**THE FUTURE OF COAL**

*By Gary Antonides*

In the last newsletter, the Clean Power Plan (CPP) was mentioned as one of the environmental regulations that was likely to be cancelled by the Trump Administration. Trump did issue an executive order to "review" the CPP as well as other environmental regulations. Although the policies for the use of coal are uncertain right now, this article looks at the use of coal in this country and how technology could be used to clean up the use of coal.

In http://ngm.nationalgeographic.com/2014/04/coal/nijhuis-text, Michelle Nijhuis asks "Can coal ever be clean?" and reports that coal provides 40 percent of the world's electricity and produces 39 percent of global $CO_2$ emissions. It kills thousands a year in mines and many more with polluted air. According to the U.S. Energy Information Administration, in 2011 the average daily consumption of coal was 18 pounds per person in the U.S.

In West Virginia, whole Appalachian peaks have been knocked into valleys to get at the coal and streams run orange with acidic water. Air pollution in China, much of it from coal, is blamed for more than a million premature deaths a year. Coal is the dirtiest, most lethal energy source we have, but by most measures it's also the cheapest. So the real question is whether it can ever be clean *enough* to prevent local disasters and a radical change in global climate.

In August 2015, the Environmental Protection Agency (EPA) issued the final draft of the Clean Power Plan. The plan would be issued under the Clean Air Act, which has already been used to dramatically reduce the emission of sulfur dioxide, nitrogen oxides, and soot particles from American power plants. But carbon dioxide, the main cause of global warming, is a problem on a much larger scale.

Photograph by Robb Kendrick

Cheap natural gas has lately reduced the demand for coal in the U.S., but everywhere else, especially in China, demand is surging. During the next two decades several hundred million people worldwide will get electricity for the first time, and most will probably use power produced by coal. Even the most aggressive push for alternative energy sources and conservation could not replace coal right away. But we could start to capture carbon, as we do sulfur and nitrogen, and store or sequester it underground -- carbon capture and storage (CCS).

Some techniques for CCS involve treating the stack gases of conventional power plants. This is called "post-combustion" treatment. This was used at American Electric Power's (AEP) Mountaineer Plant, on the Ohio River in New Haven, West Virginia. It uses a million pounds of Appalachian coal every hour and supplies electricity to 1.3 million customers in seven states. Those customers pay about a dime per kw-hour, but nobody pays for the privilege of spewing six to seven million metric tons of carbon dioxide into the atmosphere every year. Carbon is dumped without limit because in most places it costs nothing to do so and because there is no law against it in the U.S.

In 2009, AEP attached a chemical plant to the back of its power plan that captured about 1.5 percent of Mountaineer's stack gases and compressed and injected the $CO_2$ into a porous sandstone formation more than a

mile below the banks of the Ohio. This system was the size of a ten-story apartment building—and that was just to capture a tiny fraction of the plant's carbon emissions. This energy-intensive technique could eat up as much as 30 percent of the total energy output of a coal plant if it were capturing all its carbon.

AEP planned to scale up the project to capture a quarter of the plant's emissions, and the company had agreed to invest $334 million. The U.S. Department of Energy (DOE) had agreed to match that. The deal was scrubbed when state utility regulators told the company that it could not charge its customers for a technology not yet required by law. The process worked, but it would take a regulatory or technical breakthrough to make it worthwhile.

Elsewhere, for more than four decades, the oil industry has been injecting compressed carbon dioxide into depleted oil fields to coax trapped oil to the surface. The Saskatchewan Government's Boundary Dam Integrated Carbon Capture and Sequestration Demonstration Project uses a post-combustion, scrubber technology to capture 90% of the $CO_2$ emitted by one of the units of the plant. The $CO_2$ is piped to and utilized for enhanced oil recovery in nearby oil fields.

In North Dakota, a "pre-combustion" technique is used in one of the world's largest underground carbon-storage operations. This plant gasifies the coal before burning it. Gasification is a process that converts organic or fossil fuel into carbon monoxide, hydrogen and $CO_2$. This is achieved by reacting the material at high temperatures (greater than 700 °C), without combustion, but with a controlled amount of oxygen and/or steam. Gasification can make power generation more efficient and allows the $CO_2$ to be separated more easily and cheaply. Gasification also removes the sulfur dioxide and mercury

Since 2000, more than 20 million tons of carbon dioxide from this North Dakota plant has been piped 200 miles north into Saskatchewan where a Canadian company pushes the $CO_2$ deep into sprawling oil fields that had their heyday in the 1960s. Two to three barrels of oil are dissolved out of the reservoir rock by each ton of $CO_2$. This Plant, the Great Plains Synfuels Plant, began operating in 1984, according to https://www.dakotagas.com/.

