Energy Resource Series for Adult and Youth Energy Programs

4. Coal

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Preface

The U.S. government has decreed that for the next few years coal will become a major energy source to bridge the gap from fossil fuels to other sources of energy. This will have a significant impact on Kentucky, since it is one of several states that has an abundance of coal.

The mining and use of coal will require many decisions, some of them voting decisions by the public. These decisions will directly affect the lives of all Americans.

This publication is the fourth in a 12-part energy resource series designed for the adult and student with a serious interest in the energy situation. Each publication examines a different energy source with consideration given to the advantages and disadvantages associated with its use.

When necessary, diagrams and/or tables are used to clarify or elaborate upon information found in the text. Questions with answers are included at the end of each publication so that you can test what you have learned.

The author wishes to thank Larry Wells and Linda Bach of the Department of Agricultural Engineering, University of Kentucky, for reviewing the text.

The Energy Resource Series for Youth and Adult Energy Programs includes the following publications:

AEES-21 Energy Overview
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The Origin of Coal

Coal is very close kin to the other fossil fuels, oil and gas. If a chunk of coal is examined with a powerful magnifying glass you will notice a lot of red and gold color. The marks of plants can be plainly seen on many pieces. The imprint of plants and sometimes of animal skeletons indicates to skilled scientists how coal was formed.

Facts uncovered by scientists seem to indicate that coal was being formed as many as 250 million years ago. Prior to that time, conditions on the earth caused tremendous growth of giant, leaf type plants. Some of these grew to heights of hundreds of feet and were extremely dense. Eventually this lush growth died, became matted down, and rotted. On the matted down layer new growths would emerge. The rotted, compacted layer is called peat and resembles a piece of partially decayed wood.

Geologists estimate that vast areas of this type of growth became covered by many feet of swamp-like earth. Upheavals, probably caused by earthquakes, put great pressure on the peat and at the same time sealed it tightly and preserved it in layers much like we preserve food in sealed jars and cans. Geologists estimate that 8 to 10 feet of lush plant growth were compressed into 1 foot of peat.

The dead plants which form this layer of peat took carbon from the air while they were living, using energy from sunlight in a process that is called photosynthesis to build their plant tissues (see AEES-29, Wood). It is at this point that the external energy source, sunlight, raised the chemical energy in the plant tissues to a higher level. When the plants died and were preserved by being sealed, the energy remained. Man can now dig them and utilize the remains as fuel by releasing the pent up energy through the process of fast oxidation commonly called burning.

When the decayed plants were tightly squeezed by the pressure of the great amount of earth above, large amounts of oxygen and hydrogen were driven out, but the carbon remained. (The process of decay or decomposition is caused by living bacterial organisms which give off oxygen and hydrogen gases.) Thus, what we call coal has been formed from the peat material. Coal has no fixed chemical formula but is called a hydrocarbon fossil fuel because it contains large quantities of carbon in chemical combination with hydrogen and because it came from living plants.

Coal Classification

Geologists actually classify coal as a sedimentary rock because it was formed from some of the same processes used in forming sedimentary rock.

Scientists have divided coal into two main classes, anthracite or hard coal and bituminous or soft coal. Evidently, anthracite was formed under higher pressure which forced out more of the moisture and gases. Anthracite makes up a very small percentage of the earth's supply of coal (Figure 1). Scientists further divide the bituminous coal into two parts; one is much softer than the other and is called sub-bituminous. It has less heat value per pound and usually contains more unwanted minerals that cause trouble when burning. The known reserves of the two soft coal types are about equal in amount. The following paragraphs summarize the classifications of coal.

Fig. 1.—This map shows the known deposits of the various classes of coal in the continental United States. The large deposits in Alaska are not shown.
Anthracite—This coal usually is found deeper in the earth than the others. This is reasonable since greater pressure left it with the higher carbon content. It is very sparse in the United States. It is such a good fuel that when burned it produces almost no smoke. It usually sells for a much higher price per pound than other coal. Nevertheless, its heating ability is almost the same as the better grades of bituminous.

