Coal

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Coal is a fossil fuel extracted from the ground by underground mining or open-pit mining (strip mining). It is a readily combustible black or brownish-black sedimentary rock. It is composed primarily of carbon along with assorted other elements, including sulfur. Often associated with the Industrial Revolution, coal remains an enormously important fuel and is the largest single source of electricity world-wide. In the United States, for example, the burning of coal generates 50% of the electricity consumed.

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Etymology and folklore

The word "coal" came from Anglo-Saxon col, which meant charcoal. Coal was not mined in Britain before the late Middle Ages; i.e. after ca. 1000 AD. Mineral coal was referred to as sea-coal, either because it was found on beaches occasionally having fallen from the exposed coal seams above or washed out of underwater coal seam outcrops, or because it was easier to transport by sea rather than on the very poor road system; in London, England there is still a Seacoal Lane (off the north side of Ludgate Hill) where the coal merchants conducted their business.

It is associated with the astrological sign Capricorn. It is carried by thieves to protect them from detection and to help them to escape when pursued. It is an element of a popular ritual associated with New Year's Eve. To dream of burning coals is a symbol of disappointment, trouble, affliction, and loss, unless they are burning brightly, when the symbol gives promise of uplifting and advancement.

Santa Claus is said to leave a lump of coal instead of Christmas presents in the stockings of naughty children.
[edit]

Composition

Carbon forms more than 50 percent by weight and more than 70 percent by volume of coal (this includes inherent moisture). This is dependent on coal rank, with higher rank coals containing less hydrogen, oxygen and nitrogen, until 95% purity of carbon is achieved at Anthracite rank and above. Graphite formed from coal is the end-product of the thermal and diagenetic conversion of plant matter (50% by volume of water) into pure carbon.

Coal usually contains a considerable amount of incidental moisture, which is the water trapped within the coal in between the coal particles. Coals are usually mined wet and may be stored wet to prevent spontaneous combustion, so the carbon content of coal is quoted as both a 'as mined' and on a 'moisture free' basis.

Lignite and other low-rank coals still contain a considerable amount of water and other volatile components trapped within the particles of the coal, known as its macerals. This is present either within the coal particles, or as hydrogen and oxygen atoms within the molecules. This is because coal is converted from carbohydrate material such as cellulose, into carbon, which is an incremental process (see below). Therefore coal carbon contents also depend heavily on the degree to which this cellulose component is preserved in the coal.

Other constituents of coals include mineral matter, usually as silicate minerals such as clays, illite, kaolinite and so forth, as well as carbonate minerals like siderite, calcite and aragonite. Iron sulphide minerals such as pyrite are common constituents of coals. Sulphate minerals are also found, as is some form of salt, trace amounts of metals, notably iron, uranium and cadmium, and rarely gold.

Methane gas is another component of coal, produced not from bacterial means but from methanogenesis. Methane in coal is dangerous as it can cause coal seam explosions especially in underground mines, and may cause the coal to spontaneously combust. It is, however, a valuable by-product of some coal mining, serving as a significant source of natural gas.

Coal composition is determined by specific coal assay techniques, and is performed to quantify the physical, chemical and mechanical behaviour of the coal, including whether it is a good candidate for coking coal. [edit]

Creation

Coal is formed from plant remains that have been compacted, hardened, chemically altered, and metamorphosed by heat and pressure over geologic time.

Coal was formed in swamp ecosystems which persisted in lowland sedimentary basins similar, for instance, to the peat swamps of Borneo today. These swamp environments were formed during slow subsidence of passive continental margins, and most seem to have formed adjacent to estuarine and marine sediments suggesting that they may have been in tidal delta environments.

When plants die in these peat swamp environments, their biomass is deposited in anaerobic aquatic environments where low oxygen levels prevent their complete decay by bacteria and oxidation. For masses of undecayed organic matter to be preserved and to form economically valuable coal the environment must remain steady for prolonged periods of time, and the waters feeding these peat swamps must remain essentially free of sediment. This requires minimal erosion in the uplands of the rivers which feed the coal swamps, and efficient trapping of the sediments.

Eventually, and usually due to the initial onset of orogeny or other tectonic events, the coal forming environment ceases. In the majority of cases this is abrupt, with the majority of coal seams having a knife-sharp upper contact with the overlying sediments. This suggests that the onset of further sedimentation quickly destroys the peat swamp ecosystem and replaces it with meandering stream and river environments during ongoing subsidence.

