LEAGUE OF WOMEN VOTERS®

COAL—THE GREAT HOPE, THE FALSE PROMISE OR A DISASTER IN THE MAKING?

By Chad Tolman (LWVDE)

Coal – Is It:

The great hope?
It is cheap and readily available in many parts of the world; it can reduce oil imports and fuel economies in developing countries.

The false promise?
If all the costs from mining, transportation, electricity production, and disposal of wastes are counted, and added to the costs of environmental degradation and human health impacts, coal is not "cheap." It accounts for much of the emissions of sulfur and nitrogen oxides, mercury, particulate matter, and carbon dioxide in the world today.

A disaster in the making?
The carbon content of coal per unit of energy produced is the highest of all the fossil fuels. The carbon/energy ratio for coal is 5, oil is 4 and gas is 3.[1] Currently, coal-fired power produces about 50% of the electricity in the United States and 80% in China.[2] If the world's remaining coal is burned and the carbon dioxide (CO_2) released, the atmospheric concentration of CO_2 could be increased by 100 to 300 parts per million (ppm)—enough to produce catastrophic consequences. A recent MIT study found that China is already consuming about twice as much coal as the US,[3] which has the equivalent of 500 coal plants of 500 megawatts (MW) each. China is adding two that size each week,[4] causing its CO_2 emissions to increase by 9% just in 2006.[5] The feasibility of carbon capture and sequestration (CCS), which might make it possible to keep most of the CO_2 out of the atmosphere by storing it deep underground, has not yet been demonstrated at a commercial scale.

Abundant Reserves

Coal was the first fossil fuel to be used in significant quantities. Following the invention of the steam engine in Eighteenth Century England, coal powered the world's industrial revolution, gradually replacing human, animal, wind, wood and water power for heating, transportation, farming and manufacturing.

Coal may be the last of the conventional fossil fuels to be used up, since there is more of it than there is oil or natural gas. Figure 1 shows estimated global totals of these fuels in GtC (gigatons or billions of metric tons of carbon) and the amount that has already been burned (appearing as the darker **Emissions (1750-2004)** at the bottom of the first three bars in the figure). For coal, two estimates of reserves are shown, one by the IPCC (Intergovernmental Panel on Climate Change) and a smaller estimate by the EIA (Energy Information Administration). A more recent estimate by David Rutledge, Chair of Engineering and Applied Science at Cal Tech, puts remaining coal reserves at 450 billion tonnes[6]—less than the EIA estimate.

The amount of unconventional fossil fuels, listed as 'Other' in Figure 1, is not well known but is huge. Most experts estimate the amount to be about 10,000 GtC[7]--eight times the height of the bar shown--just in methane hydrates (not including shale oil or tar sands). Note that the oil is already about half gone, as expected for the time, called 'Peak Oil,'[8] when the rate of oil production reaches a maximum before its inevitable decline.

It has been said that there is enough coal to last for a long time. If the remaining coal contains 450 GtC, and were burned at a constant rate of 6 GtC/yr, it would last only 75 years. But if the rate of burning increases rapidly, as seems likely, especially as oil runs out, it won't last that long.[9] The rate of coal burning in China, where it is the major energy source, is increasing rapidly. Experts estimate that China's energy consumption will more than double by 2020, corresponding to an average increase of over 5%/year.[10]