Bituminous—This is the most economically important type of coal because of its abundance and good burning characteristics. It is the fuel used to fire large electric generating plants. Other important industrial uses are for coke in steel production and as a raw material for many chemicals. It is the fuel for buildings or homes heated with coal.

Sub-bituminous—The major difference from regular bituminous coal is that it contains much more moisture, and thus does not burn as readily.

Cannel—This type of coal is formed from seeds of plants rather than the tissue parts. This fuel may be started readily by a match.

Other types—All these additional classes contain more moisture than those previously mentioned. Brown and lignite contain about 50 percent moisture. Peat contains about 90 percent moisture, and the signs of plants can readily be seen on many large lumps.

It is claimed that the world's only cannel coal mine is located in Hancock County, Kentucky. The owners theorize that this special coal was formed 250 million years ago from seeds, nut shells and spores that floated and settled in low spots and then were covered. The coal is packaged and sold mainly as a good fireplace fuel.

Most coal deposits in the United States are in layers called beds. These can vary in thickness from less than 1 foot to hundreds of feet. The average thickness is around 10 feet. These layers can be quite extensive in area, covering parts of several states or relatively small areas through hills, where the coal bed is exposed all around the edge. Geologists agree that at one time, in these hilly areas, there was a continuous bed of coal over a vast area. Through the ages, erosion has cut valleys between the hills that are now standing. This erosion took away a large portion of the original coal (Figure 2). These layers may run at various slopes or have a wavy pattern. Geologists must use core drilling to determine the distance to the bed of coal and the thickness of it. By this method they also determine the outer edge of the bed of coal. After the bed of coal is mapped extensively, mining engineers determine the best methods of extraction.

Figure 1 shows the location of the three main types of coal found in the United States. Note that both East and West Kentucky have large areas of coal deposits, amplifying the importance of coal to Kentucky.

During the first half of 1976, Kentucky led the nation in coal production, with West Virginia a close second. Data from the United States Bureau of Mines showed that Kentucky mined 26 million tons in the West and 16 million in the East, for a total of 42 million tons. West Virginia mined a total of 40 million tons during this period.

Fig. 2.—A cross section of rough hilly country. The cross hatched part indicates a layer of coal across each hill. Thousands of years ago this layer was probably continuous and covered by much more earth. Erosion from rain and wind, through the many centuries, has eaten away the earth and coal until only this remains.

**Mining Methods**

The mechanics of extracting coal from the ground can be divided into two methods—surface mining and deep mining.

**Surface Mining**

The surface method usually proves to be the most efficient if a bed of coal lies relatively flat and is covered by a ratio of 40:1 or less of earth to coal thickness. In practice, the economics indicate that 1 foot of coal thickness can pay for the removal of 40 feet of earth above it. Likewise a 10-foot thickness could have 400 feet of earth, and the surface operation still could be economically feasible. The earth and rock that cover the coal are referred to as overburden. The advent of giant earth moving machines has made surface mining of this coal possible.

Figure 3 indicates one way these very large earth moving machines do their job of uncovering a bed or layer of coal (A). The machine scoops out a ditch down to the surface of the coal, piling the
overburden (B) high to one side in what is called a spoil bank (C). Similar but smaller machines then dig the exposed coal and haul it away. This ditch can extend for many miles depending on the size of the area of the coal layer. Next, the large machine moves in the opposite direction, digging a ditch (D) down to the surface of the coal adjacent to the first pass. Overburden from this second pass is dumped in the ditch made by the first trip across the area. Usually during the second and succeeding passes a wider ditch can be dug since the overburden does not have to be piled so high. Using this method, all coal is removed from the bed.