Burial by sedimentary loading on top of the peat swamp converts the organic matter to coal by the following processes;

- compaction, due to loading of the sediments on the coal which flattens the organic matter
- removal of the water held within the peat in between the plant fragments
- with ongoing compaction, removal of water from the inter-cellular structure of fossilised plants
- with heat and compaction, removal of molecular water
- methanogenesis; similar to treating wood in a pressure cooker, methane is produced, which removes hydrogen and some carbon, and some further oxygen (as water)
- dehydrogenation, which removes hydroxyl groups from the cellulose and other plant molecules, resulting in the production of hydgen-reduced coals

Generally, to form a coal seam 1 metre thick, between 10 and 30 metres of peat is required. Peat has a moisture content of up to 90%, so loss of water is of prime importance in the conversion of peat into lignite, the lowest rank of coal. Lignite is then converted by dehydrogenation and methanogenesis to sub-bituminous coal. Further dehydrogenation reactions, removing progressively more methane and higher hydrocarbon gases such as ethane, propane, etcetera, create bituminous coal and, when this process is complete at sub-metamorphic conditions, anthracite and graphite are formed.

Evidence of the types of plants that contributed to carbonaceous deposits can occasionally be found in the shale and sandstone sediments that overlie coal deposits and within the coal. Fossil evidence is best preserved in lignites and sub-bituminous coals, though fossils in anthracite is not too rare. To date only three fossils have been found in graphite seams created from coal.

The greatest coal-forming time in geologic history was during the Carboniferous era (280 to 345 million years ago). Further large deposits of coal are found in the Permian, with lesser but still significant Triassic and Jurassic deposits, and minor Cretaceous and younger deposis of lignite. In the modern European lowlands of Holland and Germany considerable thicknesses of peat have accumulated, testifying to the ubiquity of the coal-forming process.

In Europe, Asia, and North America, the Carboniferous coal was formed from tropical swamp forests, which are sometimes called the "coal forests". Southern hemisphere Carboniferous coal was formed from the Glossopteris flora, which grew on cold periglacial tundra when the South Pole was a long way inland in Gondwanaland. [edit]

Types of coal

As geological processes apply pressure to peat over time, it is transformed successively into:
- Lignite - also referred to as brown coal, is the lowest rank of coal and used almost exclusively as fuel for steam-electric power generation. Jet is a compact form of lignite that is sometimes polished and has been used as an ornamental stone since the Iron Age.
- Sub-bituminous coal - whose properties range from those of lignite to those of bituminous coal and are used primarily as fuel for steam-electric power generation.
- Bituminous coal - a dense coal, usually black, sometimes dark brown, often with well-defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities also used for heat and power applications in manufacturing and to make coke.
- Anthracite - the highest rank, used primarily for residential and commercial space heating. [edit]

Uses

Coal rail cars in Ashtabula, Ohio [edit]

Coal as fuel See also Clean coal

Coal is primarily used as a solid fuel to produce heat through combustion.

World coal consumption is about 5,800 million short tons (5.3 petagrams) annually, of which about 75% is used for electricity production. The region including China and India uses about 1,700 million short tons (1.5 Pg) annually, forecast to exceed 3,000 million short tons (2.7 Pg) in 2025. [1] The USA consumes about 1,100 million short tons (1.0 Pg) of coal each year, using 90% of it for generation of electricity. Coal is the fastest growing energy source in the world, with coal use increasing by 25% for the three-year period ending in December 2004 (BP Statistical Energy Review, June 2005).

When coal is used in electricity generation, it is generally pulverized and then burned. The heat produced is used to create steam, which is then used to spin turbines which turn generators and create electricity. Approximately 40% of the Earth's current electricity production is powered by coal, and the total known deposits recoverable by current technologies are sufficient for 300 years' use at current rates (see World Coal Reserves, below).

A promising, more energy efficient way of using coal for electricity production would be via solid-oxide fuel cells or molten-carbonate fuel cells (or any oxygen ion transport based fuel cells that do not discriminate between fuels, as long as they consume oxygen), which would be able to get 60%-85% combined efficiency (direct electricity + waste heat steam turbine), compared to 30-40% currently possible with only steam turbines. Currently these fuel cell technologies can only process gaseous fuels, and they are also sensitive to sulfur poisoning, issues which would first have to be worked out before large scale commercial success is possible with coal. As far as gaseous fuels go, one idea is pulverized coal in a gas carrier (nitrogen), especially if the resulting carbon dioxide is sequestered, and has to be separated anyway from the carrier. A better idea is coal gasification with water, then the water recycled. [edit]

Gasification

High prices of oil and natural gas are leading to increased interest in "BTU Conversion" technologies such as coal gasification, methanation, liquefacation, and solidification.