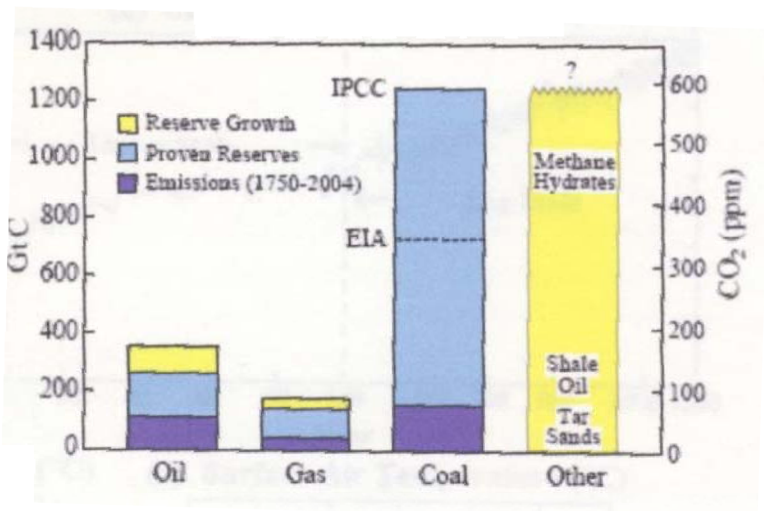

Figure 1. Fossil Fuel Reservoirs, from Figure 6(b) of James Hansen et al., **Climate Change and Trace Gases**. On the web at: http://www.giss.nasa.gov/~jhansen/docs/RoyalSoc.070218.pdf
Note that the scale of CO_2 concentrations on the right side of Figure 1 refers to the change in atmospheric concentration if all of the CO_2 emissions from burning the fossil fuel indicated were to remain in the atmosphere.[11]

Coal-Power Technology

The demand for energy is rising steadily in the U.S., Europe and Japan — and more rapidly in China, India and other developing countries. The abundance of coal reserves across the globe makes it the fuel of choice for new power plants and an inevitable part of the world's energy mix for the foreseeable future. This holds true for the U.S., which has more coal than any other nation, 27% of the world's total, and has been called the Saudi Arabia of Coal.[12] Developing new technologies to use coal in ways that minimize carbon emissions is imperative.

Pulverized-coal (PC) power plants

Most of the coal mined today is pulverized and burned with air to generate electricity, using the heat of combustion to make steam that drives turbines. Though coal is cheap, it is also dirty, and burning it produces large quantities of CO_2[13]—the main anthropogenic greenhouse gas that contributes to global warming—along with oxides of sulfur and nitrogen (SOx and NOx),[14]

mercury, fine particulate matter, and large amounts of solid waste, as well as waste heat. Only about 30% of the heat produced by a normal PC plant is actually delivered as electrical energy at the point of use. New "supercritical" power plants are starting to come on line that can improve efficiency to 45% by using higher-temperature, higher-pressure steam.[15]
The SOx, NOx and mercury from burning coal can be partially removed by scrubbers, but all of the CO_2 at present goes into the atmosphere. The burning of coal produces 50% of U.S. electrical generation and 36% of total U.S. CO_2 emissions.[16]

Integrated Gasification/Combined Cycle (IGCC) power plants
One of the promising technologies for reducing coal's environmental impacts is Integrated Gasification/Combined Cycle (IGCC) electrical generation. In this process, the coal is heated with steam and oxygen to produce synthesis gas (syngas), which consists mostly of hydrogen (H_2), carbon monoxide (CO), and CO_2,[17] along with smaller amounts of other gases like hydrogen sulfide (H_2S). Removal of the CO_2 and H_2S gives a mixture of H_2 and CO that can be burned with air in a gas combustion turbine, much like natural gas, to generate electricity, forming water and CO_2. Using part of the waste heat from the turbines to produce steam for additional power generation increases energy recovery and gives the process the 'Combined Cycle' (CC) part of its name.

Currently, IGCC plants cost about 20 percent more to build than conventional PC power plants and are also more expensive to operate. Even without CO_2-capture, electricity produced by IGCC costs 5 to 11 percent more to make. With CO_2-capture and storage below ground, the cost increases to 30 percent or more above a PC plant.[18]

IGCC plants can do a much better job of capturing SOx, NOx, and mercury than can conventional pulverized-coal plants because the pollutants can be removed before going into the turbines, when there is little nitrogen in the gas stream. For the same reason, the capture of CO_2 can be more readily incorporated into an IGCC plant than into a conventional PC plant. Since the CO_2 formed in producing syngas contains little nitrogen, it can be compressed and liquefied and then pumped deep underground for long-term storage (sequestration), if the geology is favorable.

