COAL

A SOURCE OF CONSUMABLE ENERGY

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Interdisciplinary Science 102

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What Is Coal and How Is It Formed

Coal is one of the most useful natural resource found in the earth. Ralph Waldo Emerson said, “We may well call it black diamonds. Every basket is power and civilization.” It has been given credit for being the power source that made the industrial revolution possible and advancing civilization as we know it today.

Coal is an organic sedimentary rock. It is composed of mostly organic materials with small amounts of inorganic minerals. The amount of organic material can vary quite a bit. Generally, anything with over 33% minerals is considered as shale, rather than coal. (Argonne)

To the left is a black and white image of a typical piece of coal you would find in any coal pile. It is about two inches across. The bands represent the process of laying down different layers of organic material. (Argonne)

There are two schools of thought with regards to how coal is formed, catastrophic burial and gradual accumulation. The arguments for and against both theories are documented although the more widely accepted theory is gradual accumulation. In the appendix links to web sites for both theories have been included.

As per the USGS, “Coal systems are the result of the geological processes related to the formation, chemical and physical alteration and thermal maturation of the organic sediment.” Coal formation is believed to have begun between 360 million–290 million years ago. This is called the Carboniferous Period or the ‘first coal age’. Coal is formed
when plants die in peat swamp environments. These plants are deposited in a low oxygen aquatic environment which prevents their complete decay. Undecayed organic matter is preserved for long periods of time allowing build up of this organic material. Sudden burial by sedimentary loading together with the movement of the earth’s crust buried these swamps and peat bogs sometimes at great depths. This burial converts the organic material through compaction and removal of water from the peat and plant matter. With heat and compaction, the methanogenasis process occurs which removes more oxygen, hydrogen and some carbon. This process is known as coalification. It takes approximately 10 to 30 meters of peat to produce a 1 meter coal seam.

All types of coal are ranked by purity and carbon content. They are Lignite, Sub-bituminous coal, Bituminous coal, and Anthracite.

( graphic provided by World Coal Institute)
- **Lignite** — the lowest rank, a brown coal with moisture content sometimes as high as 45%, very high ash content, heat content ranges from 9 to 17 million BTUs/short ton

- **Sub-Bituminous coal** — moisture content of 20 to 30%, heat content ranges from 17 to 24 million BTUs/short ton

- **Bituminous coal** — carbon content around 60 to 80% with the rest being oxygen, hydrogen, and sulfur, heat content ranges from 21 to 30 million BTUs/short ton

- **Anthracite** — moisture content is less than 15%, heat content ranges from 22 to 28 million BTUs/short ton (Wikipedia)

Coal is comprised of more than 50% carbon by weight and more than 70% carbon by volume. Coal also includes mineral matter such as silicate minerals, carbonate minerals, iron sulfate minerals, sulfate minerals, trace metals like iron, uranium, cadmium and rarely gold. Coal also contains a considerable amount of incidental moisture.

**Coal as an Energy Source**

Coal is most often used as a solid fuel for heat through combustion but there are several other ways in which to use coal. Liquefactions is when coal is converted into gasoline or diesel. Coal can be converted into ‘coal gas’ or manufactured gas. This was used in the US prior to the development of the safer natural gas. Coke fuel is derived from low ash, low sulfur bituminious coal baked at 1000 degrees Celsius. This is used as a fuel and reducing agent for smelting iron ore. There are also fuel cells using coal that work like batteries transforming chemical energy into electricity.

Coal can be found in every continent in over 70 countries. The largest reserves can be found in the USA, Russia, China and India. Coal reserves are found through
exploration involving creating geological maps of an area, followed by geochemical and geophysical surveys and exploratory drilling.

About 25% of the world's coal reserves can be found in the United States. In the U.S., coal is used primarily to generate electricity although it is also used as a primary energy source for many industries, including cement, steel and paper. As per the Energy Information Agency 2005 Annual Electric Power report released in November, coal-fired capacity accounted for nearly 33 percent of the US electric generating capacity in 2004.

Figure ES 1. U.S. Electric Power Industry Net Summer Capacity, 2004

Source: Energy Information Administration, Form EIA-860, "Annual Electric Generator Report."
The Energy Information Agency’s Annual Coal Report released September 2004, reported coal production in the United States increased in 2004 by 40.3 million short tons to end the year at 1,112.1 million short tons (3.8 percent higher than 2003). The rebounding economy in 2004 helped to drive up the demand for coal during 2004. In addition, coal prices rose across the board in 2004. The average open market f.o.b. mine price increased 11.6 percent over 2003 to $19.93 per ton.

The U.S. Government collects data on energy consumption. In the appendix is an excerpt from a table from the Energy Information Agency showing U.S. Coal Consumption for 2004 and the 3rd quarter of 2005. For complete information you may visit the website at http://www.eia.doe.gov/cneaf/coal/quarterly/html/t28p01p1.html. Based on information provided by the EIA, the demand for coal will continue to increase as other sources of energy become more scarce and costly.