![Fig. 3.](image)

This system of coal removal will work even when the surface of the land is rather rough and rolling and when the layer of coal slants and rolls slightly. Surveying crews take data from core drills and determine the best path the machine should take. Fortunately, most of the coal beds in the United States lie in fairly level layers making all systems of surface mining simpler.

After all the coal has been removed from the bed the surface is rough where the large machine has piled the overburden. Smaller land leveling machines, similar to those used in road building, begin reshaping the surface to specifications determined before any digging was started. Last of all, farm type equipment comes to the area, develops a seed bed, and seeds the surface. Many times the finished surface is in much better shape for potential production or use than before mining began. This reclamation or restoration of the land is the final step in surface mining.

Deep Mining

Room and Pillar Method

When the layer of coal is too far beneath the earth's surface to be mined efficiently by large, earth moving equipment, underground methods must be employed. The method commonly used today in the United States is called "room and pillar" mining (Figure 4).

First, two or more shafts are dug straight down to the coal layer; one is for moving men up and down (F), while the others are used for ventilation (G) and lifting coal (D). Air is exhausted by large fans at the top of the elevator shafts (D,F). Spreading out through the coal layer from the base of the coal lift shaft is a series of main and cross tunnels as complex as any city street system.

![Fig. 4.](image)

At the end of these tunnels are the mining machines. The mining machine (A) is usually very low so that it can move in tunnels not over 4 feet high. On its front is a large, horizontal rotating drum covered with sharp, tough, steel teeth. This toothed drum can be raised and lowered so that it can reach the face of the coal from the floor level to several feet high. Extensions can be put on so that it can reach the top of very thick layers of coal. Teeth on the drum tear loose small chunks of coal that fall to a conveyor (B) near the floor.

The conveyor picks up the freshly mined coal from the floor, carries it backwards several feet behind the machine and dumps it into rubber tired shuttle cars (C). Several of these cars are hooked together and pulled by a battery-powered engine. They make their way through the main tunnel system to the coal lift shaft where the coal is dumped into an elevator (D) and lifted to the surface. There, it is washed, sorted and loaded in the tipple (E). While these shuttle cars are away from the mining machine, others are being loaded so that a fairly constant flow of coal is maintained from the face of the surface. For this reason the word continuous has been given to this type of mining machine.

Tunnels are made in the layer of coal parallel to each other, all the way to the outer edges of the layer. They are far enough apart so that the coal
left between can support the earth and rock overhead. Other tunnels can be run across these, at right angles, and the remaining coal is similar to pillars or columns holding up the ceiling of a large room. Hence the name “room and pillar” is used for this system of underground mining. If these pillars remain in position to prevent surface cave-in, about half the original coal in the layer will be left to support the mine roof.

If the engineers and surveyors determine that it is safe, it is possible under certain conditions to remove some or all of the pillars as the miners “retreat.” This means that after the tunnels have reached the outer extremities of a bed of coal, or it is not economically feasible to push them any further, all equipment is gradually brought back toward the main shafts. During this move some or all of the pillars can be systematically dug out allowing the mine roof to cave in. Eighty to 90 percent of the coal can be removed in this manner.

Long Wall Method

Another, more expensive, system has been developed to eliminate the great loss of leaving pillars in place. It is called the “long wall” method. In using this method a long straight tunnel is cut out into the layer. This tunnel is then moved sideways letting the roof cave in on the previously dug tunnel. When the first tunnel is cut, hydraulic roof supports are placed very close together to support this roof. Then a long conveyor belt is set up on the floor next to one side of the tunnel or on the side in the direction they want to move. A shearing machine moves along the tunnel side cutting the coal loose and letting it fall onto the conveyor belt. The conveyor belt moves the coal to shuttle cars and then up the elevator to the surface. After a few inches have been sheared off the wall the conveyor belt is moved sideways up against the wall of coal. After the tunnel has moved 10 to 12 feet sideways a new row of hydraulic supports is put in place near the belt. The previous row is remotely lowered and slowly moved near the new ones.