Two IGCC plants are in operation in the U.S. They control pollutants like sulfur and particulates but do not separate out carbon. A permit application for a new 690 MW IGCC power plant in Washington State was recently denied because it would not include carbon capture and storage.[19]

Coal-to-liquid (CTL) fuels
The technology for making liquid transportation fuels (gasoline, diesel, or jet fuel) from coal is well established. It was invented in the 1920s and used by Nazi Germany in World War Two, and later by South Africa. Governor Schweitzer is proposing to do it in Montana.[20] The problem is that CTL fuels produce CO_2 both when the fuel is made and again when it is burned—roughly twice as much per mile as hydrocarbon fuels[21] derived from petroleum. This means that coal should **<u>not</u>** be used to make significant amounts of transportation fuels, if we are to avoid serious damage to the climate system. For the same reason, tar sands, oil shale, and methane hydrates should not be developed as energy sources unless the carbon in them can be effectively captured and sequestered.

Carbon Capture and Sequestration (CCS)

If we are to stabilize the composition of the atmosphere to prevent continuing global warming, nearly all of the CO_2 from coal will need to be captured and sequestered (stored) permanently.[22] It remains to be seen, however, how widespread suitable geological formations for deep underground storage are, and how much CO_2 they can hold. The most likely candidates are saline aquifers, underground coal seams, and geologic formations deep below the ocean floor.[4] There is also a risk that the stored CO_2 might later leak and escape into the atmosphere.

Experience with CCS technology is still very limited and short term. Oil and gas companies have pumped CO_2 underground to help flush oil and gas from depleted fields, but this does not sequester carbon. In one old oil field in Texas, CO_2 has been injected into a well and carefully monitored since 2004 to see if it is escaping.[23] At present, the largest sequestration project is injecting one million tons/year of CO_2 from the Sleipner gas field into a saline aquifer under the North Sea.[24] Much more than that is produced each year by a typical coal-fired power plant. A much larger scale CCS project is envisioned in Australia, which has a lot of coal.[25] Meanwhile, the one large-scale CCS prototype project on the drawing boards in the U.S.—FutureGen—was cancelled in January 2008 because of dramatic cost increases.

Environmental Damage from Coal Mining

Not to be overlooked in this discussion is the tremendous environmental damage caused by the mining of coal itself. Increasingly, in the Eastern United States, Appalachian coal is being mined by mountain top removal. This method requires that forests be clear-cut, the overburden of soil and rock loosened with high explosives, and the resulting debris pushed into nearby streams and valleys.[26] See Figure 2.

Figure 2. Mountaintop removal coal mine in southern West Virginia encroaching on a small community nearby. Photo by Vivian Stockman. From: http://www.ohvec.org/galleries/mountaintop_removal/007/index

Since coal will continue to have a place in the U.S. energy portfolio for some time to come, U.S. energy policy should promote mining coal in ways that are less environmentally destructive.

The Bush administration is proposing a new stream buffer zone rule to make it easier to mine coal in this way. Over 700 miles of streams were destroyed by the practice between 1985 and 2001, and the damage is likely to double by 2018.[27]

Looking Ahead

Generating "clean coal" energy with IGCC plants incorporating CCS is very expensive, making renewable energy more competitive financially. The recent experience in Delaware illustrates this point. As a result of a large increase (59%) in residential electricity rates in 2006, the legislature ordered Delmarva Power to issue a Request for Proposals (RFP) for new electrical power generation in the state. Three bids were received: one for a 600 MW IGCC coal plant with a CCS option, one for an offshore wind farm with 200 3 MW turbines, and one for a small 180 MW combined cycle gas plant. To everyone's surprise, the wind bid came in with a lower cost per MWh than the IGCC coal plant, even without CCS added, with much less environmental impact, and was chosen as the preferred option.[28] The Delaware Public Service Commission and three other state agencies have now approved a 25-year power purchase agreement between Delmarva Power and Bluewater Wind for the first U.S. offshore wind farm.[29]

To avoid the negative impacts of coal combustion on greenhouse gas concentrations, all future U.S. coal-powered plants must incorporate IGCC and CCS. By developing these new clean technologies, the U.S. will be in a position to help developing countries continue to use coal in ways that do not increase carbon emissions. "Emissions will be stabilized only through global adherence to carbon dioxide emission constraints. China and India are unlikely to adopt carbon constraints unless the United States does so and leads the way in the development of CCS technology."[30]