The gas in the pipeline is over 2000 psi, which makes it a supercritical fluid, which is as dense as the liquid phase, but it flows easily, making it ideal for transporting through pipelines. It is predicted that the $CO_2$ enhanced oil recovery operation will extend the field's commercial life by around 25 years.

Sites for storing $CO_2$ have to be chosen carefully, but European researchers estimate that a century's worth of European power plant emissions could be stored under the North Sea. According to the DOE, similar "deep saline aquifers" under the U.S. could hold more than a thousand years' worth of emissions from American power plants.

A new power plant being built in Kemper County, Mississippi was designed with carbon capture in mind and will also gasify its coal. This is the first American power plant designed from scratch to capture carbon. It has been delayed multiple times, but is supposed to be operational any day now. It will capture more than half its $CO_2$ emissions and pipe them to nearby oil fields. The project is supported in part by DOE.

A third technology uses pure oxygen for combustion (oxy-fuel). This process results in simpler flue gasses, from which the $CO_2$ can be more easily separated. Examples of oxy-fuel CCS plants are in Germany, Australia and Spain. The DOE's National Energy Technology Laboratory in Morgantown, West Virginia is working on an advanced version of this scheme.

https://www.washingtonpost.com/news/energy-environment/wp/2017/04/10/the-quest-to-capture-and-store-carbon-and-slow-climate-change-just-reached-a-new-milestone/?utm_term=.bc024edc7316&wpisrc=nl_green&wpmm=1 reports on a new large-scale technology in Decatur, Illinois that combines corn-based fuels with the burial of carbon dioxide deep underground. It could potentially result in actual removal of greenhouse gases from the atmosphere. DOE invested $ 141 million into this project. The facility is operated by ethanol giant Archer Daniels Midland (ADM). They are struggling to move beyond feedstocks like corn, which can create conflicts with food supplies. Eventually, this technology could be quite significant from a global climate perspective.

At the Decatur plant, $CO_2$ is stripped out of the fermentation process in which corn is converted to ethanol and which yields an almost perfectly pure stream of $CO_2$ gas. The gas is then converted to "supercritical," fluid form and piped underground. The $CO_2$ will not be used for the purposes of enhanced oil recovery, which would add to the economic viability of CCS. However, oil recovery has drawn criticism because it promotes further use of fossil fuels.

Despite campaigning about the importance of "clean coal", the Trump administration is aiming to slash research funding for these kinds of technologies.

In West Virginia, century-old coal mines are now closing as power plants convert to natural gas. With gas prices in the U.S. near record lows, investing in advanced coal technology here may actually be a mistake. However, in China, coal provides about 80 percent of China's electric power, and it isn't used just for making electricity. Since coal is so plentiful, it's also used for making industrial chemicals, liquid fuels, and other products, a role played by petroleum in most countries.

Coal has also made China first among nations in total $CO_2$ emissions, though the U.S. remains far ahead in emissions per capita. Because of public complaints about air quality and awareness of the risks of climate change, China has invested hundreds of billions of dollars in renewable energy and is now a top manufacturer of wind turbines and solar panels. But they are also pushing ultra-efficient coal power and simpler, cheaper carbon capture. China's first power plant designed from scratch to capture carbon will reportedly be complete in 2020, and is supposed to capture 80 percent of its emissions.

Last fall, the Intergovernmental Panel on Climate Change (IPCC) advocated an emissions budget for the planet—the total amount of carbon we can release if we don't want the temperature rise to exceed 2 degrees Celsius (3.6 degrees Fahrenheit) above the 19th century level. Many scientists believe more than this would result in serious harm. They concluded that we've already emitted more than half of our carbon budget, and, on our current path, we'll emit the rest in less than 30 years. To meet the 2 degree goal, we need to reduce global emissions by roughly 80 percent in the next 30 or 40 years. Carbon capture has the potential to deliver big emissions cuts quickly. But carbon capture technology won't spread until governments require it, either by imposing a price on carbon or by regulating emissions directly.

In the 1990s, when the EPA used the Clean Air Act to impose a cap on total emissions of sulfur dioxide from power plants, the power industry predicted disastrous economic consequences. Instead the cap produced innovative, progressively cheaper technologies and significantly cleaner air. Carbon-capture systems are at much the same stage that sulfur dioxide systems were in the 1980s.

The state of the technologies discussed above are largely a result of the U.S. Department of Energy (DOE) conducting a joint program with the industry and State agencies in the late 1980s and early 1990s to demonstrate clean coal technologies large enough for commercial use. It sponsored 18 programs, and now https://en.wikipedia.org/wiki/Clean_coal_technology reports that there are now more than 80 carbon capture and sequestration projects in the United States.

