ITAM

INTRODUCTION TO AUSTRALIA'S MINERALS

COAL

Coal in a Sustainable Future

QUEENSLAND MINING COUNCIL

Australian COAL Association

NSW Minerals Council

Coal

CONTENTS

Did you know?

The thickest seam of coal anywhere in the world is the 233 metres of brown coal which occurs at Loy Yang in Victoria.

Coal Overview

Coal is an organic sedimentary rock made up of the altered remains of mainly plant material. Coal, oil and gas are called fossil fuels because they are all formed from the remains of once-living organisms. These fossil fuels provide most of the energy required for human activities. Our present lifestyle depends on abundant and relatively cheap coal, oil and gas.

Most of the coal mined around the world is used for electricity generation in power stations, for steel making or for other industrial production. Power stations are often built beside their feeder coal mines to reduce transport costs. Most of the world's coal production is used within the country in which it is mined.

Australia is the world's largest coal exporter. It is one of the few countries in the world where more of the coal that is mined is exported than is used in the country. In 2002, coal exports of more than 200 million tonnes earned over $13 billion for Australia. These exports contribute enormously to Australia's balance of payments, offsetting the cost of imports. Taxes and royalties paid to government by mining companies and their employees contribute significantly to the welfare of all Australians.

Coal mining and export employs many Australians directly and indirectly. Thousands of workers are employed in the coal mines, at preparation facilities, on railways and at ports. In recent years large machines and workplace changes have increased the productivity of Australian coal mines supporting a vibrant export industry.

In addition to those employed directly in the coal industry, many other Australians are employed indirectly, such as in the transport sector. A number of new towns have been established in regional areas to service the mines developed since the 1960s.

Opencut coal mining does disturb large areas on the mining lease, but modern rehabilitation techniques now return this land to productive use or native ecosystems. Underground mining can cause subsidence at the surface but careful planning, regulation and monitoring minimises damage and compensation is available to those affected. Burning of coal, and other fossil fuels, adds greenhouse gases to the atmosphere. On-going research and the adoption of clean coal technologies in all facets of coal mining, preparation and use are continuing to significantly reduce greenhouse emissions.

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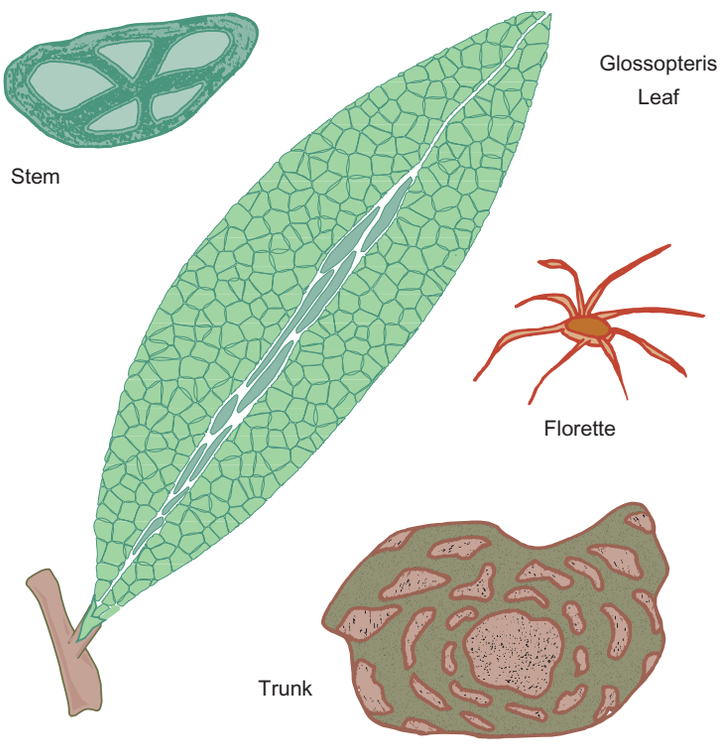
Front Cover: Mine technicians discussing plans at Bengalla Mine. Photo courtesy of Bengalla Mining Company.

Formation of Coal



Glossopteris leaf. Most of the black coal in the Sydney and Bowen Basins is made up of the remains of the Permian age seed fern Glossopteris.

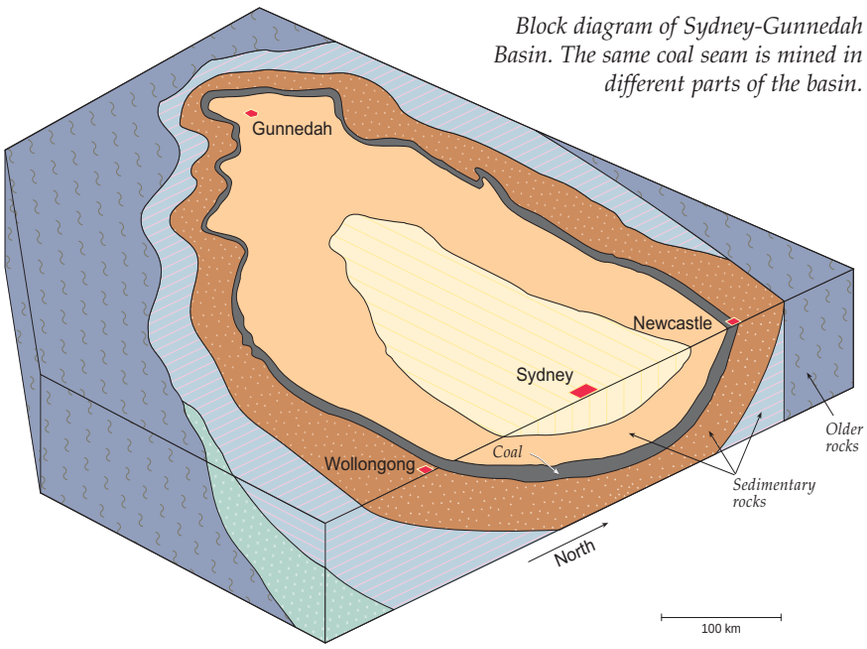
Increase in coal rank

Peat **Brown Coal** **Sub Bituminous** **Bituminous**

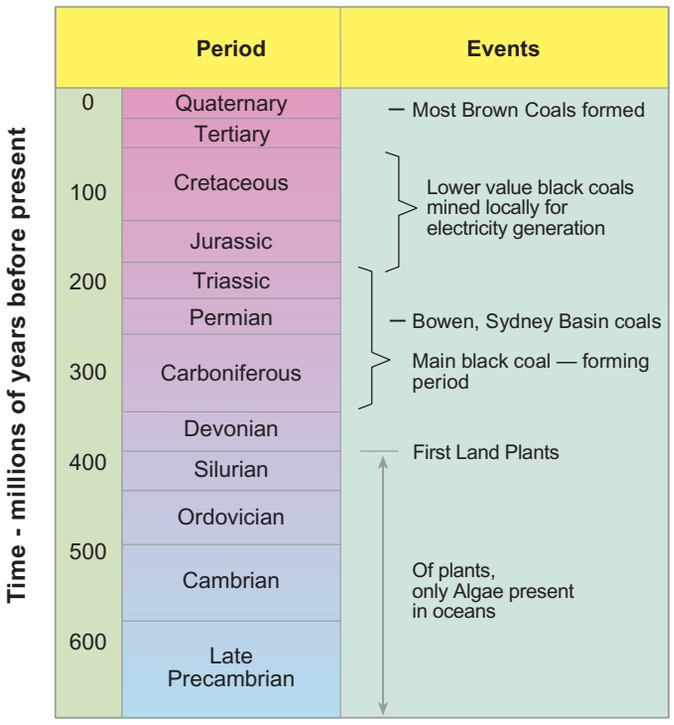
Coal Basins

Coal forms when plant matter is buried by sediment in structures called basins. These basins are depressions in the Earth's crust formed when the crust buckles as a result of movements of the tectonic plates.

Coal formation could only become possible after plants moved onto the land from the sea. This happened at about the end of the Silurian Period, 400 million years ago. Therefore coal is only found in rocks deposited since about 400 million years ago.



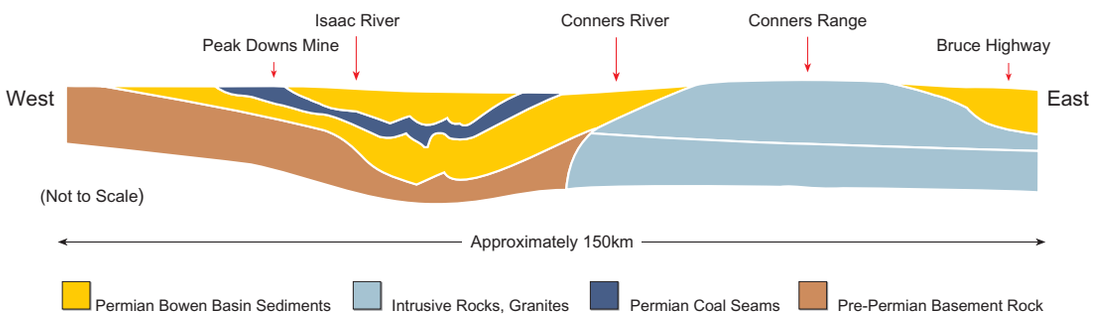
Block diagram of Sydney-Gunnedah Basin. The same coal seam is mined in different parts of the basin.



