OIL vs. WARMING
FOSSIL FUEL SCARCITY WILL NOT SAVE US FROM GLOBAL WARMING

Antonio Zecca and Luca Chiari

Abstract

The extent of global warming which will be experienced on the Earth in the next centuries will be constrained by the trajectories of the anthropic fossil fuel consumption as well as by geological fuel availability.

An important paper by W. P. Nel and C. J. Cooper (Nel and Cooper, 2009) will appear in Energy Policy (already available online) attempting to connect the ongoing fossil fuels depletion and the greenhouse warming caused by CO_2 emissions. Nel and Cooper conclude that even if all the available fossil fuels would be burned at the maximum possible rate during this century, the consequent warming would cap at less than 1 °C above the 2000 level. Since the conclusion is of outmost importance for policies which will determine the future of mankind, it is worth to investigate how the conclusions of Nel and Cooper disagree with the results of the IPCC reports.

Here we will examine the part of Nel and Cooper paper regarding the physics of the climate system. We will not deal with Nel and Cooper evaluations about resources/reserves of fossil fuels. We will use throughout the paper their evaluations in order to make easier the comparison with our results. At the end of this writing we will give a short comment only on the resource evaluation and on the economic part of the paper.

We anticipate here that Nel and Cooper calculations do not deal correctly with three aspects of the climate system. This leads to underestimate the global warming by a factor possibly larger than 1.5. Their conclusion *"that the extent of global warming may be acceptable and preferable compared with the socio economic consequences of not exploiting fossil fuel reserves to their full technical potential"* is strongly misleading.

1. Introduction

The paper by Nel and Cooper (denoted as N+C hereafter) evaluates the global fossil fuel production curve until 2100 using a logistic analysis of the historical production data (Hubbert, 1956; ASPO, 2009) (par. 2-5). Projections are given also for non-renewable nuclear energy (par. 6) and for renewable sources (par. 7). These data are used as an input for an energy-economic model outlining possible growth trends of the world economic system (par. 8-10). This model allows N+C to devise four world total energy supply scenarios plus one scenario for fossil fuel availability up to 2100 (fig. 22). Starting from these scenarios it is possible to compute the CO_2 emissions in the same period. It is now a matter of translating the past and future emissions into the future atmospheric CO_2 concentrations.

2. CO_2 permanence time

Here comes the first debatable point in N+C calculation. CO_2 concentration is an intricate function of emissions. Once CO_2 is emitted we can assume that in a sufficiently long time the Earth system will absorb it into the so-called CO_2 sinks. We can list (with no aim of being exhaustive) continental and marine biology, continental vegetation, the oceanic mixing layer and the deep ocean. Each of these sinks acts with its own typical time from the seasonal scale of vegetation to millennia for the deep ocean, and therefore

CO_2 is still present in atmosphere years and decades after the release. The Bern carbon cycle model (IPCC, 2007, pp. 213, 790; Joos et al., 2001) describes the absorption of a pulse injection of CO_2 into the atmosphere as the sum of three exponential decays – which can be thought as connected with the intrinsic times of sinks. The Bern model is used in the IPCC reports. N+C use their own model, although the model is not described in the quoted paper and no equation is given for the time dependence of the CO_2 concentration in atmosphere. Nevertheless it is possible to infer from their fig. 25 that the two versions AH(0.03) and AL(0.022) of their model show a single lifetime of the order of ~30 and ~50 years respectively.

We have made an independent evaluation of the CO_2 permanence time using an a-priori treatment of the emission and concentration historical data. Our evaluation does not allow to pinpoint the presence of different lifetimes: we end up with a single average lifetime of the order of 36 years. This is consistent with N+C quoted values and with the average lifetime we can evaluate from both the models of Siegenthaler & Oeschger (Siegenthaler and Oeschger, 1980) and Maier-Reimer & Hasselmann (Maier-Reimer and Hasselmann, 1987). We are aware that both our single lifetime and the two models used by N+C underscore the presence of long time constant CO_2 sinks and this is at odd with physical sense. We conclude that the two AH(0.03) and AL(0.022) models used by N+C underestimate the future concentration increases, the error being larger at longer elapsed times. Even willing to distrust the Bern model, our analysis gives a reason to believe that the temperature increases calculated by N+C are underestimated. In the absence of an "adjudicator" giving a more reliable time dependence for CO_2 concentration following a pulse injection, we will not give here a correction factor. Nevertheless, in order to account for the long time constant CO_2 sinks, N+C temperature increases should be probably increased by a factor larger than 1.

3. Climate sensitivity

Once the time evolution of the CO_2 concentration is computed, the next step is to infer the time evolution of the global surface temperature. This is made through the equation:

$$\Delta T = \lambda 5.35 \ln\left(C/C_0\right)$$

where ΔT is the temperature increase at a given year relative to a reference year (2000 in N+C); C and C_0 are the CO_2 concentrations at that given year and in 2000. The coefficient λ is the climate sensitivity; λ can assume values between 0.3 and 1.3 °C/(W/m^2). The lowest value can be achieved in a climate system with no feedbacks, like a planet with an inert atmosphere, while the highest value can be achieved in a system with very strong feedbacks. In the present climate state of the Earth, λ is believed to have a value close to 0.7 °C/(W/m^2) (Seinfeld and Pandis, 2006; Hansen et al., 2000; IPCC, 2007, pp. 798-799). N+C calculate the λ value in a very naive way: they use the equation

$$\Delta T = \lambda \Delta F$$

collecting from IPCC 2007 the 1850 to 2000 global temperature increase (ΔT = 0.76 °C) and the corresponding ΔF value (ΔF is the change in the radiative forcing due to all the optically active gases: ΔF ~ 1.84 W/m^2). This way they calculate λ ~ 0.41 °C/(W/m^2). This value is very low and certainly far from the accepted value λ ~ 0.7 °C/(W/m^2).

