World Coal Future

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Introduction

In this Anthropocene era (<u>http://en.wikipedia.org/wiki/Anthropocene</u>) the amount of coal extracted from the Earth and burned for fuel was crucial for the initiation of the industrial revolution c1760

(<u>http://en.wikipedia.org/wiki/Industrial_Revolution</u>) and now is crucially deleterious for the survival of *Homo sapiens* sapiens on the Earth. See <u>http://en.wikipedia.org/wiki/Coal</u> for much information about coal.

This document discusses many salient facts and displays many graphs about the extraction of coal from the Earth and burning it for fuel. Especially emphasized will be the environmental effects of burning coal including the effects on the health of humans and the effects on global warming (aka climate change)(<u>http://en.wikipedia.org/wiki/Global_warming</u>).

Environmental Effects of Coal Extraction

There are many aspects to the deleterious environmental effects due to extracting coal from the Earth (<u>http://en.wikipedia.org/wiki/Environmental_impact_of_the_coal_industry</u>):

- Landscape destruction, including mountain-top removal (<u>http://www.roperld.com/science/minerals/EnergyLandscapeDestruction.htm#coal</u>)
- Pollution of streams and water tables, such as soil from mountain-top removal
- Pollution of the air, including dust and diesel fumes
- Methane released into the atmosphere, a powerful global-warming gas
- Noise pollution
- Human diseases and deaths
- Wildlife diseases and deaths

As shown below coal extraction in West Virginia, Virginia, Kentucky and Tennessee, the states where mountain-top removal has been greatest, have been on a steep decline since before year 2000. In the case of Virginia the peak was at 1990 during the GHWB administration (a Republican "War on Coal"?).



It has been a mystery to the author as to why the coal companies and state and federal governments have not launched massive programs to populate the areas of mountain-top removal with wind and solar farms to provide permanent, more desirable, jobs for workers who are losing their coal jobs, as well as clean energy for them to use.

Environmental Effects of Burning Coal for Energy Production

There are many aspects to the deleterious environmental effects due to burning coal as an energy source or in industrial processes (<u>http://en.wikipedia.org/wiki/Environmental_impact_of_the_coal_industry</u>):

- Fine particulates in the air
- Ground level ozone in the air
- Soot in the air and on the ground
- Pollution of the air, including sulfur, lead, arsenic, mercury and many other compounds
- Coal fly ash in streams, which can be highly radioactive

References:

- <u>http://en.wikipedia.org/wiki/Burning_the_Future:_Coal_in_America</u>
- http://en.wikipedia.org/wiki/Mountain_Top_Removal_(film)
- <u>http://en.wikipedia.org/wiki/Mountain_top_removal</u>

Global Warming Due to Burning Coal for Energy Production

There has been a movement to use the term "climate change" instead of "global warming". The author prefers "global warming" because the average warming of the Earth due to more solar energy being absorbed by the Earth is what is causing climate change. The warming of the Earth is not uniform; in fact, it is possible that some areas will be colder than they were before global warming started. The artic is warming about twice as fast at the temperate and tropic areas.

Burning coal for energy releases more greenhouse gases (GHG) into the atmosphere than does burning gasoline, made from crude oil, or natural gas

(http://en.wikipedia.org/wiki/Greenhouse gases#Relative_CO2_emission_from_various_fuels):

Fuel	CO ₂ emitted
	(g/10 ³ J)
Natural gas	~50
Gasoline	~67
Coal	~90

So, quitting burning coal for energy will have the largest effect in mitigating global warming than quitting burning natural gas or gasoline. However, even with electricity mostly generated by burning coal, electric vehicles cause less GHG than driving an equivalent gasoline car because electric motors are more than three times as efficient as gasoline engines.

Carbon-Dioxide Sequestration from Burning Coal

Burning coal for energy without making global warming worse requires that the carbon dioxide emitted be captured and stored for many years. This is called carbon-dioxide sequestration or carbon sequestration (http://en.wikipedia.org/wiki/Carbon_sequestration ; http://en.wikipedia.org/wiki/Carbon_sequestration ; http://en.wikipedia.org/wiki/Carbon_sequestration ; http://en.wikipedia.org/wiki/Clean_coal_technology). Of course, it requires energy to capture the carbon dioxide and store it; the production of that energy must not emit carbon dioxide.

The major push for carbon sequestration is in China (<u>http://www.globalccsinstitute.com/location/ccs-china</u>).