Geological Time Scale.

The greatest deposits of coal occur in basins containing rocks of the Carboniferous and Permian Periods (about 350 to 250 million years ago).

Coal has continued to form in basins all around the world since the Silurian Period. Younger basins contain coals of lower energy value because the coal forming process has not continued for as long as it has in the older basins. The coal in the older basins has been compressed under thick piles of sediment for long periods, resulting in higher grades of coal.

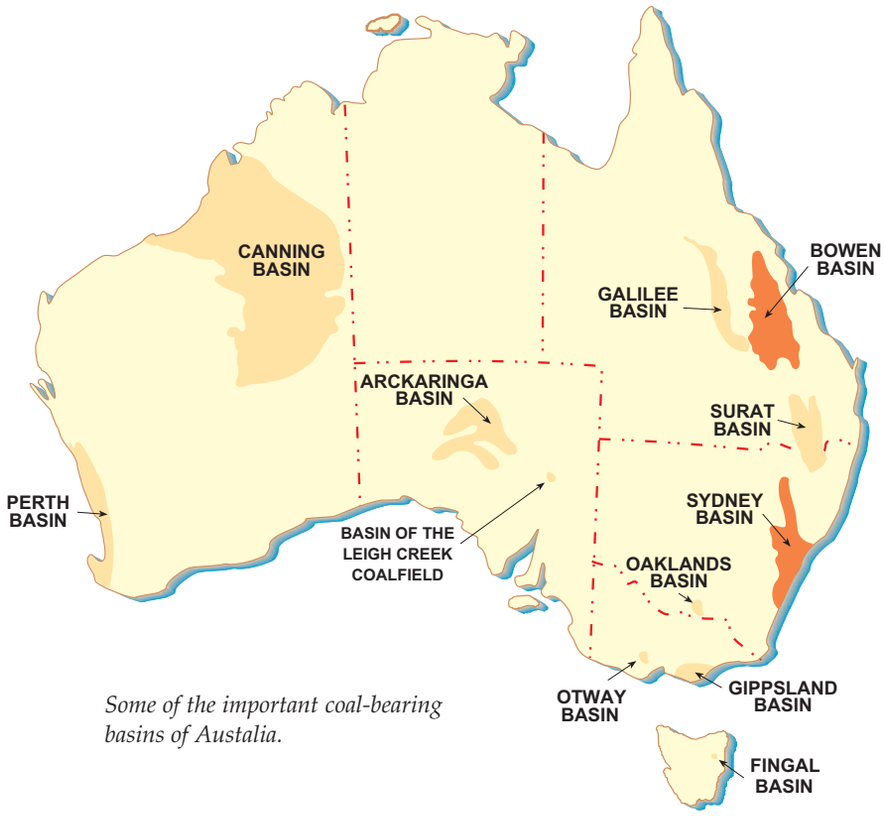


Typical Cross Section of the Bowen Basin.

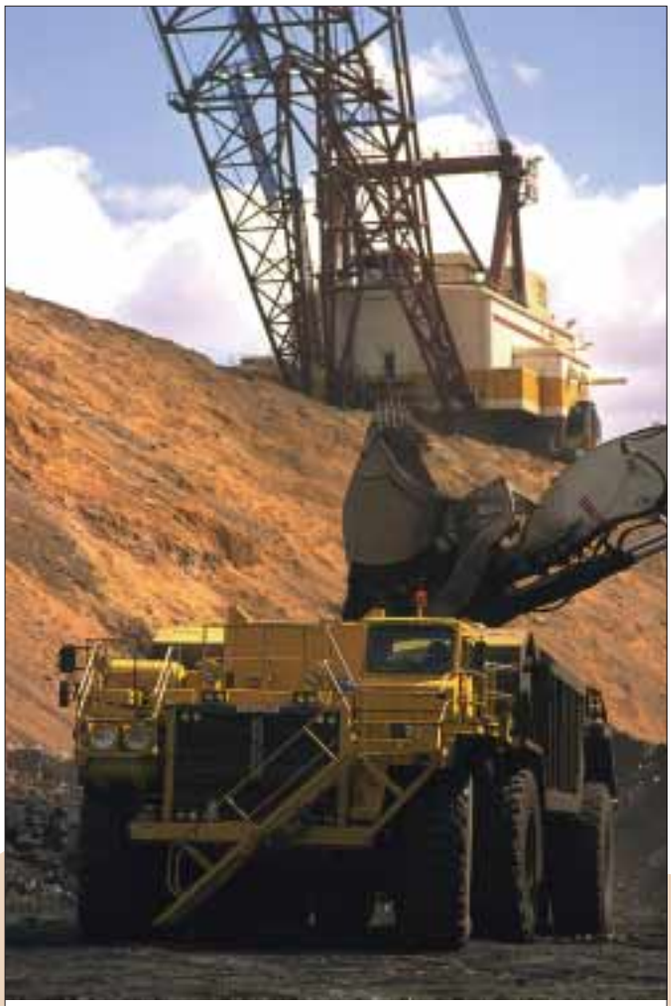
Coal Basins

High grade coals exist in basins in a number of areas around Australia. In eastern Australia, coal formed during the Permian Period in two large basins. These two basins are the Sydney-Gunnedah Basin in NSW and the Bowen Basin in Queensland. They contain most of the high grade bituminous coal and some anthracite that is extracted for electricity generation, steel making and export. The coal is mined by both opencut and underground methods.

In the Sydney-Gunnedah Basin coal is mined at each of the edges of the basin. At the southern edge lies the Illawarra Coal Measures, at the northern edge, the Hunter Coalfield, and the Western Coalfield lies at the western edge. To the north-west lies the Gunnedah Coalfield. Coal at the centre of the Sydney Basin is mostly too deep to mine economically at present.



Some of the important coal-bearing basins of Austalia.



An example of current mining methods.
Photo courtesy of BHP Billiton Mitsubishi Alliance

The Permian coals in the Sydney-Gunnedah and Bowen Basins are mostly formed from the remains of an extinct seed-fern called Glossopteris. The large leaves, fronds, roots and trunk of the deciduous Glossopteris trees provided the raw material which later became the coal measures.

Coals formed in basins belonging to the Triassic and Tertiary Periods are important locally in some States of Australia. Most of them are sub-bituminous or brown coals used for electricity generation. Because these younger coals are generally lower in energy value, they are not usually suitable for export.

Types of Coal

The process of coalification converts the plant material, which consists essentially of compounds of carbon, hydrogen and oxygen, to coal. Coal, in its purest form, consists of carbon only. The different grades or types of coal vary between relatively unchanged plant material and pure carbon.

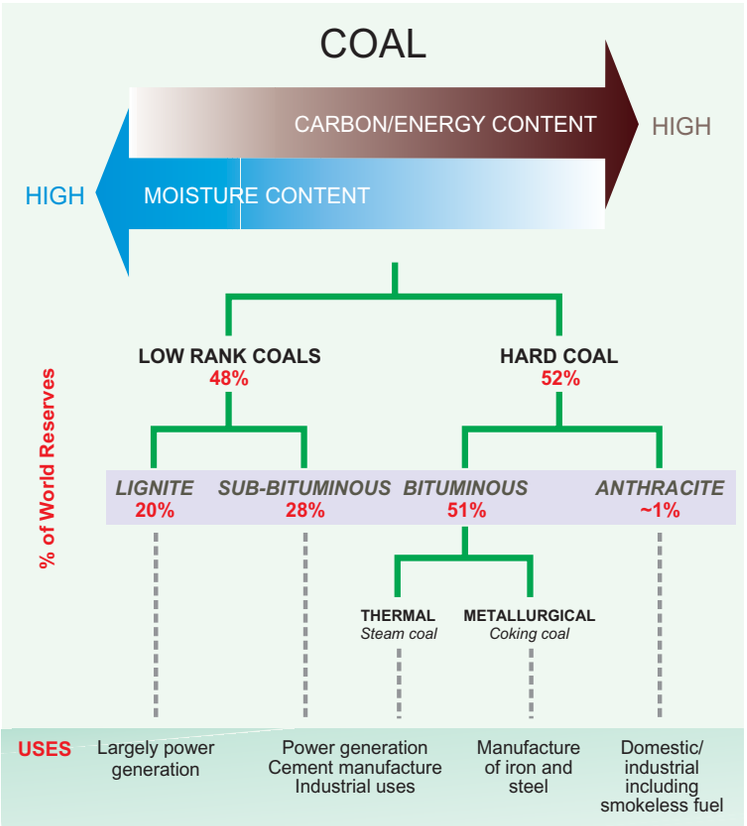
There are a number of ways in which the different types of coal can be classified. Some classifications rely on the use to which the coal is put, for example coking coal or steaming coal.

