Working toward cleaner coal: Part 1

By Jo Seltzer, Special to the Beacon

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If you are reading this story on a computer, you are probably using electricity from coal.

Our modern life style depends upon an uninterrupted and inexpensive supply of electrical energy. Coal powered electric plants operate around the clock to fill the demand for energy. Currently, half of the electrical power in the U.S. comes from burning coal. The percentage is even higher in Missouri—76 percent. And, in the St. Louis area alone, electrical consumption—and therefore the use of coal—is up 50 percent since 1990.

Most scientists and policy makers agree that we must make a transition to renewable and cleaner sources of energy as quickly as possible. In the meantime, however, a great deal of the electricity that we rely upon 24/7 will be generated by burning fossil fuels.

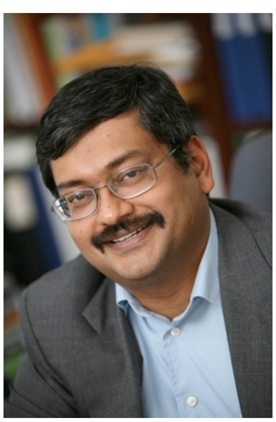
The Obama administration recognizes that we will continue to burn coal to generate electricity; in May it earmarked $2.4 billion for clean coal research. To the environmental lobby, "clean coal" is an oxymoron. Coal as a power source is inherently dirty: first in its mining, then through pollutants in smokestack emissions and in the the release of vast quantities of the greenhouse gas carbon dioxide (CO2) into the atmosphere.

How much coal?.

1 kilowatt hour (kWh) is the amount of electricity needed to burn a 100 watt light bulb for 10 hours.

2 pounds of coal were burned to produce that kWh, producing 1.34 pounds of carbon dioxide. (A figure from 1999.)

The average household in the U.S. uses 936 kWh/month. That amount of electricity takes 1872 lbs of coal—nearly a ton—and produces 1254 pounds of carbon dioxide.



Pratim Biswas
Photo courtesy of Washington University

"Perhaps we should have named our organization the Consortium for Clean-er Coal Utilization," reflected Professor Pratim Biswas of Washington University School of Engineering.

The Consortium for Clean Coal Utilization is a partnership between Washington University and local energy and coal companies to advance research and education in this area. Arch Coal and Peabody Energy have committed $5 million each to the research effort. Ameren has put in $2 million. A main goal is to establish a research facility bigger than a university lab, but smaller than a commercial one.

Among energy options, coal has many advantages, points out Professor Rich Axelbaum, head of the Consortium. It is plentiful, inexpensive, and most of the world either has coal reserves or access to them. For areas that have no access to hydroelectric power, the only 24/7 option to fossil fuels is nuclear power. That option is politically contentious on national and international fronts.

Efforts to clean coal

Those who say they “don’t believe” in clean coal are ignoring history. Coal plants used to put out so much particulate matter from their smokestacks that people could sometimes see the pollution in the form of soot or smog, notes the Department of Energy’s Thomas Sarkus.

Thanks to advances in clean air technology, in this country today pollution from burning coal is greatly reduced. Particulates and smokestack emissions that cause acid rain have been all but eliminated in many areas. And engineers have devised ways to tackle mercury contamination.

Beginning in the 1950’s, two technologies arose to control smog and soot from burning coal. One is a fabric filter or “baghouse” analogous to a vacuum cleaner.

The other is the electrostatic precipitator, much like the air purifying devices many St. Louisans have in their homes. With the electrostatic precipitator, particles from flue gas are given a negative charge and then collected on positively charged metal plates. The plates are cleaned regularly, and the collected “fly ash” is then used to make concrete.

Today, the over 1000 coal-powered electrical plants in the country are equipped to remove particles greater than 2.5 microns. (A micron is a millionth of a meter, or one thousandth of a millimeter.) Most toxic metals (with the exception of mercury) are removed with these particles. Ameren plants in St. Louis remove 99% of particulate matter from flue gas.

