved, the high costs, and the CO₂ by-products made the development of this technology unlikely. However, major technological advances together with carbon storage have opened up renewed prospects for environmentally acceptable, large-volume production of hydrogen. Coal is well-positioned to provide the quantities of hydrogen needed to move towards a new and different energy economy. Europe, Japan, the USA and New Zealand all have active hydrogen programmes and are considering coal as an option to produce hydrogen.

Coal & Our Energy Future

Alleviating poverty, maintaining secure supplies of energy, and protecting the natural environment are some of the biggest challenges facing our world today. The production and use of coal is linked to each of these challenges.

SECTION SIX END

FURTHER READING

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www.australiancoal.com
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WORLD COAL INSTITUTE

>> The World Coal Institute (WCI) is a non-profit, non-governmental association of coal enterprises. >>

The WCI is a UN-accredited organisation and the only international group working worldwide on behalf of the coal industry. The WCI is based in London, with member companies located worldwide. The WCI promotes:

- >> Coal as a strategic resource, essential for a modern quality of life, a key contributor to sustainable development, and an essential element in enhanced energy security.
- >> A progressive industry committed to technological innovation and improved environmental outcomes within the context of a balanced and responsible energy mix.

The objectives of the World Coal Institute are to:

- >> Provide a voice for coal in international policy debates;
- >> Improve public awareness of the merits and importance of coal as the single largest source of fuel for the generation of electricity;

- >> Widen understanding of the vital role that metallurgical coal fulfils in the worldwide production of the steel on which all industry depends;
- >> Ensure that decision makers - and public opinion generally - are fully informed on the advances in modern clean coal technologies; advances that are steadily improving the efficient use of coal and greatly reducing the impact of coal on the environment;
- >> Support other sectors of the worldwide coal industry in emphasising the importance of coal and its qualities as a plentiful, clean, safe and economical energy resource;
- >> Promote the merits of coal and upgrade the image of coal as a clean, efficient fuel, essential to both the generation of the world's electricity and the manufacture of the world's steel.

Membership is open to coal enterprises from anywhere in the world, with member companies represented at Chief Executive level.

For more information on the activities of the World Coal Institute, please visit our website: www.worldcoal.org

For enquiries on how to become a member of the WCI, please contact the Secretariat:

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