One common classification system divides coals into various rankings based on a range of properties. The order of rank of the coals from lowest energy-value to highest energy-value is:

- Peat
- Lignite
- Sub-bituminous
- Bituminous
- Anthracite.

Did you know?

A walking dragline in an open cut mine may weigh as much as 2,500 tonnes, is as tall as a four storey block of flats, has a boom as long as a football field and costs as much as $70 million.



Types of coal and their uses.
Image courtesy of World Coal Institute

Another simple classification uses only black coal (also called hard coal) and brown coal (also called soft coal). The higher energy-value black coal includes anthracite and the bituminous coals. Brown coal includes lower energy-value lignite and peat.

Pure carbon has the highest energy value when burnt and therefore makes the most valuable fuel. Anthracites may contain more than 90% carbon with only a few percent of volatile materials. Lignite, on the other hand, may need to be dried to remove the over 50% of water it contains before the 50 to 60% of carbon is able to be burned.

Dragline operating in an opencut coal mine.

Photo courtesy of BHP Billiton Mitsubishi Alliance

Uses of Coal

Coal mined in Australia is mainly used for electricity generation (steaming or thermal coal) and in the production of iron ore and steel (coking or metallurgical coal).

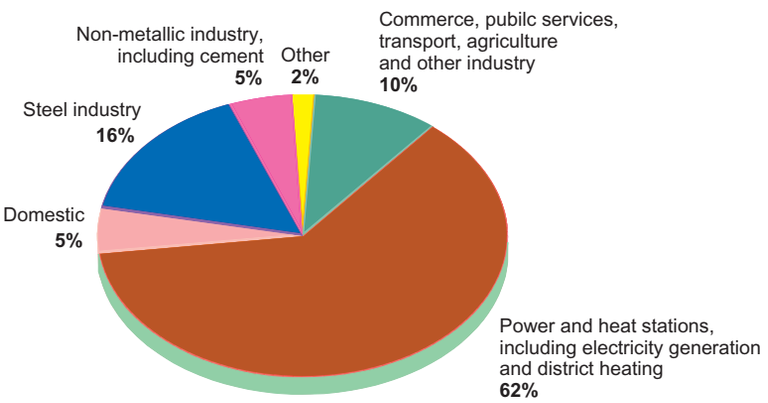
Steaming Coal

Of the more than 3.6 billion tonnes of steaming coal produced annually around the world, over 50% is used for electricity generation. In New South Wales and Queensland over 90% of their electricity is produced from coal-fuelled power stations. The coal is burnt in a boiler and the steam produced drives a turbine, which in turn, drives the generator which produces the electricity.

Many power stations are built beside the coal mine which is the source of the fuel. The reason for this positioning is that electricity is much easier and cheaper to transport than coal.

The energy transformations involved in a power station are from chemical (coal), to heat (boiler), to kinetic (turbine) to electric (generator). Each transformation involves energy losses, with the result that only about 35 to 42% of the original energy is converted to electrical energy. Improvements in technology are increasing the efficiency of these changes all the time.

Electricity is vital to the efficient functioning of our society. In general, the higher the standard of living of the country, the more electricity per head of population that country uses.



Uses of coal around the world.

Coking Coal

Another major use for coal is in the production of iron and steel. Coal is converted to coke before being fed into the blast furnace. Coke is produced by heating coal in a coke oven which excludes air. The water and gases are driven off and collected for the production of a range of useful chemicals. Left behind is a sponge-like lump of almost pure carbon, which is coke.

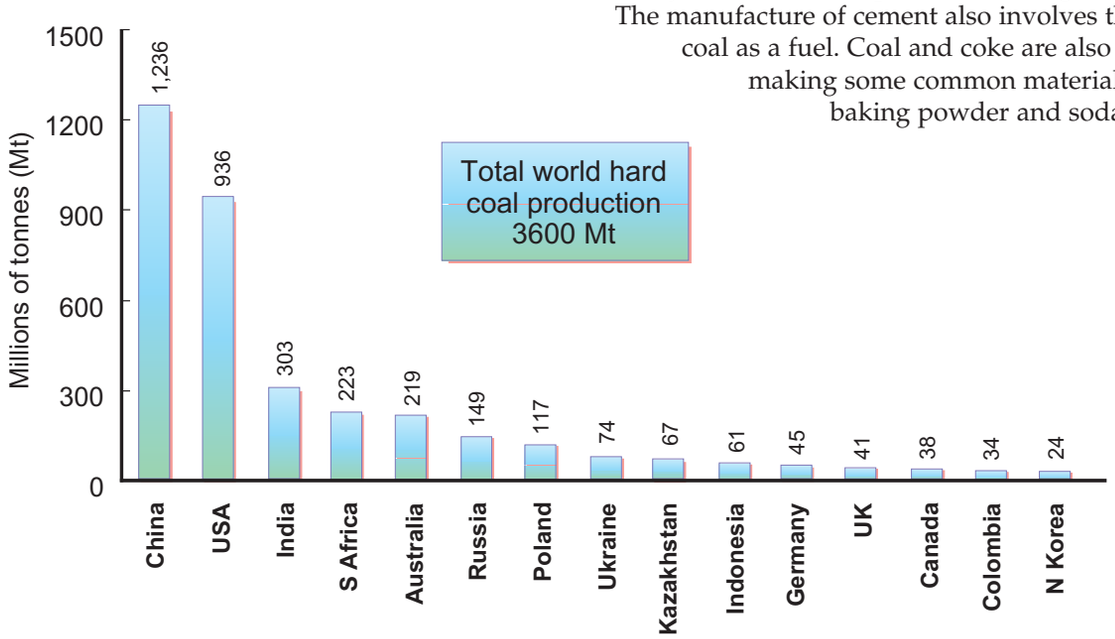
In a blast furnace, carbon in the coke combines with oxygen to release the heat needed to change the iron minerals to pure iron. The result is a pool of molten iron at the bottom of the furnace with a layer of slag, containing the impurities, floating on top of the iron.

Most industrial processes involve the use of steel in machinery and a great deal of steel is used for motor vehicle production and in the construction industry.

Other Uses

Coal and its products are used in the production of a variety of chemicals important to a range of industries. The manufacture of cement also involves the use of coal as a fuel. Coal and coke are also used in making some common materials like baking powder and soda water.

World hard coal production for 2002, (top 15 producers).



History of Coal

New South Wales
In the early days of the colony of New South Wales coal was discovered both to the north and south of Sydney. Explorer George Bass, of Bass and Flinders fame, found outcrops of coal at what is today the village of Coalcliff, near Wollongong in 1797. The outcropping beds were part of what is now called the Illawarra Coal Measures in the southern part of the Sydney Basin. Although coal had been exported from New South Wales since 1799, the most important coal mine in the area, at Mt Keira, began commercial production in 1857. This mine operated for over one hundred and thirty years, finally closing in 1991. Most of the coal mined in the Illawarra area was originally produced for the Port Kembla steelworks. In recent years large tonnages have been exported.

Abandoned mines may become tourist attractions. A Pit Pony shows how coal was moved underground in earlier times. Photo courtesy of W. G. 'Haggis' Shackleton

Aboriginal inhabitants of the Hunter Valley may have used and traded coal outcropping on the banks of the Hunter River at the site of what is now the city of Newcastle. European explorers noted this occurrence in 1797, not long after the first settlement was established at Sydney Cove. Newcastle is now the major port for export of black coal from the Hunter Valley mines.

Queensland
In Queensland the first coal discovery was made by Major Edmond Lockyer in 1825 when he collected coal from a seam outcropping on the banks of the Brisbane River. The first coal mine in the State opened in 1843 at Redbank near Ipswich. This area remains an important coal mining and electricity generating centre for the state. Explorer Ludwig Leichhardt discovered coal in the Bowen Basin in 1845 and water well diggers discovered coal instead of water at Blair Athol in 1864. It was not until 1936 that Blair Athol became the State's first continuous opencut coal mine. Much later, in the 1960s, Queensland took the lead in Australia's great export boom with coal from this basin.

Davey Lamp.
Photo courtesy of W. G. 'Haggis' Shackleton

Victoria
Brown coal was discovered in the Gippsland area in the early days of the colony of Victoria. The first attempts to mine the coal were unsuccessful. When overseas experience and technology was applied in the 1940s Victoria was able to build a massive electricity generating industry based on the plentiful brown coal.

Western Australia
Coal was first mined in the Collie area in the southwest of the State in the 1890s to provide fuel for steamships and trains. Since 1916, coal mined in this area has provided a resource for Western Australia's electricity generation.

History of Coal

South Australia
In South Australia, brown coals were discovered in a number of the sedimentary basins in the 1880s, both in outcrops and in bores drilled for water. The only large, present day mining occurs at Leigh Creek, in the north of the State. Here, Triassic sub-bituminous coal has been mined by opencut methods since 1944. The coal is railed to Port Augusta for use in two power stations which provide the majority of electricity for the State. Large deposits of higher energy value coals occur in South Australia's sedimentary basins, however they are deeply buried and relatively far from the coast.