Since the Earth's climate will plunge into the next 100,000-years major ice age as fossil fuels deplete, it would be wise for humans to store the carbon-dioxide in such a way that it can be released a thousand or so years later to slow the entrance into the next major ~100,000-years ice age. Is human society intelligent enough to do that?

The author has done a rough calculation as to how the transition into the next major ~100,000-years ice age might occur (http://www.roperld.com/science/Energy GlobalWarming IceAge.htm):



The temperature change is relative to year 1700. The slow drop into the next major ~100,000-years ice age was underway when large global warming was caused by the fast entrance into the industrial revolution due to burning of fossil fuels, agriculture and deforestation. After fossil fuels, mostly coal toward the end, are essentially depleted at year ~2100 (see below), after a few hundred more years of high temperatures the plunge into the next major ice age will be much faster than it would have been if global warming had not occurred. It is problematic as to whether humans can survive that plunge; if humans do survive, they will surely evolve very rapidly to be very different than they are now, as they did in the plunge into the last major ~100,000-years ice age. (Climate Change and Human Evolution: http://anthro.palomar.edu/homo/homo_3.htm)

Earth Temperature Sum (Worst Case & Climate Sensitivity 3 to 6)

Modern Global Warming (Worst Case & Climate Sensitivity 3 to 6)

Earth Average Temperature without Global Warming

2.0 2.5 3.0

Amount of Coal Available for Extraction from the Earth

In the following fits to coal-extraction data:

- If the data are decreasing during the last few years, a best fit is done.
- If the data are rising during the last few years, a fit is done using the current recoverable-reserves value with the assumption that the future peak will be symmetric.

World Coal Extraction







For the US, estimated recoverable reserves indicate that another future peak could occur. However, mitigation of future disastrous climate change implies that such a future peak should not occur.

The following graph shows the amount already extracted and the total amount to be extracted for nations with the largest extraction amounts.



The following graph shows the extraction rates versus year for nations with the largest extraction.



United States Coal Extraction



The estimated recoverable reserves indicate that another future peak could occur. However, mitigation of future disastrous climate change implies that such a future peak should not occur.

The following graphs show coal extraction data for US states with the largest extraction. The red curves are the best fits to the data using the Verhulst function (<u>http://www.roperld.com/science/minerals/VerhulstFunction.htm</u>) to fit the data.









For many states the estimated recoverable reserves indicate that another future peak could occur. However, mitigation of future disastrous climate change implies that such future peaks should not occur.

The following graph shows the amount already extracted and the total amount to be extracted for the 17 U.S. states with the largest extraction amounts.



The following graph shows the extraction rates versus year for 6 U.S. states with the largest extraction.



Coal Exports from the United States

The following graph shows total coal exports from the United States since 1961:



The exports to the major nations (Canada; Japan; and other, see below) are:



About one-third of the "other" category in recent years in the graph above is for China and India:



Replacing Coal as a Source of Energy Production

Construction of renewable energy infrastructure is increasing so fast in the United States that by 2020 it will generate much more electricity than coal, natural gas and nuclear reactors:



Generating electricity by renewable energy is growing exponentially in the United States:



So, there is hope that the current exponential rate of creating the infrastructure for electricity generated from renewable sources in the United States will continue for several more decades. In some countries, such as Germany and Spain, it is increasing faster than in the United States.

With this fast rise in generating electricity from renewable sources, future coal extraction from the Earth could be reduced to half of the current reserves (474×10^9 tons), the green curve in the graph below:



Good Uses for Coal

Some good uses for coal are:

- Carbon fiber (<u>http://composite.about.com/od/aboutcarbon/a/Carbon-Fiber-Basics.htm</u>; <u>http://en.wikipedia.org/wiki/Carbon_(fiber)</u>) is used to make large objects that need to have a low mass, such as airplanes and ground vehicles. It can be made from coal (https://web.anl.gov/PCS/acsfuel/preprint%20archive/Files/41 1 NEW%20ORLEANS 03-96 0349.pdf).
- Activated carbon (<u>http://en.wikipedia.org/wiki/Activated_carbon</u>) can be made from coal; it has many small pores and is used as filters for certain chemicals and substrates for chemical reactions.
- Organic chemicals can be made from coal.

References

- <u>http://www.coalage.com/features/2284-100-years-with-coal-age.html?start=5</u>
- <u>http://www.southernenvironment.org/cases/mountaintop_removal_coal_mining/</u>

"<u>True Cost of Coal</u>" Art



The True Cost of Coal



The True Cost of Coal



The True Cost of Coal