After several moves the roof caves in behind, but the working area, by the face, is kept safe by the hydraulic supports. Using this method all the coal in the bed is removed, compared to about one-half using the “room and pillar” method. The cost of equipment in the “long wall” method is much greater, about three times, due mainly to the sophisticated hydraulic supports which can be remotely controlled. Getting all the coal goes a long way toward making this system feasible.

Other Methods

Other methods of reaching the deeply buried bed of coal may be utilized rather than the vertical shafts but these depend upon the terrain and what engineers and surveyors determine as the most economical method. Sometimes sloping shafts or drift shafts are used to get to the layer of coal. These are shown in Figures 5 and 6.

Fig. 5.—A diagram illustrating a drift mine. Many times the edge of a bed of coal comes out on the side of a hill. It is easier to enter the layer of coal at this point than to dig and operate through vertical shafts and proceed with the same equipment as an underground mine. Several small holes must be bored from the surface for air inlets for the ventilation system. Large exhaust fans would be located near the tipple building at the right hand edge of the drawing.

Fig. 6.—This diagram illustrates a sloping mine operation. The name comes from the sloping tunnel dug to the coal bed from the closest point on the surface. The shuttle coal cars can climb this gentle slope, eliminating the need for vertical elevators. This operation is similar to the drift mine.

Sometimes coal is found in multiple layers. This indicates that there were several prehistoric time periods when extremely lush growths of giant tree-like plants took place and were buried by upheaval of the earth’s crust. The vertical shaft system simply penetrates through these layers and the elevators and equipment serve all levels for the purpose of lifting the coal, and allowing workers access and ventilation.
Coal Auger Method

One other type of mining operation used in eastern Kentucky is the coal auger. It is useful in areas where a hill has a layer of coal across it, and the outer edge of the layer is exposed around all or most of the hill. This would be similar to the cross section shown in Figure 2. A bench, that is, flat place is cut around the hill with a bulldozer. The large auger driving machine is placed on this level bench. The giant steel blades of the auger look very much like a grain conveyor or like a wood bit. These coal augers can be about 6 feet in diameter. They are mounted in pairs, rotating in opposite directions and can be side by side or one above the other. The disadvantage of this type of equipment is that a maximum distance of drilling into the layer is about 300 feet. Therefore, this equipment is used in special places such as small hills where the auger can reach nearly all the way through the layer or drill into the layer from all around the outside edge.

In actual practice this method is used very little because there are very few places where it can be used to an advantage. When it can be used it removes only 75 percent of the coal from a layer because the 25 percent remaining must keep the overburden from caving in. Otherwise the augers would be removing only dirt.

The one big advantage this method has over underground methods is that no miners have to work underground.

Underground Mine Safety

A critical situation in underground mines is water drainage. Since the earth's crust contains quite a lot of water this must be contended with in all mines. Usually at all low points in the tunnel system a sump is arranged to collect the drainage. A pump near this sump pushes the water to the surface where it is suitably disposed of.

All coal beds contain quite a lot of trapped gases which were by-products of microbial decomposition of the dead plants. When a coal layer is being dug into, these gases are released into the tunnels. Adequate ventilation at the face of the coal where cutting and drilling is taking place is imperative. Sometimes engineers may determine that an over-concentration of combustible gases is safer and more economical than excess ventilation air such as in long single tunnels. There is no danger of explosions in over-concentration, but humans have to wear oxygen equipment which is uncomfortable and somewhat inconvenient. Most of the time adequate ventilation can be designed into the mine.

Three things which occupy much of the planning and management time of the underground mine safety engineers are roof strength, water removal, and adequate ventilation.

The Tipple

Coal, as it leaves the mine, is called mine-run coal. Usually it is delivered immediately to a tipple. This is actually a cleaning, sorting and loading building. The name comes from the process of unloading by tipping; the shuttle cars do this when they come up out of a mine.