In the past, coal was converted to make coal gas, which was piped to customers to burn for illumination, heating, and cooking. At present, the safer natural gas is used instead. South Africa still uses gasification of coal for much of its petrochemical needs.

Gasification is also a possibility for future energy use, as it generally burns hotter and cleaner than conventional coal, can spin a more efficient gas turbine rather than a steam turbine, and makes capturing carbon dioxide for later sequestration much much easier. [edit]

Liquefaction

Coal can also be converted into liquid fuels like gasoline or diesel by several different processes. The Fischer-Tropsch process of indirect synthesis of liquid hydrocarbons was used in Nazi Germany, and for many years by Sasol in South Africa - in both cases, because those regimes were politically isolated and unable to purchase crude oil on the open market. Coal would be gasified to make syngas (a balanced purified mixture of CO and H2 gas) and the syngas condensed using Fischer-Tropsch catalysts to make light hydrocarbons which are further processed into gasoline and diesel. Syngas can also be converted to methanol: which can be used as a fuel, fuel additive, or further processed into gasoline via the Mobil M-gas process.

A direct liquefaction process Bergius process (liquefaction by hydrogenation) is also available but has not been used outside Germany, where such processes were operated both during World War I and World War II. SASOL in South Africa has experimented with direct hydrogenation. Several other direct liquefaction processes have been developed, among these being the SRC-I and SRC-II (Solvent Refined Coal) processes developed by Gulf Oil and implemented as pilot plants in the United States in the 1960's and 1970's.[2]

Yet another process to manufacture liquid hydrocarbons from coal is low temperature carbonization (LTC). Coal is coked at temperatures between 450 and 700 °C compared to 800 to 1000 °C for metalurgical coke. These temperatures optimize the production of coal tars richer in lighter hydrocarbons than normal coal tar. The coal tar is then further processed into fuels. The process was developed by Lewis Karrick, an oil shale technologist at the U.S. Bureau of Mines in the 1920s.[3]

All of these liquid fuel production methods release carbon dioxide (CO2) in the conversion process. Carbon dioxide sequestration is proposed to avoid releasing it into the atmosphere. As CO2 is one of the process streams, sequestration is easier than from flue gases produced in combustion of coal with air, where CO2 is diluted by nitrogen and other gases.

Coal liquefaction is one of the backstop technologies that limit escalation of oil prices. Estimates of the cost of producing liquid fuels from coal suggest that domestic U.S. production of fuel from coal becomes cost-competitive with oil priced at around 35 USD per barrel [4], (break-even cost), which is well above historical averages - but is now viable due to the spike in oil prices in 2004-2005. [5].

Among commercially mature technologies, advantage for indirect coal liquefaction over direct coal liquefaction are reported by Williams and Larson (2003). Estimates are reported for sites in China where break-even cost for coal liquefaction may be in the range between 25 to 35 USD/barrel of oil. [edit]

Coking and use of coke

Main article: Coke (fuel)

Coke is a solid carbonaceous residue derived from low-ash, low-sulfur bituminous coal from which the volatile constituents are driven off by baking in an oven without oxygen at temperatures as high as 1,000 °C (2,000 °F) so that the fixed carbon and residual ash are fused together. Coke is used as a fuel and as a reducing agent in smelting iron ore in a blast furnace. Coke from coal is grey, hard, and porous and has a heating value of 24.8 million Btu/ton (29.6 MJ/kg). Byproducts of this conversion of coal to coke include coal-tar, ammonia, light oils, and "coal-gas".

Petroleum coke is the solid residue obtained in oil refining, which resembles coke but contains too many impurities to be useful in metallurgical applications. [edit]

Harmful effects of coal burning

Combustion of coal, like any other compound containing carbon, produces carbon dioxide (CO2), along with varying amounts of sulfur dioxide (SO2) depending on where it was mined. Sulfur dioxide reacts with water to form sulfurous acid. If sulfur dioxide is discharged into the atmosphere, it reacts with water vapor and is eventually returned to the Earth as acid rain.

Emissions from coal-fired power plants represent the largest source of artificial carbon dioxide emissions, according to most climate scientists a primary cause of global warming. Many other pollutants are present in coal power station emissions. Some studies claim that coal power plant emissions are responsible for tens of thousands of premature deaths annually in the United States alone. Modern power plants utilize a variety of techniques to limit the harmfulness of their waste products and improve the efficiency of burning, though these techniques are not widely implemented in some countries, as they add to the capital cost of the power plant. To eliminate CO2 emissions from coal plants, carbon sequestration has been proposed but is not yet in large-scale use.