**Problems Facing the Use of Coal in the Future**

**Workforce**

Coal mining is hazardous work. Just within the last few months two major mining accidents have claimed the lives of miners as they worked deep underground. The population of coal miners is aging and the industry is finding it difficult to recruit younger replacement workers. The following graph is an excerpt from a graph published by the US Department of Labor, Mine Safety & Health Administration. It show the
Average Number of Employees at Coal Mines in the United States, by Primary Activity

<table>
<thead>
<tr>
<th>Year</th>
<th>Underground Mines</th>
<th>Surface Mines</th>
<th>Total</th>
<th>Strip</th>
<th>Auger</th>
<th>Culm Bank</th>
<th>Dredge</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Underground</td>
<td>Surf at UG</td>
<td>Total</td>
<td>Strip</td>
<td>Auger</td>
<td>Culm</td>
<td>Dredge</td>
<td>Total</td>
</tr>
<tr>
<td>1980</td>
<td>127,169</td>
<td>15,480</td>
<td>142,649</td>
<td>70,776</td>
<td>584</td>
<td>360</td>
<td>70</td>
<td>71,790</td>
</tr>
<tr>
<td>1985</td>
<td>89,073</td>
<td>11,959</td>
<td>101,012</td>
<td>62,516</td>
<td>628</td>
<td>382</td>
<td>126</td>
<td>63,652</td>
</tr>
<tr>
<td>1990</td>
<td>70,955</td>
<td>11,486</td>
<td>82,441</td>
<td>54,940</td>
<td>874</td>
<td>607</td>
<td>147</td>
<td>56,568</td>
</tr>
<tr>
<td>1995</td>
<td>49,437</td>
<td>10,385</td>
<td>59,822</td>
<td>44,918</td>
<td>867</td>
<td>759</td>
<td>93</td>
<td>46,637</td>
</tr>
<tr>
<td>2000</td>
<td>37,663</td>
<td>8,470</td>
<td>46,133</td>
<td>39,537</td>
<td>948</td>
<td>673</td>
<td>196</td>
<td>41,354</td>
</tr>
<tr>
<td>2001</td>
<td>39,667</td>
<td>8,727</td>
<td>48,394</td>
<td>42,271</td>
<td>1,175</td>
<td>772</td>
<td>161</td>
<td>44,379</td>
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<tr>
<td>2002</td>
<td>38,075</td>
<td>8,540</td>
<td>46,615</td>
<td>41,315</td>
<td>1,077</td>
<td>694</td>
<td>116</td>
<td>43,202</td>
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<tr>
<td>2003</td>
<td>35,408</td>
<td>8,221</td>
<td>43,629</td>
<td>39,326</td>
<td>782</td>
<td>610</td>
<td>146</td>
<td>40,864</td>
</tr>
<tr>
<td>2004</td>
<td>37,187</td>
<td>8,095</td>
<td>45,282</td>
<td>41,206</td>
<td>867</td>
<td>765</td>
<td>113</td>
<td>42,951</td>
</tr>
</tbody>
</table>

decreasing number of miners working over the last 24 years. This recruitment problem will need to be addressed to insure an uninterrupted coal supply.

The recent mining accidents have brought to light a number of safety problems in our aging mines within the US. The mining industry is being encouraged to install self-contained rescue shelters in the mines. This would greatly improve the chances of survival during an underground accident but there are costly. This along with other safety concerns will need to be addressed if the industry hopes to encourage new workers into their employment.

Ecology

Mining, whether underground or surface mining, poses ecological hazards. Thanks to stricter regulations, improvements have been made but disturbances to soil, water, vegetation and other resources during extraction can still be significant. (BLM)

Below is a picture of NW Wyoming's Powder River Basin coal mine. This field produced
354 million tons of coal in 2004. It is easy to see how surface mining changes the landscape.

Picture provided by Bureau of Land Management

Pollution

Coal-fired power plants are a big contributor to the air pollution problem. "Power plant smokestacks are public health enemy number one for their contribution to deadly particulate pollution across the eastern United States," said Dr. John Balbus, a physician and head of a health program. "Particulate pollution contributes to tens of thousands of premature deaths annually, heart attacks, strokes and asthma attacks." (Environmental Defense) For a look at some of the worst air pollutant contributors visit “The Scorecard Pollution Information Site” by Green Media Toolshed at http://www.scorecard.org/env-releases/cap/rank-facilities.tcl?how_many=25&p pollutant=so2&fips_state_code=Entire+United+States.
This web site is very useful for looking at the number of different pollutants and who are the worst offenders. In an article published by the USGS, the principle pollutants generated by coal combustion are particulates, sulfur & nitrogen oxides, trace elements including mercury, arsenic, fluorine, selenium and radionuclides like uranium and thorium. In addition, there are organic compounds created by incomplete combustion.

The President's Clear Skies Initiative and EPA's Clean Air Interstate Rule and Clean Air Mercury Rule have prompted the development of technologies to reduce harmful emission from coal use. The Clear Skies Initiative proposed dramatic reductions in three pollutants emitted from coal-fired power plants. These emissions are sulfur dioxide, nitrogen oxide, and mercury. New particle recapture devices will lower particulate matter through new filtration systems and electrostatic precipitators. New research is developing more efficient technologies that can reuse power plant cooling and other process water. All these efforts will help to make coal a cleaner source of energy but many environmental groups claim that these measures do not go far enough. More work must be done to develop stronger legislation to insure that the focus on better technologies will continue while keeping coal an economically viable energy source.