Tasmania
Coal was discovered on the Tasman Peninsula near the penal establisment of Port Arthur in 1833. Today bitumous coal is still mined in the Fingal Valley on the east coast of Tasmania. Total production is limited to providing the local market, with the main user being the cement industry at Railton in Tasmania's central north. It is also used to produce steam in the confectionery, brewing and paper industries in the State.

The export boom
Until the 1960s, Australia's coal production was primarily for domestic electricity generation and steelmaking. As Japan's steel industry expanded in the 1960s it sought to import large quantities of coal from reliable, long term suppliers. Australia moved quickly to increase its exports of coking coal to meet this demand. Expansion followed as other Asian countries increased their steel production and sought high grade coking coals from Australia.

During the 1970s oil producers significantly increased the price of oil. As a result, countries looked to other sources of energy for electricity generation. Many turned to Australian producers of steaming coal for supplies to allow them to continue to produce electricity at reasonable prices. Australia's steaming coal export boom had begun.

Large ships being loaded at a coal export port.
Photo courtesy of BHP Billiton Mitsubishi Alliance

Did you know?

Each Australian will use the energy from 200 tonnes of coal in a lifetime. Mostly this will be used as electricity and in the production of materials such as steel, aluminium and plastics.

The new markets for Australian coal resulted in extensive expansion and modernisation of coal mines and ports on the east coast of Australia. Major opencut mines were developed in the Bowen Basin of Queensland using very large equipment. New railway lines were constructed and old lines upgraded to allow the large tonnages to be moved efficiently to the coastal ports. In NSW, existing underground mines became highly mechanised and productivity increased markedly.

Night time operations at a coal mine.
Photo courtesy of NSW Minerals Council

Coal Mining

Early methods
Coal beds outcropping at the Earth's surface were exploited very early in human history. As the beds were followed underground, so began the earliest underground mining. Fuel to power the machines of the industrial revolution led to rapid growth in the demand for coal during the late 19th century. The invention of the steam engine led to huge demand for coal.

Towns sprang up around the coal mines of Europe as many men were required to dig out the coal with picks and shovels. The coal 'pit' or 'colliery' was a source of many jobs, and as a result of the dangerous nature of the work, became the focus of very strong unionism.

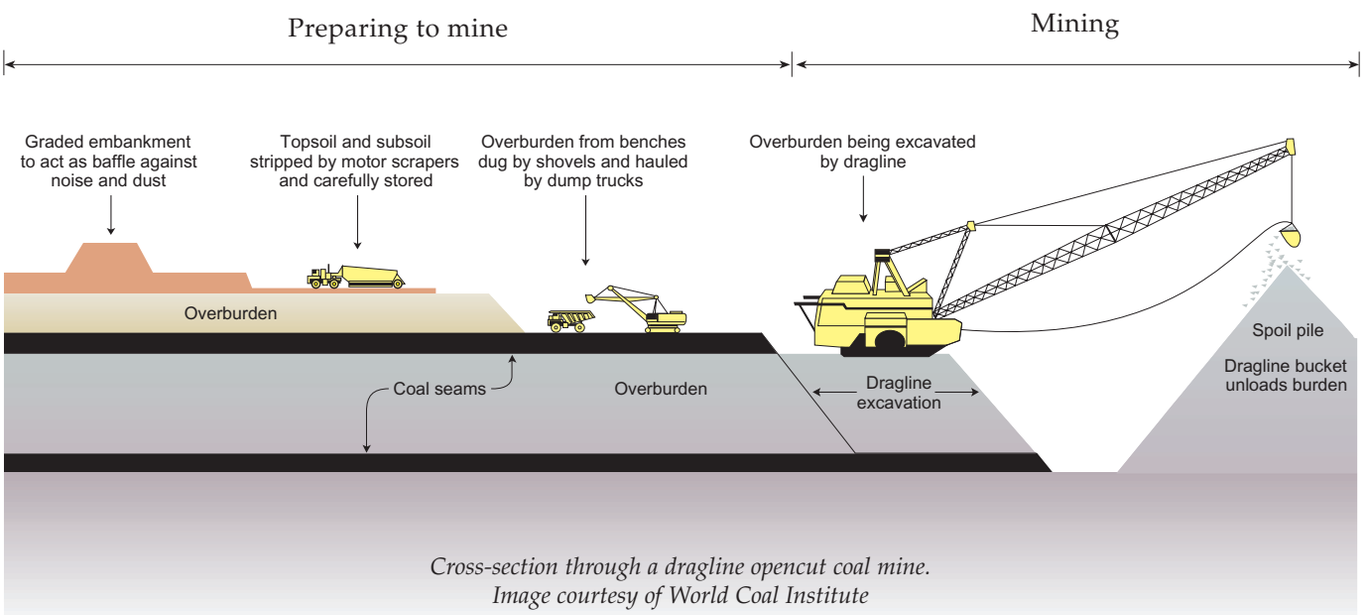
Coal miners often faced a long, dark underground trip to get to the 'face' where they dug out the coal, initially by lamplight. They were paid on the basis of the amount of coal that they produced and usually worked in small teams. Some men dug out the coal while others loaded it into horse-drawn wagons running on wooden rails.

Working in dark, cramped conditions the miners had to cope with breathing fine dust particles, the constant fear of gas explosions and the possibility of collapse of the mine roof. Canaries in cages were taken underground because they were quickly affected by the release of dangerous gases, giving miners early warning that gases were building up. Despite these precautions there were many coal mining disasters leading to large loss of life.

Gradually, mining methods improved, leading to a safer working environment and greater productivity. One early innovation was the Davey Lamp, used to detect the explosive gas methane in coal mines. Over time, hand tools were replaced with electric drills and hammers and electric trains replaced horses. However, coal mining remained a labour intensive activity.

Did you know?

A one metre thick coal seam may have started out as a pile of plant material 120 metres thick and taken over 200 million years to form.



Cross-section through a dragline opencut coal mine.
Image courtesy of World Coal Institute

Coal Mining

Modern methods
Since the 1960s large machines have increased the productivity of coal mines and miners. Large machines allow a smaller number of miners to produce greatly increased tonnages of coal.

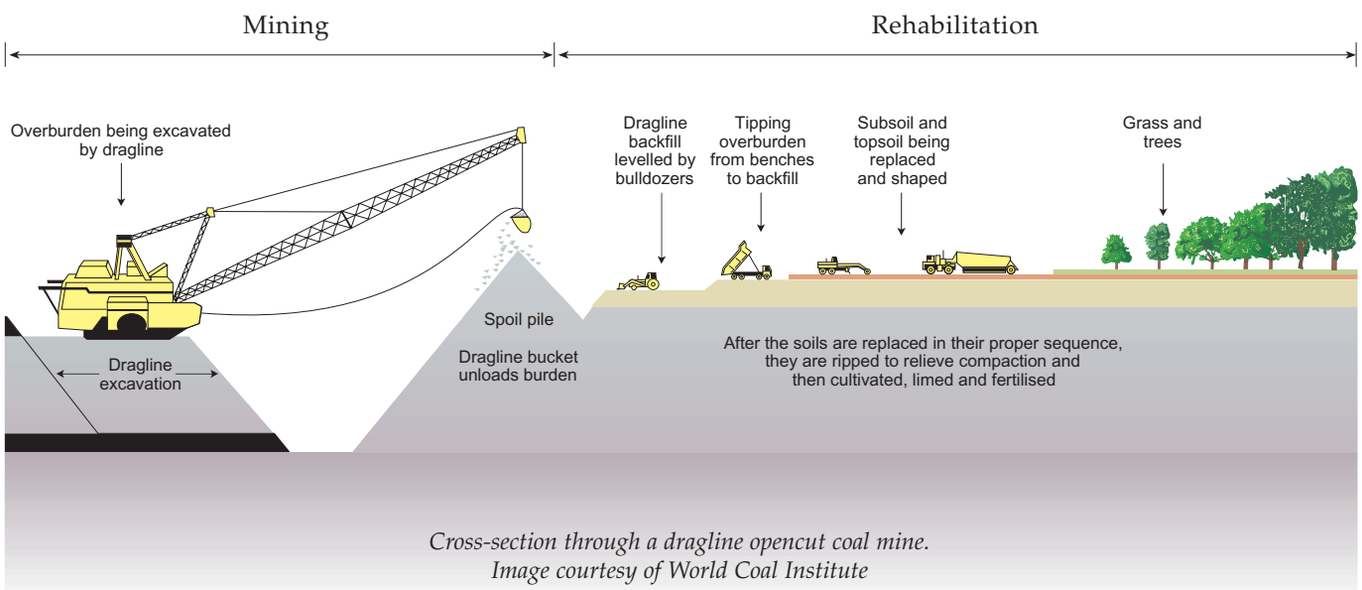
In underground mines, 'longwall' mining machines are used. They have large cutting blades which shear coal from the seam and collect it onto a conveyer belt. Hydraulic jacks support the roof over the machine. As the machine moves forward through the coal seam, the roof is allowed to collapse behind it. Moveable conveyor belts carry the coal through the mine and ultimately to the surface. The underground atmosphere is closely monitored for dangerous gas and to ensure adequate ventilation for the miners.

