Title: Illinois Coal and Clean Coal Technologies
Level: Secondary
Day/Time: One class period or Homework assignment
KERA Goals: 1.2, 5.3, 6.3

Background Information:

Coal is being used in larger amounts than ever before. Fifty-six percent of electricity generated in the United States is from coal-fired power plants. The coal industry is proud of the fact that coal is mined more safely today and is being used more cleanly than in the past. As a result, we will continue to have a cleaner and healthier environment.

Scientists have made significant progress in the last two decades to ensure that coal can be used without harming the environment. Technologies are being developed that change coal into clean-burning gases and liquid fuels. Many of these modern processes belong to an energy generation family called *clean coal technologies* (CCT).

When coal is burned to produce energy, its chemical makeup is changed and sulfur is released. To avoid environmental problems with the sulfur, coal companies and power plants take measures to remove it before, during and after burning. In pre-combustion technologies (before burning), the coal may be cleaned at the mine, at the power plant or both. When the coal is cleaned at the mine preparation plants, it is crushed and washed. This effort removes the largest amount of sulfur found in coal.

Some sulfur remains chemically bound in the coal and cannot be physically removed by *washing.* The removal of this sulfur is the target of other pre-combustion technologies, as well as that of *combustion* (during burning), *post-combustion* (after burning) and *conversion technologies*. Some examples are *chemical cleaning, fluidized bed combustion, flue gas desulfurization* and *coal gasification*.

Clean Coal Technologies (CCT)
Reasons for Using Clean Coal Technologies

The Clean Air Act Amendments of 1990 require new levels of control on the emissions, or pollution, that come from burning coal. In fact, utilities nationwide must cut sulfur emissions in half by the year 2000. Furthermore, new regulations to control toxic air pollutants and greenhouse gases are possible in the years ahead.

There is a need to develop more efficient methods of burning coal. In the 1800s, only five percent of the energy in coal was used. Today, using the technology of the 1950-60s, approximately 35 percent of the energy available in coal is used. With new technology, improvements can be made to reduce pollution and make power plants even more efficient, therefore, saving money.

Reducing the cost of operating and maintaining coal-fire power plants will make energy from

coal less expensive.

Four Categories of Clean Coal Technologies

Pre-combustion: These are technologies that are used to clean the coal before it is burned. They include actual physical cleaning or washing, chemical cleaning and new biological methods of cleaning to remove sulfur and ash. All types of coal cleaning are often called *coal beneficiation*.

Coal beneficiation has centered on two areas– physical and chemical. Now, there is a third area – biological.

Physical cleaning separates undesirable substances, such as dirt, rocks and inorganic, or *"pyritic" sulfur* (sulfur combined with iron), from the coal. Often this is done using water. There is a difference in the density or weight of coal and other substances. Therefore, when the coal is crushed and washed, the heavier impurities, or unwanted materials, separate from the coal, making it cleaner. Today, coal is being ground into much smaller sizes similar to powder. This allows for up to 90 percent of the pyritic sulfur to be removed.

Column flotation is a cleaning method that floats finely ground coal in water. The coal has been chemically conditioned to stick to rising air bubbles. This allows nearly all inorganic matter, such as pyritic sulfur, to sink to the bottom of the flotation column. This method is being demonstrated by the Illinois State Geological Survey at Kerr McGee's Galatia Mine preparation plant.

Sulfur chemically combined with the carbon in coal, or *organic sulfur*, cannot be removed by physical cleaning, nor can nitrogen be removed. *Chemical cleaning* is used to remove organic sulfur from the coal. One technique is called *molten-caustic leaching* in which coal is submerged in a chemical that actually leaches the sulfur and other minerals from the coal.

Biological cleaning involves using bacteria that literally "eat" the sulfur out of the coal. Scientists are trying to improve the sulfur-removing characteristics of the bacteria through experimentation. Other scientists are using fungi, while still others are trying to find a way to duplicate the enzyme, or chemical, inside of the bacteria that eat the sulfur. They can then inject the enzyme directly into the coal to speed the cleaning process.