Figure 7 is a simplified cross-section diagram of a tipple. Coal from the mine is dumped at the top of the building so that gravity moves the coal through the necessary steps and arrives at the bottom in vehicles ready to move out across the country to consumers.
In some cases, people may be stationed here to remove rocks and other large, unwanted material, and drop them down a disposal chute.

The coal then is washed. Since coal floats, such things as small rocks, gravel and stones will sink and thus are separated, with the unwanted materials going to the bottom of the water vat and ending up in the refuse bin (H). At the same time the coal floats off to the side and over at (D). The refuse can be drained into the holding bin with the water occasionally being returned to the vat (C), if water is a scarce item at the tipple site.

The washed coal arrives at the upper end of the sloping sizing screen (E). This screen vibrates causing the coal to travel across it toward the low end. This results in the smallest pieces falling through and into the first collecting funnel (F) and down into the holding bin (G) for that size. At any time this material can be released to fall into a vehicle (J), whether a rail car or a truck, for delivery to the consumer. In this manner the mine-run coal is cleaned and sorted into various sizes and held for delivery.

In some cases the customer will ask for a certain mixture of sizes. Tipples are usually equipped with a conveyor under all the bin spouts (not shown in Figure 7) so that certain amounts from any bin can be added to certain amounts from other bins and this mixture dropped into the delivery vehicle.

Most coal in the United States is transported by rail car. The Ohio and Mississippi Rivers also carry millions of tons each year by barge. Coal used by industry around the Great Lakes region is transported by ship and barge on the Great Lakes. Some coal is moved across the country by pipeline. To do this, finely ground coal is mixed with water to form a slurry and is moved through the pipe by pumps. At the end of the line the slurry is dried to remove the water. Civil engineers at the University of Kentucky recently have developed new methods for making pipeline movement of coal more efficient.

Many electric power plants are built near the mines so that large trucks can bring coal from the tipple directly to the generating plant. It is more efficient to transport electricity over power lines than to move the coal. However, coal used to heat buildings or used in the steel and chemical industry must be shipped via truck or rail.

Most large industrial plants, where coal is an important ingredient to their operation, store large quantities for insurance against unforeseen interruption in their supply shipments. Most coal is simply stockpiled outside and handled by large mechanical loaders. Anthracite and bituminous coal needs to be protected by at least a roof and good surface drainage, or it will deteriorate rapidly in value.

The following table gives an overall picture of past and future trends in U.S. coal production and use.

<table>
<thead>
<tr>
<th>Use</th>
<th>1950</th>
<th>1976</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tons produced¹</td>
<td>480</td>
<td>611</td>
<td>1,025</td>
</tr>
<tr>
<td>Electric power²</td>
<td>18</td>
<td>63</td>
<td>68</td>
</tr>
<tr>
<td>Steel industry</td>
<td>22</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Chemical industry</td>
<td>55</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Exports</td>
<td>5</td>
<td>10</td>
<td>7</td>
</tr>
</tbody>
</table>

¹In millions of tons taken from U.S. mines for each respective year.
²As a percent of tons produced for each respective year.

### Products and Uses of Coal

Coal can be turned into many useful products, possibly many more than one would suspect. When raw coal is heated in a closed, oven-like chamber it gives off gases. What is left over is called coke. Each individual oven is usually about 18 inches wide, 15 to 20 feet high and about 30 feet long. This slot is filled with coal and heated by gas burners within the walls of the oven. A single coke plant can have 10 to 50 such ovens side-by-side. Coke is the basis for such things as paint, phonograph records, graphite used in lead pencils, lubricants, electrodes, acetylene and baking soda.

Gases formed by heating the raw coal can be condensed by cooling them. The products of the first stages of condensation are the tars. From this tar come products, such as insecticides, moth balls, perfume, sulfa drugs, aspirin, dyes, sulfuric acid, artificial silk and some vitamins.

