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Fire or Ice? The role of peak fossil fuels in climate change scenarios

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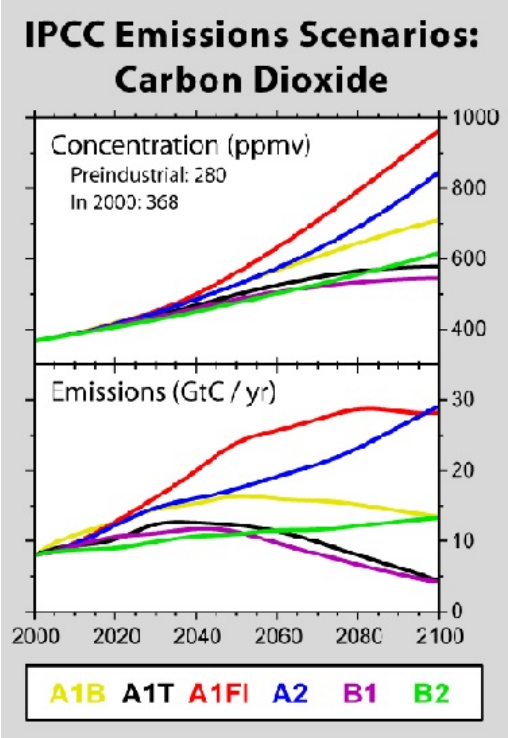

Carbon dioxide emission scenarios according to IPCC (from http://www.globalwarmingart.com). "Peaking" of the major fossil fuels, oil, gas and coal, could radically change these projections.

Will the world end in fire or in ice? That is, are we going to be hit by global warming or are we going to freeze because of lack of fossil fuels? We don't know yet, but it is starting to appear clear that geology is placing a major constraint on anthropogenic CO_2 emissions and, therefore, on global warming. Here, I present a brief summary of some of the recent papers that have appeared on the subject.

Until recently, most simulations of future climate have been run without taking into account "peaking" of the major fossil fuels. Concepts such as "peak oil" are not discussed, and not even mentioned, in the reports of the International Panel on Climate Change (IPCC). But, with peak oil coming, or already arrived, the subject is starting to appear in scientific journals, blogs, and conferences. In a previous post , I reported about the "Mission Earth" seminar held in Zurich in 2009 where climatologists and depletion experts gathered to exchange views. Here, I present a short review of the status of the field. There is a very small number of papers published in

scientific journals on this subject and I think this summary includes them all. I also tried to include a number of less formal studies published on the web or presented at conferences.

Some early papers raised the question of the discrepancy of the standard IPCC scenarions and the peak oil projections. The first one was probably **Jean Laherrere** with a paper published in 2001. Later on **Anders Sivertsson** , **Kjell Aleklett** and **Colin Campbell** wrote in 2003 in "The New Scientist" a paper titled "Not enough oil for climate change". They criticized the IPCC scenarios for being overoptimistic in terms of oil and gas reserves. These early papers didn't attempt to calculate the future concentrations of CO2 in the atmosphere.

Perhaps the earliest attempt to quantify the effects of CO2 on climate while taking depletion into account was the work by **Pushker Kharecha** and **Jim Hansen** who produced a paper titled *"Implications of "peak oil" for atmospheric CO2 and climate"*. This study was published in 2008 but became available on line as a working paper in April 2007. In the first version of the paper, Kharecha and Hansen start from the premise that the CO2 concentration in the atmosphere should not be allowed to exceed 450 ppm; later on they arrived to the conclusion that the dangerous limit is more likely to be around 350 ppm. So, they examine several scenarios that involve policy measures to force the reduction of emissions. They find that, if no such measures are taken, CO2 concentrations might rise to near 600 ppm by the end of the century, mainly as the result of coal combustion. Oil and gas would peak before 2030 in most of the scenarios considered and would give only a minor contribution to the total of the emissions.