Longwall mining machine in operation.
Photo courtesy of NSW Minerals Council

The use of large 'walking draglines', huge mobile bucket excavators, has allowed opencut mining to expand dramatically. Following blasting the excavators can strip off large depths of overburden (the rocks layers overlying the coal seam) efficiently, exposing the coal seam. The coal can then be mined with loaders and large capacity dump trucks. Water sprays are used to control dust.

After the coal has been recovered, the overburden is replaced and shaped to resemble the original landforms. The topsoil, which was originally stripped off and stored separately, is spread over the surface and the area is replanted with vegetation.

Coal preparation
When the raw coal reaches the surface it is processed to provide a pure product. These surface processes are called 'preparation'. The coal is first crushed to a specified size and passed over a sieve to remove fine particles. The main process involves washing the coal to remove as much of the non-coal material, usually shale, as possible. The coal is allowed to dry out and then is stored in stockpiles and fed into giant bins before loading into railway trains.



Cross-section through a dragline opencut coal mine.
Image courtesy of World Coal Institute

Rehabilitation

The environmental performance of mining operations in Australia is central to the industry's continued viability. Coal mining represents only temporary use of the land under which the coal lies. Mining aims for sustainable development where the land, after mining is completed, is still able to be productive for future generations. Modern opencut mines are planned in such a way that the land surface may be returned to much the same appearance before mining took place. The land can be contoured, then sown to pasture, planted as forest native ecosystem or used in some other productive or recreational use. The cost of rehabilitation is built into the overall cost of the mining and the rehabilitation process is subject to government regulation.

Vickery coal mine, near Gunnedah, NSW, during mining operations. Photo courtesy of Coal and Allied

In opencut mining, rehabilitation involves firstly removing and stockpiling the topsoil for later replacement. The rocky material overlying the coal (overburden) is then removed by giant draglines or shovels and trucks to expose the coal seam. The seam is mined and then the overburden is replaced. Large bulldozers then reshape the overburden until it closely resembles the original contours of the land. The stockpiled topsoil is then returned to the shaped land and pasture or other plants are sown. Careful attention is paid to ensure that erosion does not affect the new landscape.

Dams may be built to control runoff and to assist retention of water. Rehabilitation progresses behind the surface mining. This means that only a relatively small area of land is affected at any time.

In the case of underground mines the land surface remains largely unaffected, although sometimes subsidence of the surface may occur over mined out areas. The coal mining industry uses a range of engineering techniques to design the layout and dimensions of underground mine workings so that surface subsidence can be anticipated and controlled.

Vickery coal mine after rehabilitation.
Photo courtesy of Coal and Allied

Environment

The environmental effects of mining need to be controlled by good mine planning. Mine owners wish to be good neighbours to the landowners surrounding them. As part of the mining approvals process, a major environmental impact assessment must be undertaken so that the public, local community and government authorities are properly informed when considering a mining proposal.

Land Management
One way of being a good neighbour involves building earth wall barriers to keep noise, dust and pollution onsite. The walls prevent noise from spreading across the countryside. Dust is minimised by spraying water over roads, stockpiles and dumping areas. Sometimes an area surrounding the mine is set up to act as a buffer zone protecting the neighbours. Native animals and stock animals can live happily quite close to the mine. The mine plan involves a succession of rehabilitation after mining in an area is completed.

Management of the animals and plants in the local area is important to miners. At the Blair Athol coal mine in the Bowen Basin a unique koala breeding and management program is conducted by the mine's environmental officers.

Air Quality and Emissions Control
Careful measurement and monitoring of noise, dust and water and air quality is undertaken around each mine. This monitoring is undertaken by environmental scientists employed by the mining company. Findings from the monitoring sites are continuously fed back to the mine management team to enable better planning and operations. Government regulators receive the monitoring results and assess whether standards are being met. Local communities are also advised.

Water quality
The quality of water is critical at mine sites and is continuously monitored. Salts and sediment are taken up in the water draining from the disturbed area of the minesite. This water is collected in settling ponds to allow the sediment to settle. Chemicals are added to neutralise any acidic water and to precipitate salts. The treated water is reused to prevent dust and is also used in the coal preparation plant. Coal mines are major re-users and recyclers of water. All water leaving mine sites must meet stringent environmental regulatory standards.

An environmental scientist monitors vegetation at a rehabilitated mining site.
Photo courtesy of BHP Billiton Mitsubishi Alliance

A rehabilitated mining site.
Courtesy of BHP Billiton Mitsubishi Alliance

Waste material
Fine coal sediments (or tailings), left over from coal preparation are retained in dams so that they can dry out and be covered with overburden and revegetated. In some cases tailings can also be used in some power stations to generate electricity. Coarser waste (non-coal material) of gravel size is buried under the overburden during rehabilitation of the site.

Energy
Energy is conserved in some underground coal mines by draining methane from the mine and burning it to produce electricity to run the mine. Burning coal-seam methane instead of releasing it into the atmosphere also dramatically reduces greenhouse gas emissions associated with coal mining. Computer modelling of dragline operations has led to improvements which save energy.

Transport

Coal Transport
Most of the coal produced throughout the world is used within the country in which it is mined. Coal for export makes up only approximately 15% of the total world production. Australia is the largest coal exporting country.

In many countries most of the coal mined is used for the production of electricity and it therefore makes sense to produce that electricity near the source of the coal. This is because electricity can be transported through wires much more cheaply than coal can be transported by means of railways or roads. Electricity generating stations are therefore often sited very near to coal mines.

Coal is transported by conveyor directly to the power station.
Photo courtesy of Barry Cook

If a mine and electricity generating station are quite close, the coal may be transported on a conveyor system between them. Conveyor systems are more efficient to operate than most alternative transport methods over short distances.

Railways provide the most efficient transport system for moving large quantities of coal over medium distances. Efficient railways are vital to Australia's coal export success. Trains may carry over 8,000 tonnes of coal, be up to two kilometres in length and consist of six locomotives and 100 rail trucks. The aluminium rail trucks are specially designed to allow them to be emptied quickly for rapid turnaround.

One train may carry up to 8,000 tonnes of coal from the mine to port.
Photo courtesy of Barry Cook

Coal from the mine is washed and sized in the preparation plant before being loaded for transport by rail.
Photo courtesy of MIM Holdings Limited

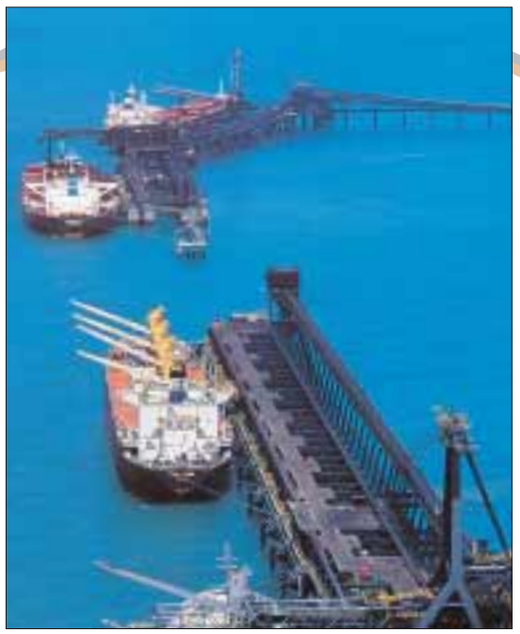
Transport

Coal terminals are located at deepwater ports and contain a stockpile of coal of sufficient size to allow ships to be loaded quickly and efficiently. Large stacker machines stockpile the coal delivered by the rail system. Reclaimer machines take coal from the stockpile for transport to the loading conveyors on the dock.

Export coal terminals are located at Abbot Point, Hay Point-Dalrymple Bay, Gladstone and Brisbane to service the Queensland mining centres. The Sydney-Gunnedah Basin mining areas of NSW are serviced by the coal terminals at Port Waratah-Newcastle and Port Kembla. Over 200 million tonnes of coal were exported from Australia through these terminals in the 2001 calendar year.

The ships that carry export coal are large and specially designed for rapid loading and unloading. The largest carry over 200,000 tonnes and usually travel on a specific route.

One innovative method of transporting coal which has been tried experimentally involves a slurry pipeline. Crushed coal is mixed with water to form the slurry and is then pumped along the pipeline before being dried at the end point. Such systems have been used to transport coal over short distances but are not yet proven to be economically viable.



Loading ships at the Hay Point and Dalrymple Bay coal terminals.
Photo courtesy of BHP Coal Pty Ltd

Did you know?

Coal is transported around the world in large bulk ships, the largest of which may carry over 200,000 tonnes at a time.