Another major health concern is the use of low grade coals for domestic use in developing countries. Coal is used in poorly ventilated or unventilated stoves for heating and cooking. This allows for direct exposure to emissions which creates serious health problems.

**The Future of Coal**

According to the Energy Information Administration, there were about 1,081 billion short tons of recoverable reserves of coal in 2002. In theory, at the current rates of
production and no measurable changes in the coal reserves, there will be enough coal to last another two centuries. The global problem we face is that over the next 30 years the demand for energy will increase by almost 60% with two-thirds of the increase coming from developing countries. According to the World Coal Institute, the use of coal has grown faster than any other fuel in the pasts 2 years with China leading the way in increased demand. As other fossil fuel sources continue to be depleted and cost continues to rise, the reliance on coal will grow.

As the political unrest continues in the Middle East and the cost of oil continues to rise, coal will become a critical resource for the United States. According to the USGS, “Coal is the only primary energy source that can be supplied totally from domestic production.” So coal is a useful and abundant source of energy that if managed wisely has the potential of powering the United States for many years to come. The problem will be finding a balance between our need for a cheap abundant source of fuel and maintaining a habitable environment through controlling and/or eliminating the harmful pollutants currently being produced.
WORKS CITED


## U.S. Coal Consumption by End-Use Sector

### Data for: 3rd Quarter 2005

**Report Released: December 21, 2005**

### U.S. Coal Consumption by End-Use Sector

(Thousand Short Tons)

<table>
<thead>
<tr>
<th>Year and Quarter</th>
<th>Electric Power</th>
<th>Coke Plants</th>
<th>Other Industrial</th>
<th>Residential and Commercial</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2004</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January - March</td>
<td>252,263</td>
<td>5,905</td>
<td>16,413</td>
<td>1,537</td>
<td>276,117</td>
</tr>
<tr>
<td>April - June</td>
<td>238,499</td>
<td>5,931</td>
<td>14,861</td>
<td>1,024</td>
<td>260,315</td>
</tr>
<tr>
<td>July - September</td>
<td>270,735</td>
<td>5,893</td>
<td>14,878</td>
<td>1,024</td>
<td>292,531</td>
</tr>
<tr>
<td>October - December</td>
<td>254,771</td>
<td>5,942</td>
<td>16,042</td>
<td>1,537</td>
<td>278,292</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,016,268</td>
<td>23,670</td>
<td>62,195</td>
<td>5,122</td>
<td>1,107,255</td>
</tr>
<tr>
<td><strong>2005</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January - March</td>
<td>256,224</td>
<td>5,585</td>
<td>15,678</td>
<td>1,537</td>
<td>279,023</td>
</tr>
<tr>
<td>April - June</td>
<td>242,555</td>
<td>6,047</td>
<td>14,541</td>
<td>1,024</td>
<td>264,168</td>
</tr>
<tr>
<td>July - September</td>
<td>282,367</td>
<td>6,009</td>
<td>14,759</td>
<td>1,024</td>
<td>304,159</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>781,146</td>
<td>17,641</td>
<td>44,978</td>
<td>3,585</td>
<td>847,350</td>
</tr>
<tr>
<td><strong>2004</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January - September</td>
<td>761,497</td>
<td>17,728</td>
<td>46,153</td>
<td>3,585</td>
<td>828,963</td>
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<tr>
<td><strong>2003</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January - September</td>
<td>753,304</td>
<td>18,184</td>
<td>45,258</td>
<td>2,965</td>
<td>819,711</td>
</tr>
</tbody>
</table>

1. The electric power sector (electric utilities and independent power producers) comprises electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public -- i.e. NAICS 22 plants. The reported coal consumption is the total for producing electricity and useful thermal output.

2. Industrial combined-heat-and-power (CHP) and a small number of industrial electricity-only plants. The reported coal consumption is the total for producing electricity and useful thermal output.

3. All industrial sector fuel use other than in "Coke Plants" and "Industrial CHP."

4. Includes commercial combined-heat-and-power (CHP) and a small number of commercial electricity-only plants, such as those at hospitals and universities. The reported coal consumption is the total for producing electricity and useful thermal output.

5. All commercial sector fuel use other than that in "Commercial CHP" and residential sector.

Note: Total may not equal sum of components because of independent rounding.

Informative Website with Lots of Links

APPENDIX

Websites – Gradual Accumulation Theory of Coal Formation

http://www.ket.org/Trips/Coal/AGSMM/agsmmhow.html

http://chemistry.anl.gov/carbon/coal-tutorial/coalgeneral.html

http://www.blm.gov/educaton/00_resources/articles/energy/energy1.html


Websites – Rapid Coal Formation

http://www.answersingenesis.org/creation/v6/i1/mtsthehels.asp

http://www.geocities.com/truedino/ch2dino.htm


http://dialogue.adventist.org/articles/06_1_coffin_e.htm