Shortly after the paper by Kharecha and Hansen, **David Rutledge** published a post on "The Oil Drum" website with the title *"The coal question and climate change"* (June 2007). Later on, in December 2008, Rutledge also presented his results as an invited talk at the fall meeting of the American Geophysical Society. Rutledge set up an approach that would be used again by other authors; that is, he started with an estimate of the available resources, from that he generated a production curve that involves "peaking" and then he calculated CO2 emissions in the atmosphere. Then, by means of the software package named "MAGICC," available from NCAR, Rutledge generates climate scenarios in terms of CO2 concentrations and atmospheric temperatures. The results are that geological constraints on coal production (what he calls "producer limited" profile) would limit CO2 concentrations to about 480 ppm even without policy measures to curb emissions. Under these conditions, temperatures might rise of approximately 1.6 deg. C. Rutledge concludes that "if we wish to reduce the temperature rise, we must bury the CO2 (assuming that it will not leak out for 1,000 years), or establish preserves for fossil fuels that prevent them from being produced."

Robert Brecha examined the question in his 2008 paper *"Emission scenarios in the face of fossil-fuel peaking"* . His approach is very similar to that of Rutledge. Brecha calculates a series of scenarios in terms of fossil fuel production - including oil, gas and coal - on the basis of reserve estimates and logistic production curves. No policy interventions are assumed. Subsequently, he estimates CO2 concentrations and atmospheric temperatures using the MAGICC software package. His conclusions are that the world energy production could peak from 2030 to 2050, depending on assumptions, causing CO2 emissions to peak as well. The CO2 accumulated in the atmosphere would continue to grow after the energy peak, but it would be slowly absorbed by the effect of the natural "sinks" of the ecosphere. By the end of the century, CO2 concentrations would stabilize in a range from ca. 480 to 580 ppm and temperatures could rise by 1-3 deg C. Brecha's results indicate - again - that geology, alone, may not be sufficient to stop anthropogenic global warming from reaching dangerous levels.

Luis De Sousa and **Euan Mearns** (2008) took an approach similar to the papers by Brecha and Rutledge, but arrived at somewhat different conclusions in terms of policy recommendations. For estimating emissions, they use a model that they developed earlier and that they term "Olduvai Revisited" (2008). The model is based on resource estimates and forecasts which assume "bell shaped" behavior of the production curves. They find a global peak for fossil fuel

production by 2018. Using the MAGICC software package, they find that, for this scenario, CO2 concentrations should not rise over 450-500 ppm and that temperatures should not rise over 1 deg. C. De Sousa and Mearns conclude that fossil fuel decline will keep CO2 concentrations below levels that are or were considered dangerous by climate experts and that there is no need to burden the OECD and non-OECD countries with artificial measures to mitigate emissions to achieve this end.

The latest entry on this subject published in a scientific journal is a paper by **Willem Nel** and **Christopher Cooper** which appeared in "Energy Policy" (2009) with the title *"Implications of fossil fuel constraints on economic growth and global warming"*. The paper is very detailed and comprehensive in its estimates of fossil fuel reserves; it also includes estimates on the contribution of renewables, nuclear and unconventional fuels. The authors generate production scenarios based on logistic curves. CO2 concentrations and atmospheric temperatures are calculated by a detailed modeling approach. In what they call the *Energy Reference Case*, Nel and Cooper find a peak in the total world primary energy production that should take place around 2025. According to the authors' model, the peak will not slow the growth of the gross world product. It will keep growing for a couple of decades longer, peaking only around 2050. CO2 emissions are expected to peak with primary energy, that is around 2025. The calculated maximum CO2 concentrations don't exceed 500 ppm, except for the most pessimistic scenario, in which 550 ppm are reached. From these concentrations, Nel and Cooper calculate that the temperature increase prior to 2100 should not exceed 1°C. They conclude that this increase in temperature is not dangerous and that reaching these CO2 levels is preferable to facing the economic and social consequences of not fully exploiting the remaining fossil fuels.