Coal Terminals

A - Abbot Point

D - Dalrymple Bay

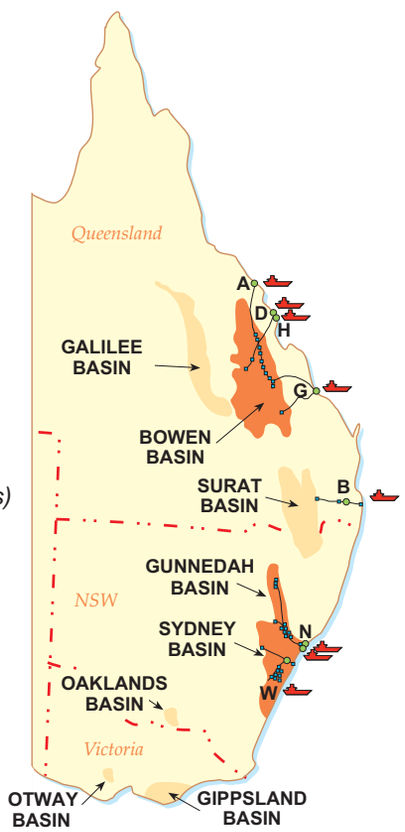
H - Hay Point

G - Gladstone

B - Brisbane *(Fisherman Islands)*

N - Newcastle *(Port Waratah and Kooragang)*

W - Wollongong *(Port Kembla)*



A coal loading operation.
Photo courtesy of BHP Billiton Mitsubishi Alliance

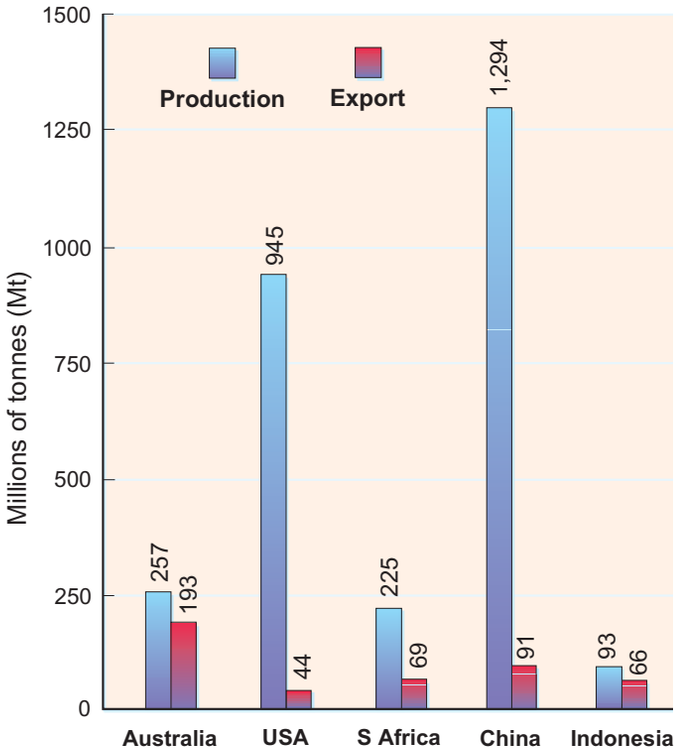
Coal Exports

Australia is the world's largest coal exporter, exporting nearly 200 million tonnes of steaming and coking coal in 2001. Other major exporters include South Africa, Colombia, Indonesia and China.

The export market involves only about 15% of the total world coal production of more than 3,600 million tonnes per year. Most of the coal produced in the majority of countries is used in their domestic markets. Coal production in many Western countries is very high cost and is slowly being replaced by imports.

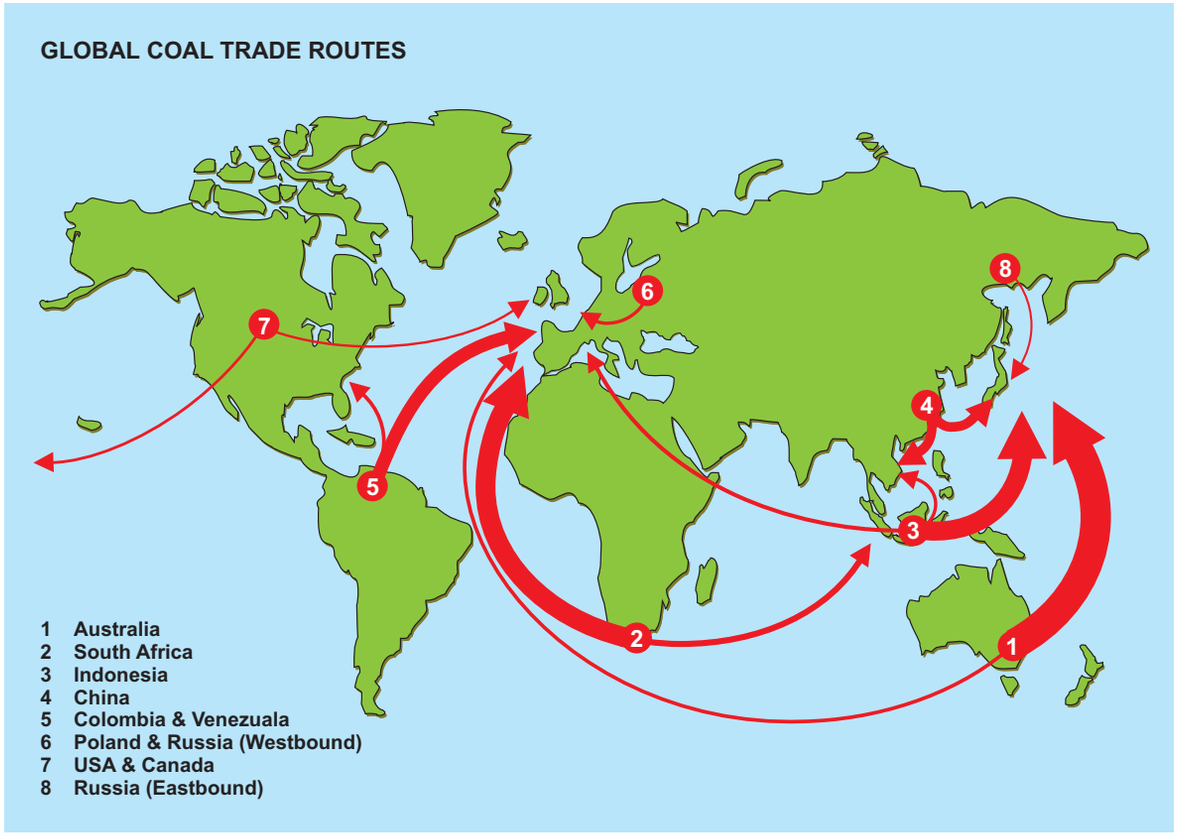
Australia has a successful coal export industry because it has:

- large quantities of accessible coal
- high quality, high energy-content coal
- mines located close to the coast
- highly mechanised and efficient mines
- efficient transport links to the ports
- efficient terminals/bulk loading facilities
- deepwater access for large ships
- low sulfur, low ash content coal
- skilled workforce and management
- low cost electricity supplies
- excellent environmental credentials.



Major Coal Producing and Exporting Nations in 2001.

Global Coal Trade Routes indicating volumes exported for 2001.



Coal Exports

Most of the export mines occur in the Sydney-Gunnedah Basin of New South Wales and the Bowen Basin in Queensland. These basins contain large deposits of near-surface, bituminous coals and are relatively near deepwater ports. High capacity rail lines connect each mining area to a port.

A stockpile of coal is maintained at the coal terminal to ensure rapid ship loading. As well, different types of coal may be blended to meet specific customer requirements.

Coal was Australia's most important export commodity in 2002. The value of the coal exported was over $13 billion. Coal is thus an important contributor to the lifestyle enjoyed by all Australians, and coal will remain a vital export earner for many decades to follow!

Ship loading facilities.
Photo courtesy of BHP Billiton Mitsubishi Alliance

Mining operations showing bucket wheel excavator.
Photo Courtesy of NSW Minerals Council