Controlling the causes of acid rain

Acid rain is caused by oxides of sulfur and nitrogen. Technology to remove sulfur dioxide from flue gas began development in the 1960’s and 1970’s. “Scrubbers” remove the sulfur from flue gas by reacting it with a calcium compound—either limestone or lime. The resulting calcium sulfate (gypsum) goes into the manufacture of wallboard. About 50% of the coal plants in the country scrub for sulfur, with more existing plants adding scrubbers today. Ameren switched to low sulfur coal to comply with clean air act requirements, and will complete installation of two sulfur scrubbers in the St. Charles plant by 2010. It has reduced its sulfur dioxide emission rate by 81% since the Clean Air Act of 1990.

Technology to remove nitrogen oxides was developed in the 1980’s and 1990’s. “Low NOx burners” are installed in all US coal-fired electrical plants, but they are only 25% efficient in normal operation. Another technology, “Selective catalytic reduction,” is analogous to catalytic converters in cars. It is more efficient, but also more expensive. By 2006, about 40% of the country’s coal-fired plants had this technology. No St. Louis area Ameren plants use it.

Mercury is poised for regulation

Coal powered electrical plants leak mercury into the atmosphere. The element mercury is a poison, and accumulates in animal tissues. Mercury is a 'trace' component of coal, but burning vast quantities of coal releases significant amounts gaseous mercury to the atmosphere. Research on control of mercury emissions has been a hot topic for about fifteen years. As a result of that research, legislators can now respond to the public demand for mercury control. For example, Washington University researchers Biswas and Axelbaum have been using nanotechnology to build mercury traps.

Rich Axelbaum
Photo courtesy of Washington University

Working toward cleaner coal: Part 2

Posted 4 p.m. Thurs., July 30 - In the push for cleaner air, public attention has now turned to the main product of burning organic matter, the "greenhouse gas" carbon dioxide. The United States emits over 6 billion tons of carbon dioxide annually, one-third each from coal and natural gas, and one-third from transportation and petroleum. Scientists and policy makers now generally agree that this greenhouse carbon dioxide is causing the average temperature of the earth to rise. The question is just how to reduce drastically the amounts of carbon dioxide added to the atmosphere.

Today, lots of money and research is aimed at sending carbon dioxide from combustion back where it came from. The process is called sequestration. Sequestration means capturing the carbon dioxide resulting from burning fossil fuels, pumping it underground, and storing it there permanently.

That's not as simple as it sounds.

- The carbon dioxide has to be purified and compressed into a liquid-like state called a supercritical fluid.
- The fluid carbon dioxide must be pipelined and pumped very deep underground (> 2500 feet.)
- The underground storage site must have be porous. It must also have a natural cap of non-porous rock like slate or shale that will keep the carbon dioxide from escaping.

This technology is not completely new. Carbon dioxide is already pumped into oil fields to enhance oil recovery. In addition, natural gas is pumped through pipelines and stored underground until needed.

Other than oil fields, deep salt-water reservoirs, porous rock such as sandstone, and even some depleted coal fields could be used for storage. The Sleipner project off the coast of Norway has been pumping a million tons of carbon dioxide annually into a salt-water reservoir since 1996.

What's Going On

A visit to the DOE-National Energy Technology website at www.netl.doe.gov gives an idea of research underway and being considered with regard to coal, oil and gas technology.

The DOE's main website, www.energy.gov , describes government funded research in all fields of energy.

Finding storage for carbon dioxide in Missouri will be difficult, since its porous rock is closer to the surface. City Power in Springfield is exploring a DOE-funded project to pump carbon dioxide into a formation about 2000 feet below the surface, reports Runar Nygaard, a professor at Missouri University of Science and Technology in Rolla.

An expensive fix

The challenges of purifying the carbon dioxide are enormous. The problem is to separate it from the nitrogen that makes up 80% of air, as well as small percentages of other gases including oxygen. Scientists are testing to see if:

- The flue gas could be bubbled through a liquid that would react chemically with the carbon dioxide, and release it later in another reaction.
- Metal-organic "sponges" could cyclically absorb and release huge amounts of the gas.
- Similar 'absorb and release' compounds could be painted on silicon wafers.