Combustion: These are technologies that are used to clean coal inside the furnace where the coal is actually burned. These new methods remove pollutants such as sulfur dioxide and nitrogen oxides. Fluidized-bed combustion is an example of this type of technology.

In fluidized-bed combustion, coal is ground into small particles, mixed with limestone and injected with hot air into the boiler. This mixture, a "bed" of coal and limestone, is suspended on jets of air and resembles a boiling liquid. This is where the name "fluidized" comes from because it resembles a liquid. As the coal burns, the limestone acts as a sponge and captures the sulfur. As in a conventional boiler, water-filled tubes collect the heat generated, creating steam. The steam is used to spin a generator which produces electricity.

This technology can reduce the amount of sulfur released by over 90 percent. Another advantage of this technology is the reduction in the boiler temperature. In conventional boilers, the temperature can reach at least 2,700 degrees Fahrenheit. Because the tumbling motion enhance the burning process, temperatures are usually around 1,400 to 1,600 degrees Fahrenheit in fluidized-bed combustion. The lower temperature is an advantage because fewer nitrogen pollutants are produced.

Archer Daniels Midland Company (ADM) in Decatur, Illinois and B. F. Goodrich in Henry, Illinois, are successfully using this type of technology.

Post-Combustion: Post-combustion technologies are applied after the coal is burned. The gases, or emission, that are released from burning coal are "cleaned" before they reach the smokestack and released into the air. This method is usually referred to as *flue gas desulfurization or scrubbing.*

"*Scrubbers"* have been used to remove sulfur from *flue gas* in the United States since 1967. In this process, the scrubbers mix the flue gas with lime or a limestone and water mixture. This mixture is known as *slurry*. Ninety-five percent of the sulfur can be removed using this method. The remaining sludge mixture resulting from flue gas desulfurization is rich in gypsum, a useful substance that can be sold and manufactured into usable by-produces such as wallboard.

Another advanced cleaning method at the post-combustion stage is *in-duct sorbent injection*. Hydrated lime, or sorbent, is injected or sprayed into the center of the duct or pipe that carries the flue gas. This allows the sulfur to be collected in the form of a dry dust or *ash*. The advantage of this method is that the technology is added as a low-cost retrofit; consequently, there is little new construction needed.

Conversion: Conversion technologies turn coal into a gas or liquid that can be cleaned and used as fuel. One of the most advanced conversion technologies is called *combined-cycle coal gasification.*

The combined-cycle coal gasification process basically has four steps: 1) coal is broken into gaseous molecules by bringing it into contact with high temperature steam and air; 2) the gases are purified to removed pollutants; 3) the clean gases are burned and the very hot exhaust is routed through a gas turbine to generate electricity; and 4) the residual heat in the exhaust is used to boil water for a conventional steam-turbine generator to produce more electricity. This combination of gas and steam turbines accounts for the name "combined cycle."

Combined-cycle gasification systems are among the cleanest of the clean coal technologies as the sulfur, nitrogen compounds and particulates are removed before the fuel is burned in the gas turbine.

Coal gasification can also take place underground. In underground gasification, steam and oxygen are injected into a coal seam through wells drilled from the surface. The coal seam

is ignited and partially burned. Heat generated by the combustion gasifies additional coal to produce fuel-grade gases.

These are piped to the surface where they are cleaned and used to drive gas turbines. Underground gasification is particularly useful in extracting energy from coal seams that are un-mineable.

These and many other clean coal technologies are being developed in the United States to provide solutions tot he problems facing the coal industry. In addition to addressing the problems of sulfur and other pollutants in coal, clean coal technologies will provide for more efficient use of our energy resources.

Illinois Coal and Clean Technologies
Discussion Worksheet

1. What is the purpose of the 1990 Clean Air Act and how does it relate to the Illinois coal industry?

2. List the four categories of clean coal technology:

a.
b.
c.
d.

3. What is coal beneficiation?

4. List the four types of coal beneficiation:

a.
b.
c.
d.

5. Give a brief description of the fluidized-bed combustion process.

6. Give a brief description of the flue gas desulfurization process.

7. Give a brief description of the combined-cycle coal gasification process.

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