Fossil fuels and climate change

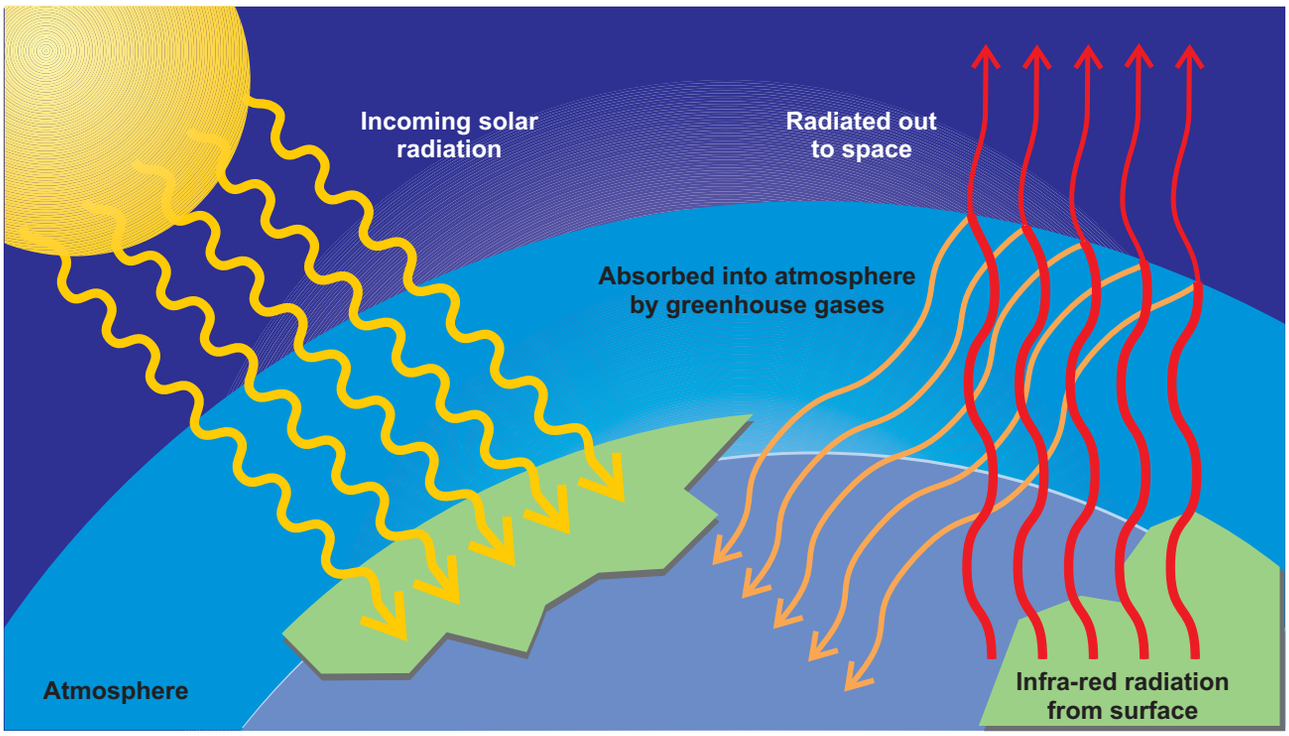
The 'greenhouse effect' is a natural process in which gases that make up the atmosphere help to regulate the Earth's climate by trapping some solar radiation that would otherwise be radiated back out into space. The process is very similar to the effect of a glassed-in greenhouse, which traps heat to help plants to grow. Without this effect, the Earth's temperature would be some 30 degrees centigrade cooler than the current average of 15 degrees.

Atmospheric concentration of carbon dioxide, the major 'greenhouse gas', and the Earth's temperature are known to have varied throughout geological history. The decay of plants and animal material is one of the natural processes which releases carbon dioxide to the atmosphere, while photosynthesis by plants removes it.

The burning of fossil fuels, including coal, oil and natural gas, releases additional greenhouse gases into the atmosphere. This has resulted in a build up of atmospheric concentrations of these gases, in particular carbon dioxide and methane. Many scientists believe that this unnatural build-up is enhancing the natural greenhouse effect, causing global warming and changes to the Earth's climate.

The use of low-cost coal for electricity generation has brought with it many economic and social benefits. It has underpinned economic development since the industrial revolution of the 19th century and is now bringing social progress and raised living standards to developing countries where nearly two billion people still have no access to electricity.

The challenge is to maintain the many benefits society derives from access to low cost coal-based electricity, while at the same time reducing or eliminating greenhouse gas emissions. As the result of a major global research and development effort over the past decade, new and emerging clean coal technologies are promising to revolutionise the way coal is used and are significantly reducing greenhouse gas emissions.



The Greenhouse Effect - without this natural phenomenon the surface temperature of the earth would be some 30 degrees cooler and life would be impossible. The Greenhouse effect is caused by gases in the atmosphere trapping solar heat radiated by the Earth. Courtesy of Australian Coal Association

Clean Coal Technologies

Clean coal technologies improve the performance of coal as an energy source and reduce its impact on the environment. They are being developed for all facets of coal production and use – from the extraction, preparation, storage and transportation, through to use in power stations, steel mills and other industrial applications. Examples of how clean coal technologies can be employed include:

In coal production…

- Reducing greenhouse gas emissions during mining by capturing methane gas and using it to provide power for the mine, for local communities, and for input to the electricity grid. Not only does this provide an additional source of energy but also helps to reduce the safety risks associated with potentially explosive methane build-up in mines.

- Using advanced preparation and cleaning techniques to eliminate impurities from coal, so that it burns more cleanly and efficiently and helps to reduce emissions to the atmosphere.

In coal use…

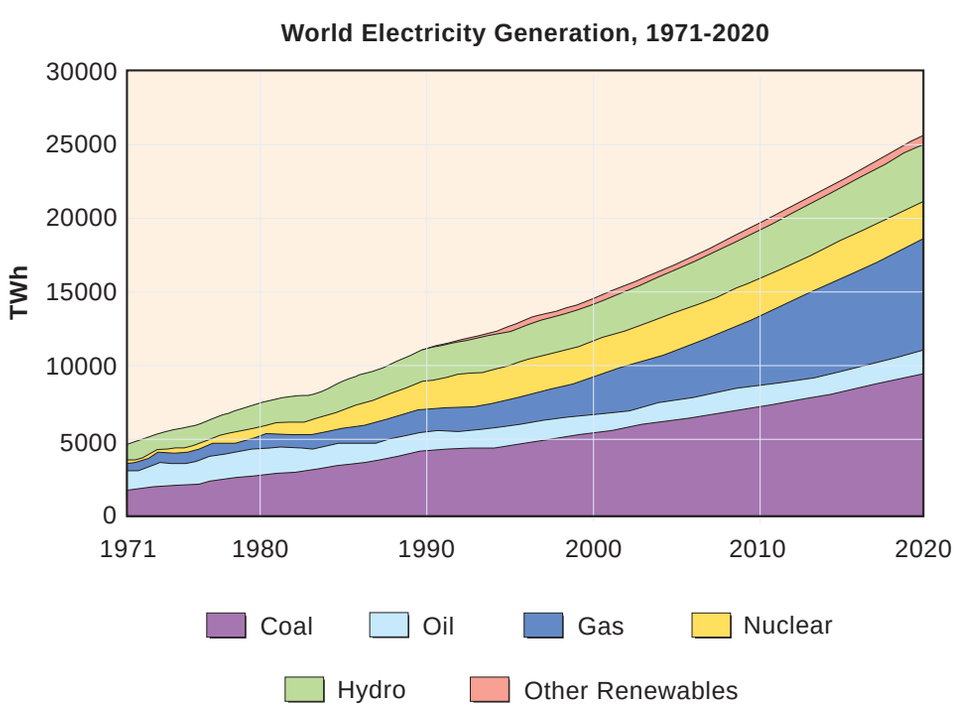
- Employing new combustion processes to improve thermal efficiency (the amount of useful energy that can be obtained from a given quantity of fuel). Increasing thermal efficiency reduces greenhouse gas emissions and other pollutants.

- Incorporating pollution control devices in power stations to capture gases such as oxides of sulfur and nitrogen, which are produced when coal is burned.

- Converting coal to gas (gasification), mainly hydrogen, and using this as the primary fuel source in power stations, instead of burning coal directly.

- Capturing the carbon dioxide (a greenhouse gas) that results from the burning of coal or coal gas, and storing it permanently underground (known as carbon sequestration).

Methane extraction system at Central Colliery coal mine, German Creek. Photo courtesy of NSW Minerals Council



TWh = terrawatt - hour

Source: International Energy Agency

A zero emission future for coal?

A number of advanced coal technologies for electricity generation are already being trialled throughout the world. Several of these have the potential to achieve electricity production from coal without emissions to the atmosphere.

One that shows great promise in terms of its high efficiency and environmental performance is the Integrated Gasification Combined Cycle (IGCC) system. In IGCC, coal is initially converted to gas, mainly carbon monoxide and hydrogen. Electricity is produced when the gas is burned in a gas turbine with the excess heat used to drive a steam turbine resulting in even greater efficiency.

Another advantage of IGCC is that a concentrated stream of carbon dioxide, a major greenhouse gas, can be produced. This can be readily captured and then stored in underground formations, resulting in zero emissions to the atmosphere.

This system also has the potential to produce chemicals and liquid fuels from the coal gas, in addition to electricity. In the future, hydrogen from coal gasification may also be used to generate clean power in fuel cells or to run hydrogen-powered vehicles.

Did you know?

Coal forms the most significant fossil fuel resource on Earth, much more plentiful than oil and gas and will therefore be the most significant source of energy for many years to come.