The next condensation stage, known as light oils, provides the basis for nylon, synthetic rubber, linoleum, dynamite, many cosmetics and saccharin, an artificial sweetener. The next stage of condensation provides the basis for many chemicals, such as ammonia used in fertilizers, and a mild anesthetic called laughing gas (nitrous oxide or N₂O) used by dentists and in many plastics. Finally, the gases that will not condense are very similar to natural gas and are used for heating and cooking in homes, or are used in the plant to heat the coal.

This is only a partial listing but it points out the extremely valuable contribution this raw product makes to our way of life, in addition to serving as a source of fuel.
Today there are many research projects of major proportions taking place in industry and universities in an attempt to break coal down into various parts and characteristics. The impetus behind this search is to find new ways to use coal as a fuel for heating, and a means of using powdered coal as a fuel for engines.

Some of this research is simply renewing on a large scale old projects of many years ago when there was little need for the answer. The most familiar of these are gasification and liquification of coal.

Considerable research is being done on ways to gasify coal in the ground and bring the gas to the surface. This method is attractive since it eliminates the need for miners to work underground. This method could make it possible to recover nearly 100 percent of the coal.

Questions

To stimulate thought and greater understanding of coal energy, answer these questions with the best word(s). Refer to the material when necessary.

1. The coal mined in Kentucky is primarily of what type?

2. During the past few years which state has ranked first in quantity of coal mined?

3. Which type of coal is most abundant in the United States?

4. Coal, like oil and gas, is a fossil fuel. (True or False)

5. The beginning of coal was the vast growth of green plants. (True or False)

6. Geologists actually classify coal as a sedimentary rock. (True or False)

7. What method is used by geologists to determine the depth, thickness and outer edges of a bed of coal?

8. Mining methods can be divided into two major categories, and

9. What ratio of overburden to coal bed thickness is the economic factor determining which mining method will be used?

10. The reshaping and seeding of the surface of the land following mining operations is called

11. The most common underground or deep mining method used in the United States today is called

12. If the pillars must stay in position what percent of the coal can be removed to the surface?

13. In some cases, tunnel cave-in following mining does not hurt anything. What percent of coal from a bed can be removed using this system?

14. The long wall method allows for nearly all coal from a bed to be mined. (True or False)
15. What is the main resistance to using the long wall system? 

16. What three things occupy most of the management and operating engineer’s time? and .

17. Freshly dug coal, as it leaves the mine, is referred to as mine-run coal. (True or False)

18. What is the purpose of a tipple building?

19. Unwanted material, separated from coal in the tipple is called .

20. Trucks and barges carry most of the coal in the U.S. (True or False)

21. It is impossible to move coal through pipes. (True or False)

22. Why are some electric generating plants built near coal fields?

23. In 1950 what was most of the coal used for?

24. In 1976 what was most of the coal used for?

25. During which of the three time periods was the greatest quantity of coal exported?

26. Did sunlight play a part in the formation of coal? (Yes or No)

27. Living organisms, called bacteria, added energy to peat which makes coal valuable. (True or False)

28. The process where external energy is added to green plants is called .
## Answers

1. bituminous  
2. Kentucky  
3. bituminous  
4. T  
5. T  
6. T  
7. core drilling  
8. surface and deep  
9. 40:1  
10. reclamation  
11. room and pillar  
12. 50 percent  
13. 80 to 90 percent  
14. T  
15. high cost  
16. drainage, ventilation, roof strength  
17. T  
18. washing, sorting, loading  
19. refuse  
20. F  
21. F  
22. easier to move electricity than coal  
23. chemical industry  
24. electric power  
25. 1976  
26. yes  
27. F  
28. photosynthesis

Printed with funds from the Kentucky Cooperative Extension Service in cooperation with the Kentucky Department of Energy as a part of the Kentucky Energy Conservation Plan.