Ironically, to power any of these schemes, more coal will need to be burned. It takes power to run belts, fans, conveyers, etc, Techniques for removing sulfur and nitrogen oxides may need to be modified. But carbon would be returned to the earth, from whence it came.

One more approach, considered very promising, works with gasified coal. If coal is burned with limited oxygen, it becomes "synthesis gas" or "syngas" consisting of carbon monoxide and gaseous hydrogen. Syngas can then be burned like natural gas.This method has been utilized in two commercial-scale plants since the 1990's. Of course, these plants still produce carbon dioxide, but in lesser quantities per unit of electricity.

Syngas is also used as a raw material in making Tylenol, Nutrasweet, Craftsman tool handles, and Kodak film.

Understanding fossil fuels

Burning any organic matter creates carbon dioxide. Carbon (C) + oxygen (O_2) = carbon dioxide (CO_2).

- Organic matter includes fossil fuels such as coal, gas, and oil. It also includes wood, biomass such as switch grass, ethanol, and oils extracted from plants or algae.
- Burning fossil fuels adds to the net carbon in the atmosphere because the fuel has been buried underground. Burning of biomass is carbon neutral, because the carbon has been stored as biomaterial above ground.
- Different fossil fuels produce different amounts of carbon dioxide per unit of electricity.
- Burning coal in most of today's electrical plants is 35% efficient. Coal is burned in a boiler, converting chemical energy to thermal energy. The thermal energy is transferred to steam turbine tubes wrapped around the boiler. The stream drives the turbine, converting thermal energy to mechanical energy. Finally, the turbine drives the generator, converting mechanical energy to electricity. Each conversion wastes energy. A state of the art coal-burning plant built today would have 40 percent efficiency.
- Natural gas produces less carbon dioxide than coal per electrical unit because it is burned with 60 percent efficiency. Gas makes electricity in two steps. First, it burns in a gas turbine similar to a jet engine that is hooked up to a generator. The hot exhaust gases then run through a stem turbine for a second round of electrical generation.
- The average automobile is about 15 percent efficient.

Maximizing carbon sequestration

Taking the gas produced from burning coal and sequestering it underground would prevent more greenhouse carbon dioxide from entering earth's atmosphere. But what if the same process could actually remove existing carbon stores from the air?

All plant materials eventually decompose with carbon dioxide as a by-product. Washington U.'s Axelbaum has proposed taking biomass from trees and grasses and combusting it together with coal, and then getting all the resulting carbon dioxide underground, This process could result in a net reduction of carbon dioxide in the atmosphere.

On its way underground the carbon dioxide waste stream could be used as food for growing algae as a source of oil, he proposes. Some algae, grown under the proper conditions, can contain 35-40% oil. Theoretically, according to Professor Gary Stacey of the Center for Sustainable Energy at the University of Missouri Columbia, one percent of current crop land could generate enough algae to supply biodiesel for all the trucks in the country.

Paul Nam of the Missouri University of Science and Technology and his wife Keesoo Lee at Lincoln University, have begun a demonstration project with some central Missouri electric cooperatives in which flue gas is bubbled through open pools of algae. The problem in open systems is contamination by microbes. Midwest Research Institute in Kansas City is trying the same general experiment in a closed system. The closed system can be kept sterile, but is much more costly.

Rising prices could spur innovation

We expect our electricity to be uninterrupted and inexpensive. Coal-powered electricity is very inexpensive, but every added step in its processing will add to our electric bills. Ameren plans to spend $2.22 to $2.6 billion between now and 2018 upgrade its four coal-powered plants to comply with environmental regulations. These expenditures will surely be passed on to the consumer.

Coal can be made cleaner. As MU's Stacey points out, cleaner coal really does not mean more coal.

Says Axelbaum of the Consortium for Clean Coal Utilization, "The public has to decide how much it's willing to pay for the cost of cleaning things up." The cost of generating electricity from coal may force the development of new, clean, and renewable energy sources. Gasoline at $4/gallon changed the automobile market, especially while the price lasted.