A zero emission coal plant of the future

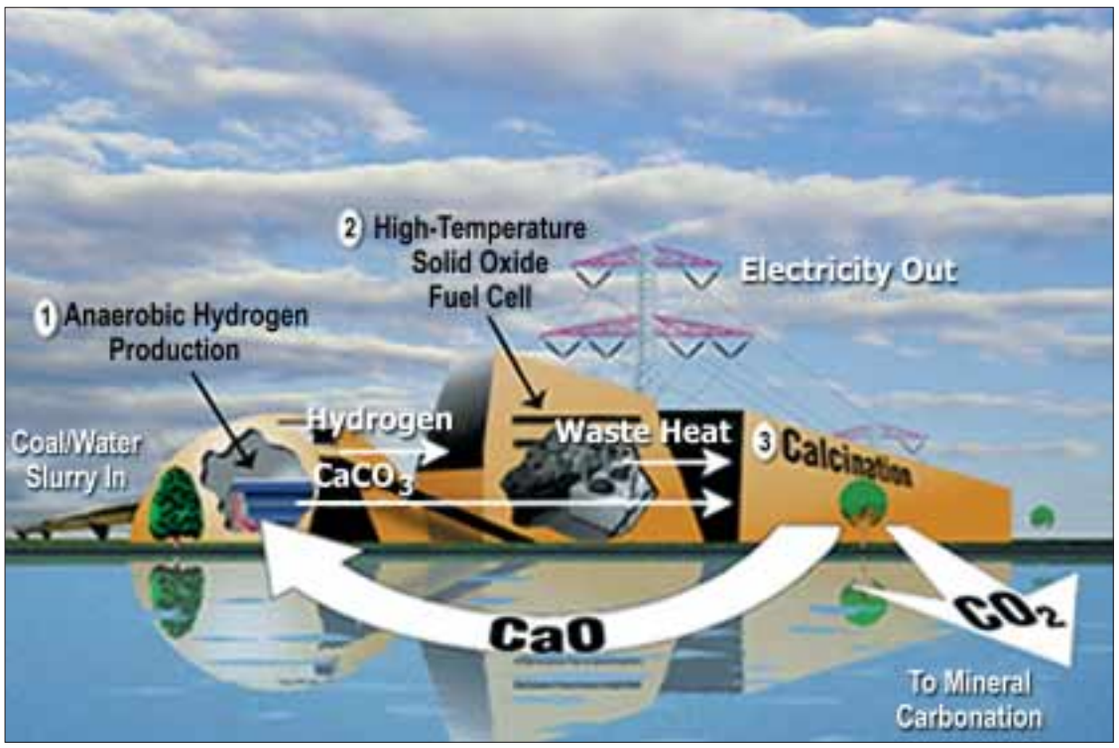


Photo Courtesy of Los Alamos National Laboratory, USA

Other Energy Sources

More than 90 per cent of the world's energy demands are met by fossil fuels, including coal, oil and gas. As the most abundant, widely distributed and lowest cost fuel, coal is used to generate more than a third of the world's electricity.

Greenhouse gas emissions and other environmental impacts associated with the use of fossil fuels have led to interest in the potential of alternative or 'renewable' energy sources. These include sources such as solar, wind, hydro, geothermal, tidal and biomass.

While the use of these alternatives is growing, none are yet capable of economically meeting society's enormous and rapidly growing demand for energy. World demand for energy of all types is expected to increase by 60 per cent over the next 20 years. Demand for electricity is expected to almost double. Renewable energy is expected to meet an increasing share of this demand. However, high costs and practical limitations mean their overall contribution will remain relatively small for the foreseeable future.

Energy trapped by plants may be converted to fuel which can supplement fossil fuels.
Photo courtesy of Bundaberg Sugar Ltd

In many parts of the world nuclear power provides another alternative to fossil fuels for electricity generation. However, higher costs and community concerns over the safety of nuclear reactors and radioactive waste have seen the uptake of nuclear power much reduced in the past few years. Australia has no nuclear power plants.

Wind powered electricity generators.
Photo courtesy of Bluewind

Photo-electric cells mounted on the roofs of buildings.
Photo courtesy of Pacific Energy

Other Energy Sources

Source	Application	Current Status	Advantages	Disadvantages
Conventional Coal	Coal is burned in a furnace to raise steam which drives a turbine.	Provides 85 per cent of Australia's and 38 per cent of the world's electricity.	The most abundant and widely distributed fossil fuel and the lowest cost form of electric power generation.	High greenhouse gas emissions.
Clean Coal including Integrated Coal Gasification Combined Cycle (IGCC) and carbon dioxide capture and storage.	Coal is reacted with oxygen and water to produce a hydrogen-rich gas which is then combusted in a turbine. Carbon dioxide is captured and permanently stored underground.	Both IGCC and carbon dioxide capture and storage have been demonstrated. Further research and development is required to reduce costs.	Maintains access to abundant, low cost energy from coal with lower or zero greenhouse gas emissions.	Higher cost than conventional coal, but potentially less costly than most alternatives.
Natural Gas	Gas is burned directly in a turbine.	Provides 17 per cent of the world's electricity.	Proven technology and lower cost than alternatives apart from coal.	High greenhouse gas emissions. Less abundant and higher cost than coal.
Nuclear	Uranium is used in a nuclear fission reaction to produce heat.	Provides 16 per cent of the world's electricity.	No greenhouse gas emissions.	The safety of reactors and the difficulty of dealing with resulting radioactive waste.
Solar	The energy of the sun is trapped by solar cells to heat water (solar thermal) or produce electricity directly (photovoltaics).	Provides less than 0.1 per cent of the world's electricity.	Renewable and low greenhouse gas emissions.	High cost. Intermittent - only works when the sun is shining.
Wind	Wind striking propeller blades is used to drive turbines.	Provides less than 0.5 per cent of the world's electricity.	Low greenhouse gas emissions.	Lower cost than solar but higher than coal and gas. Intermittent - only works when sufficient wind is present.
Hydro	Water stored in reservoirs falls through pipes via gravity and turns a turbine.	Provides 17 per cent of the world's electricity.	Relatively low greenhouse gas emissions (but may be significant while flooded vegetation in new dams decomposes).	Large scale application requires major interruption to natural watercourses and large areas of land. Suitable sites limited.
Geothermal	Water is pumped deep underground where it passes through hot geological formations. The resulting steam returns to the surface to drive a turbine.	Provides less than 0.5 per cent of the world's electricity.	Uses the natural heat of the Earth's core to produce theoretically limitless energy with no greenhouse gas emissions or other pollutants.	High cost and technological barriers still to be overcome for large scale applications.
Tidal/wave	The natural movement of tides and waves is used to drive turbines.	Provides less than 0.1 per cent of the world's electricity.	Renewable energy free of greenhouse gas emissions and other pollutants.	High cost and suitable sites are limited.
Biomass	Biomass (plant material such as agricultural or forest wastes) is burned to raise steam to drive a turbine.	Provides less than 1 per cent of the world's electricity.	Renewable and greenhouse gas neutral provided the crops used are regrown each year.	Requires very large areas of land to produce sufficient plant material.

Glossary

Anthracite a hard, black high energy value coal

Basin a depression in the Earth's crust filled with sediment

Biomass living material which can be converted to energy

Bituminous a rank of black coal of medium energy value

Bord and pillar underground mining method that leaves spaces (bords) and pillars (blocks of coal) supporting the roof

Blast furnace a tall furnace in which coke reacts with iron ore to reduce it to pure iron

Bulk commodities low value materials, such as iron ore and coal, which must be handled efficiently in large quantities if a profit is to be made from their sale

Carbon dioxide colourless, odourless gas formed when carbon combines with oxygen - CO_2. A major greenhouse gas

Coal an organic sedimentary rock formed from partly decayed plant material

Coalification the process where heat and pressure turn decomposing plant material to coal

Coal preparation process to convert mined coal to provide a pure product

Coal terminal stockpile of coal kept at a port

Colliery an underground coal mine

Coke solid lump of almost pure carbon formed when coal is heated in the absence of air

Coking coal coal used for making coke to feed a blast furnace for making steel. Also known as metallurgical coal

Dragline a large bucket excavator used in open cut mines

Generator machine which, when the magnet around its shaft is turned, generates electricity in the surrounding coils of wire

Glossopteris an extinct seed-fern which makes up most Permian coal deposits

Kinetic energy energy possessed by a moving or rotating object

Longwall mining mining technique where a mechanical shearer cuts along a coal face beneath a roof supported by hydraulic jacks

Methane a gas comprising one atom of carbon bound to four hydrogen atoms - CH_4. A major greenhouse gas

Opencut a surface mining method where coal is exposed by removing the overlying rock

Outcrop rock or mineral material exposed on the Earth's surface

Overburden waste rock material overlying a coal seam - also called spoil

Permian a major coal forming geological period, about 250 million years ago

Rank a method of classifying coal based on the amounts of carbon and volatile matter it contains

Rehabilitation the process of returning a mined land surface into productive use

Seam layer of coal - also called a bed

Sediment rock particles, such as sand and clay, produced by weathering

Thermal coal coal used in boilers for generating steam. Also known as steaming coal

Topsoil surface layer of soil

Turbine machine in which blades are turned by gas or steam, usually connected to a generator

Web addresses

Australian Coal Association: **www.australiancoal.com.au**

World Coal Institute: **www.wci-coal.com.au**

There is a virtual tour of a coal mine at the NSW Minerals Council: **www.nswmin.com.au**

Queensland Mining Council: **www.qmc.com.au**

Back Cover: Mining operations at dusk. Photo Courtesy of BHP Billiton

ITAM stands for 'Introduction to Australia's Minerals' and is the acronym for a series of booklets written to provide information for teachers and students.

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