The Clean Power Plan (CPP) initiated during President Obama's administration set carbon reduction goals for the states, and left it up to the states to develop plans to meet the goals. If a state did not have a plan after a reasonable time, the EPA could impose a plan on that state. Unfortunately, the CCP was challenged by several states and the Supreme Court issued a stay until the case could be heard. And that was even before Trump issued an Executive Order telling the EPA to "review" the CPP.

As explained in https://www.washingtonpost.com/news/energy-environment/wp/2017/02/07/senior-republican-leaders-propose-replacing-obamas-climate-plans-with-a-carbon-tax/?utm_term=.ef9f9d2f4310, there is a simpler plan that has received attention lately. Representatives from a coalition of veteran Republican officials met in February with White House officials to discuss the idea of imposing a national carbon tax, rather than the CPP to address climate change.

This newly formed Climate Leadership Council, led by James A. Baker, is proposing elimination of nearly all of the Obama administration's climate policies in exchange for a rising carbon tax that starts at $40 per ton, and is returned in the form of a quarterly check from the Social Security Administration to every American. This revenue-neutral plan has been popular among economists and some climate scientists for years. The Council estimates that the average family of four would receive $2,000 annually in dividends from the fee if it starts at $40 per ton, and as the tax rises, so would their dividends. This naturally creates a constituency for ever-tougher climate change action.

Right now there is wide disagreement on the "price" of carbon. Such a number could be used in carbon taxes or cap-and-trade systems. It can be market based or imposed by governments.

http://www.zdnet.com/article/why-carbon-capture-and-storage-will-never-pay-off/ reports that The Global CCS (Carbon Capture & Storage) Institute, based in Australia estimates that $CO_2$ would have to be priced at $23 to $92 per ton to make CCS viable. Other estimates vary considerably.

http://hub.globalccsinstitute.com/sites/default/files/publications/195008/costs-ccs-other-low-carbon-technologies-united-states-2015-update.pdf says that coal-fired generators in the US with CCS capability should be on par with

traditional coal and gas generation if carbon were priced between $48 and $109 per ton and that a price above $48 would start to incentivize investment in coal plants with CCS.

Unfortunately, global carbon markets aren't pricing $CO_2$ emissions anywhere near these levels. The EU has a carbon trading scheme, and the current price for carbon in this system is about $6.00 per ton. With the future of carbon policy so uncertain in the U.S. and abroad, it's not likely that carbon prices will rise to the point where investing in CCS makes sense.

In addition, the recent cancellation of several large CCS projects doesn't bode well for carbon prices. Two projects in Canada have been scrapped due to cost and cheap natural gas. As mentioned earlier, AEP's Mountaineer Station in West Va., was cancelled. An oxy-fuel plant planned for Illinois was cancelled in 2015. Still, the coal companies are fighting for their lives, and hope that CCS will justify their existence, even though the declining costs of renewable power may soon make CCS economically unviable.

Trump promised to bring back coal jobs, but rolling back the CPP is not likely to have much effect since the coal industry

was already suffering from three main factors: (1) increased natural gas production, (2) the growing renewable energy industry, and (3) the automation of coal mining. Also, consider that the CPP never even took effect since a stay was put on it by the courts until the case can be heard. Fortunately, several states have imposed their own taxes or cap-and-trade schemes, and more are likely if the EPA's authority is reduced.

One way states are helping is described in https://www.brookings.edu/wp-content/uploads/2016/07/State-level-carbon-taxes-Options-and-opportunities-for-policymakers.pdf. They report that a number of states have committed to deep, long-term emissions reduction targets. For example, Massachusetts, New York, and Rhode Island all have targets to reduce their greenhouse gas (GHG) emissions by 80 percent of 1990 levels by 2050, and Oregon and Vermont have goals of 75 percent reductions.

An initiative on the November 2016 ballot in Washington State would have instituted the first state carbon tax starting at $15 per metric ton of $CO_2$ on fossil fuels sold or consumed in the state. The measure would use the revenue, among other things, to reduce the state sales tax by one percentage point. The measure failed, primarily because people disagreed on how to spend the revenue.

Cap-and-trade systems seem to be more popular. Nine Eastern/Midwestern states (including Maryland)) have formed the Regional Greenhouse Gas Initiative (RGGI) for that purpose and California also has a cap-and-trade scheme.

More common still is the Renewable Portfolio Standard (RPS). This requires a certain percentage of power to come from renewable sources. Twenty-nine states have them. Maryland recently increased its RPS to 25% by 2020, and several other states are considering increases. Hopefully, the states will continue to lead in GHG reduction.