Coal also contains many trace elements, including arsenic and mercury, which are dangerous if released into the environment. Coal also contains low levels of uranium, thorium, and other naturally-occurring radioactive isotopes whose release into the environment may lead to radioactive contamination.[6][7] While these substances are trace impurities, enough coal is burned that significant amounts of these substances are released, paradoxically resulting in more radioactive waste than nuclear power.

If coal liquefaction or gasification is used to make petrochemicals, a great deal of carbon dioxide is produced in the process. If a carbon tax was introduced and sufficient CO2 was not captured, the economics of such processes would be significantly less attractive. However, if sequestration or some other process were used to dispose of this by-product, fuels produced from this process would be less polluting. Some process do not have a much greater total impact on carbon dioxide levels than ones refined from petroleum. Others may be less polluting still. Research in this field is ongoing. [edit]

Coal fires

There are hundreds of coal fires burning around the world.[8] Those burning underground can be difficult to locate and many can not be extinguished. Fires can cause the ground above to subside, combustion gases are dangerous to life, and breaking out to the surface can initiate surface wildfires.

Coal seams can be set on fire by spontaneous combustion or contact with a mine fire or surface fire. A grass fire in a coal area can set dozens of coal seams on fire.[9] [10] Coal fires in China burn 120 million tons of coal a year, emitting 360 million metric tons of carbon dioxide. This amounts to 2-3% of the annual worldwide production of CO2 from fossil fuels, or as much as emitted from all of the cars and light trucks in the United States. [11] [12]

In the United States , a trash fire was lit in the borough landfill located in an abandoned Anthracite strip mine pit in the portion of the Coal Region called Centralia, Pennsylvania from 1962. It burns underground today, 44 years later.

The reddish siltstone rock that caps many ridges and buttes in the Powder River Basin (Wyoming), and in western North Dakota is called porcelanite, which also may resemble the coal burning waste "clinker" or volcanic "scoria." [13] Clinker is rock that has been fused by the natural burning of coal. In the case of the Powder River Basin approximately 27 to 54 billion metric tons of coal burned within the past three million years. [14] Wild coal fires in the area were reported by the Lewis and Clark expedition as well as explorers and settlers in the area. [15]

The Australian Burning Mountain was originally believed to be a volcano, but the smoke and ash comes from a coal fire which may have been burning for 5,000 years.[16] [edit]

World coal reserves

It has been estimated that, as of 1996, there is around one exagram (1 × 1015 kg) of total coal reserves accessible using current mining technology, approximately half of it being hard coal. The energy value of all the world's coal is well over 100,000 quadrillion Btu (100 zettajoules). There probably is enough coal to last for 300 years. However, this estimate assumes no rise in population, and no increased use of coal to attempt to compensate for the depletion of natural gas and petroleum. A recent (2003) study by scientist Gregson Vaux, which takes those factors into account, estimates that coal could peak in the United States as early as 2046, on average. "Peak" does not mean coal will disappear, but defines the time after which no matter what efforts are expended coal production will begin to decline in quantity and energy content. The disappearance of coal will occur much later, around the year 2267, assuming all other factors do not change, which they naturally will.[17] British Petroleum, in its annual report 2005, estimated at 2004 end, there were 909,064 million tons of proved coal reserves worldwide, or 164 years reserve to production ratio.

US coal regions.

The United States Department of Energy uses estimates of coal reserves in the region of 1,081,279 million short tons, which is about 4,786 BBOE (billion barrels of oil equivalent) [18]. The amount of coal burned during 2001 was calculated as 2.337 GTOE (gigatonnes of oil equivalent), which is about 46 MBOED (million barrels of oil equivalent per day) [19]. At that rate those reserves will last 285 years. As a comparison natural gas provided 51 MBOED, and oil 76 MBD (million barrels per day) during 2001. [edit]

See also

- Major coal producing regions
- Major coal exporters
- Charcoal
- Coal mining techniques
- Clean coal
- Coal dust
- Coal-tar
- Coal Measure (stratigraphic unit)
- List of environment topics
- List of rocks
- Fluidized bed combustion
- Energy value of coal
- Coal assay

- Granular material
- Future energy development
- Indian coal
- History of coal mining [edit]

External links Wikimedia Commons has media related to: Coal

- MSNBC report on coal pollution health effects in the United States
- Clean coal technologies
- Use of coal gas in fuel cells
- Advanced methods of using coal (Japanese Coal Energy Center) [edit]

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