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.

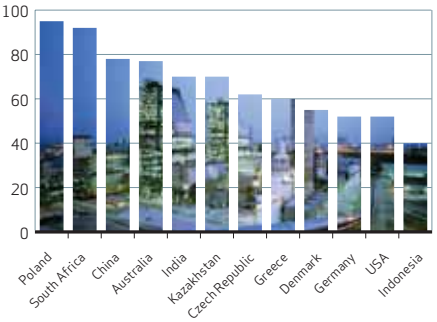
Coal was also used to produce gas for gas lights in many cities, which was called 'town gas'. This process of coal gasification saw the growth in gas lights across metropolitan areas at the beginning of the 19th century, particularly in London. The use of coal gas in street lighting was eventually replaced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

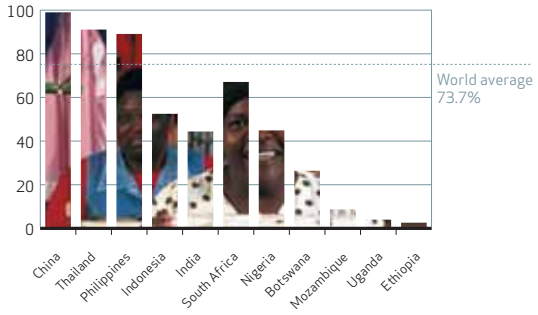
Percentage of Electricity Generated from Coal in Selected Countries (mixture of 2003 & 2002 data)

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

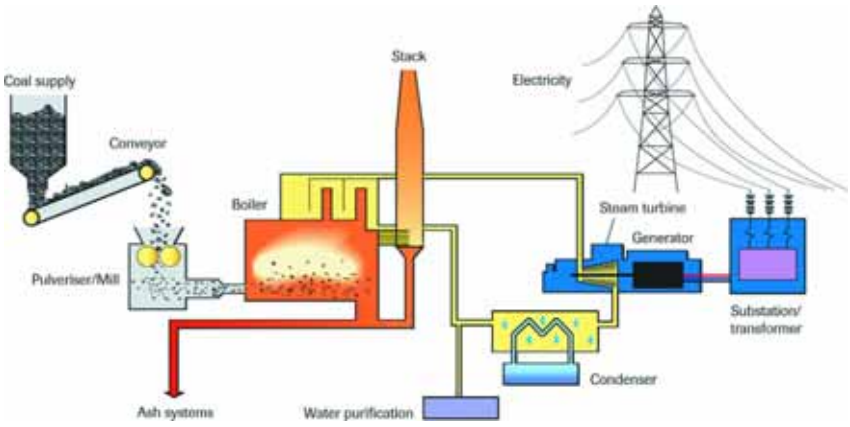
- Labour that would otherwise be spent collecting fuel is freed for more productive use, such as in agricultural and manufacturing industries. This increases household income, labour supply and the productive capacity of developing economies.

- 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).

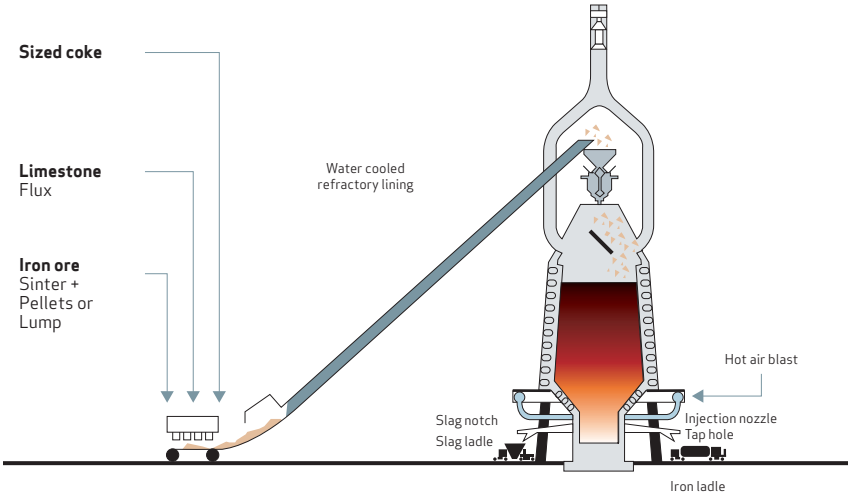
- Inefficient combustion of unconventional fuels, especially in households without flues, creates health complications. Moving households towards modern energy sources, such as electricity, improves health and productivity.

- 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

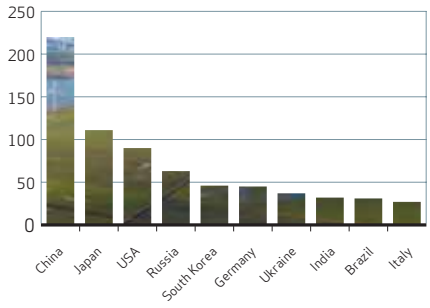
The raw materials – iron ore, coke and fluxes (minerals such as limestone which are used to collect impurities) – are fed into the top of the blast furnace. Air is heated to about 1200°C and is blown into the furnace through nozzles in the lower section. The air causes the coke to burn producing carbon 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 and producing molten steel. Much of the electricity used in EAF is produced from coal.

Top Ten Steel Producing Countries, 2003 (Mt)

Source: IISI



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.

SECTION FOUR END

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.