The study by Nel and Cooper has been challenged by **Antonio Zecca** and **Luca Chiari** (2009) in a working paper to be submitted to a scientific journal. Zecca and Chiari criticize the conclusions of the paper regarding CO2 concentrations and temperature effects. First, they argue that CO2 future concentrations are underestimated because the lifetimes of CO2 molecules in the atmosphere may be longer than assumed in the paper. Furthermore, Nel and Cooper may have underestimated the climate sensitivity due to forcing and other factors in their calculations. According to Zecca and Chiari, even for the "Energy Reference Case" scenario presented in the paper, the final temperature increase of the atmosphere may be of the order of 1.7 °C. They also stress that there is no reasonable guarantee that fossil resources that are now too expensive or difficult to extract won't be used, as Nel and Cooper assume. Therefore Zecca and Chiari consider the conclusions by Nel and Cooper to be much too optimistic in terms of the opportunity to continue to burn hydrocarbons.

Finally, let me report on what is perhaps the most recent entry in this field, the work by **Dolores Garcia** (2009) which was presented at the "Mission Earth" seminar held in Zurich in 2009. Garcia's model is a modified version of the "World3" model that was developed for the study "The Limits to Growth" published in 1972. It links together several parameters: energy, greenhouse gases, population, GDP and others. It is a truly integrated model, an approach more advanced than that of the other models described here. Nevertheless, Garcia's results are consistent with those of the other papers, with carbon dioxide production peaking around 2020. Garcia doesn't attempt to calculate temperatures, but the CO2 concentration in the atmosphere is calculated using an approximate estimation of the effect of sinks. It stabilizes at 510 ppm by the end of the century.

The studies published so far that take into account both peak oil and climate change are a truly minuscule number in comparison to the total number of papers that deal with climate change. This says a lot on how the problem was neglected so far. Nevertheless, a consensus seems to be emerging. Even with different models and different assumptions, it appears that geological constraints pose an important limit on CO2 emissions. All the studies discussed here arrive at the conclusion that, even without policy interventions, the CO2 concentration in the atmosphere will stabilize in a range that goes, approximately, from 450 to 600 ppm. These values are far below

those of the "business as usual" (bau) scenario of the IPCC that predicts a CO2 concentration of about 1000 ppm by the end of the century.

Based on these studies, peak oil (and, in general, peak fossils) is going to have a strong effect on the climate issue. For one thing, it may well make the Kyoto treaty obsolete. There would be no need for policy measures to enforce the Kyoto targets. The emission limits that today are often seen as an insufferable set of constraints on the economy, could become, in the near future, just a consequence of the reduced supply of fossil fuels coupled with a contracting economy. On the other hand, the targets of the Kyoto treaty might well turn out to be insufficient to counter global warming.

At this point, there is no consensus among the authors in terms of policy recommendations relating to these results. Some of the authors cited here conclude that peaking of fossil fuel production will be sufficient to maintain CO2 at a level below that considered dangerous by many climate experts. But this conclusion is not shared by other authors who maintain, instead, that even if we could be sure that CO2 concentrations would remain in the 450-550 ppm range, we would still face dangerous levels of global warming. Clearly, this is a difficult issue to solve, given the uncertainty in the scenarios and in the calculations of CO2 concentration in the atmosphere and the temperature effects. Furthermore, there are several phenomena that the climate models don't consider and that could make warming much more serious than currently believed. Among these, the saturation of the CO2 sinks, the positive feedback of the methane hydrates and those of the ice/albedo system. We just don't know enough to be able to say whether depletion is enough to "save" us from global warming.

However, it may not matter which threat one considers the most immediate: there exist measures that will mitigate both global warming and depletion. These are energy efficiency and replacing fossil fuels with nuclear energy or renewables. There is only one mitigation measure that doesn't cut both ways: CO2 geological sequestration. If depletion is a more immediate problem than global warming, clearly it would make no sense to waste precious resources in removing CO2 from the atmosphere. On the other hand, if oil and gas depletion leads us to rely more on coal, then sequestration might be necessary.

In my opinion, the studies I have discussed show that there are serious threats looming ahead. I believe that whether the threat be depletion or warming, we should move away from fossil fuels as fast as possible. Still, it is not at all certain that what we can do will be enough and we might well suffer for both effects: lack of fuels and global warming. It wouldn't be "fire or ice", but fire *and* ice.

I would like to thank Antonio Zecca for his comments and suggestions. This paper was modified after publication with some minor corrections and the addition of one bibliographic reference.

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