In testimony before Congress and in a series of papers summarized in one titled, **How Can We Avert Dangerous Climate Change?**, NASA's James Hansen argued in 2007 that we should not let atmospheric CO_2 increase to more than 450 ppm if we are to avoid dangerous risks to society and nature.[31] The atmospheric concentration is now about 385 ppm and increasing by more than 2 ppm/yr. Since there is enough carbon left in the remaining oil, natural gas and coal to take us way beyond 450 ppm (Figure 1), Hansen proposed that no new power plants based on coal be built without CCS, and that existing coal plants without it be phased out within a few decades. More recently, he and a number of other climate scientists, based not on climate models but on earth's past response to changing concentrations of CO_2, have concluded that the sensitivity of climate to CO_2 is much greater than had been expected and that a doubling of the pre-industrial concentration of CO_2 (280 ppm) to 560 ppm could lead to a rise of 6°C rather than 3°C as believed earlier.[32] They conclude that we must **reduce** CO_2 to 350 ppm to avoid dangerous climate change.

Lester Brown, in his recent book, **Plan B 3.0 – Mobilizing to Save Civilization**, has proposed that global greenhouse gas emissions be decreased by 80% by 2020.[33] In an article titled, **Goodbye Coal! Moving Toward a Ban on New Plants**, he points out that the U.S. has gone from 151 proposed new coal burning power plants in early 2007 to serious difficulty in financing or building any new plants based on coal. He proposes banning all new coal plants, a step that Denmark and New Zealand have already taken.[34] The League of Women Voters has now called for a moratorium on all new coal-fired power plants.[35]

Coal may be a great hope for some, but without CCS, which is still unproved and unreliable, it--like tar sands, oil shale and methane hydrates--is a disaster in the making.

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[9] The Deutsch Report (Ref. 4) projects that with business as usual, global annual CO_2 emissions from coal burning will increase from 9 Gt in 2000 to 32 Gt in 2050, corresponding to an increase of carbon emissions from 2.5 to 8.7 GtC/yr, respectively.

[10] Peter Fairley, **China's Coal Future**, ***Technology Review***, January/February 2007, pp. 56-61. At: http://www.techreview.com/Energy/17964

[11] Over a third of CO_2 emitted currently dissolves in the oceans or is taken up by plants, so that 4 GtC emitted as CO_2 produces about a 1 ppm change in CO_2 concentration. See W.C. Broecker, **CO_2 Arithmetic**, ***Science***, Vol. 315, p. 1371, March 9, 2007. At: http://www.sciencemag.org/cgi/content/summary/315/5817/1371

[12] Ken Berlin and Robert M. Sussman, **Global Warming and the Future of Coal – The Path to Carbon Capture and Storage**, The Center for American Progress, May 2007, p. 6. At: http://www.americanprogress.org/issues/2007/05/pdf/coal_report.pdf

[13] A 600 MW power plant using coal produces about 600 tons of CO_2 per hour.

[14] SOx and NOx are used to denote mixtures of oxides of sulfur and nitrogen, SO_2 and SO_3 or NO and NO_2.

[15] Ingo Paul, **Supercritical Coal Fired Power Plants – A Technology Successfully Deployed in Developing Countries**. At: http://www.worldbank.org/html/fpd/em/supercritical/supercritical.htm

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[17] Most of the chemistry of a typical IGCC plant can be represented by equation (1):

$$3C + H_2O + 2\,O_2 = H_2 + CO + 2CO_2 \qquad (1)$$

The CO can be converted into more H_2 and CO_2 by the water gas shift reaction, shown in equation (2).

$$CO + H_2O = H_2 + CO_2 \qquad (2)$$

Clean-energy.us has an excellent article, **About IGCC Power,** discussing the current state of the art of the technology, at: http://www.clean-energy.us/facts/igcc.htm

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[21] Hydrocarbons are compounds that contain only hydrogen and carbon. Ethanol also contains oxygen, and provides considerably less energy per gallon when it is burned. Because of their high energy density, hydrocarbon fuels are currently preferred for most transportation uses.

[22] J. Hansen, **Dangerous Human-Made Interference with Climate**, testimony before the Select Committee on Energy Independence and Global Warming in the United States House of Representatives, April 26, 2007. At: http://www.columbia.edu/~jeh1/testimony_26april2007.pdf

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The U.S. EPA has a web site devoted to Geologic Sequestration (GS) of carbon dioxide, See:

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