We will show that, based on the present knowledge, there is no need to believe in a value far from 0.7 °C/(W/m^2). We can rather believe that the actual negative aerosol forcing value lies in the high range of the IPCC assessment. As a matter of fact, IPCC 2007 acknowledges that the error bars on the negative aerosol forcing are very large: the most probable value being -1.45 W/m^2 (from -3.2 to -0.5) (IPCC, 2007, fig TS.5 and table therein). Let's consider that the sum of all positive forcing (optically active gases plus other positive forcings) is given a most probable value +3.2 W/m^2 (from +2.7 to +4.2) (IPCC, 2007, fig TS.5 and table therein). Using λ ~ 0.7 °C/(W/m^2) we find a most probable "virtual" greenhouse warming of ~ 2.2 °C and a most probable aerosol cooling of ~ 1.0 °C. The overall global temperature increase (1850 to 2000) should be 1.2 °C and this is non-consistent with the observed value ~ 0.76 °C (IPCC, 2007, pp. 249). This large inconsistency can be solved assuming an extremely low λ value (~ 0.41 °C/(W/m^2)) as in N+C) or by choosing a larger negative forcing ~ -2.0 W/m^2 , the last choice being entirely compatible with our present knowledge of the negative forcing components.

Coming back to N+C paper, we hold here that the use of a low λ value underscores the future global warming. The corresponding correction to their temperature values is a factor 0.7/0.41 = 1.7.

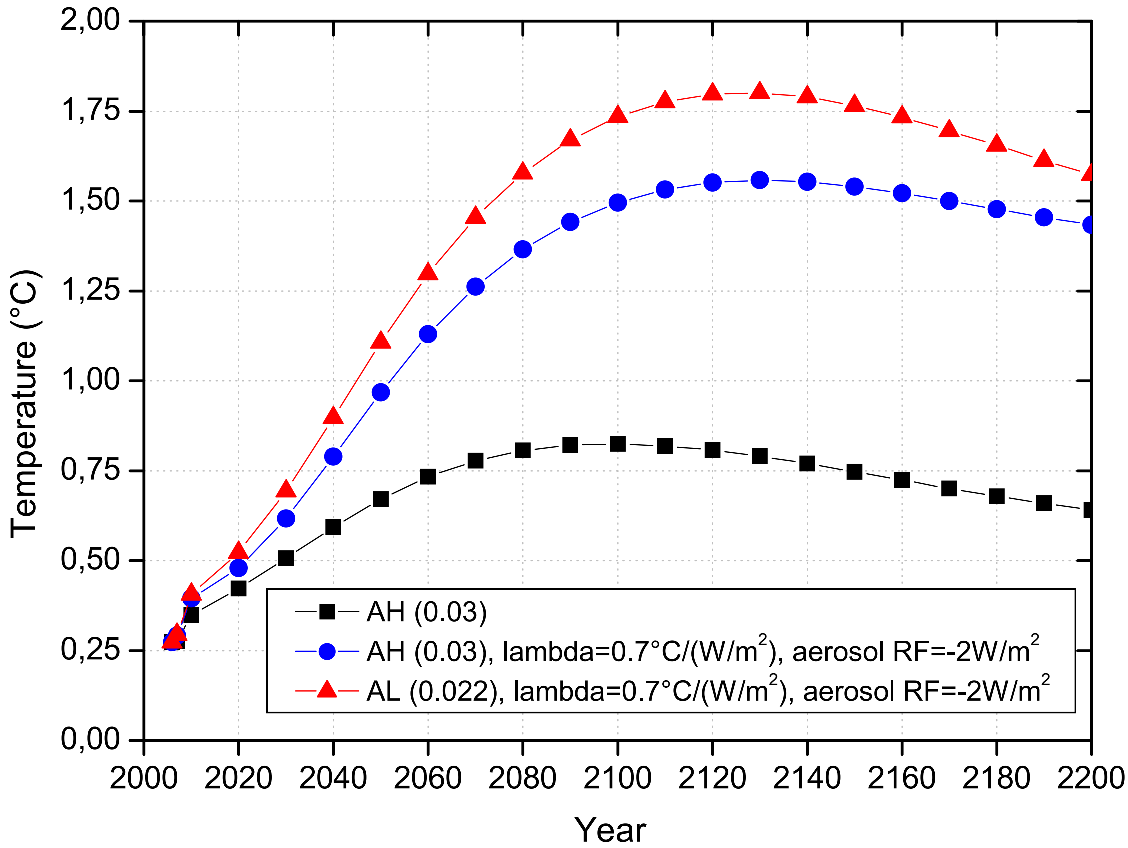
4. SO_2 offsets GHG

The above analysis of the aerosol negative forcings enters in a second manner in the calculation of the future global temperature increase. Any combustion produces simultaneously CO_2 and SO_2 emissions. It is also unanimously accepted that SO_2 aerosols partly offset the CO_2 warming (IPCC, 2007, ch. 2). This compensation is governed in time by the strongly different atmospheric permanence times of CO_2 and SO_2. We have already discussed the permanence time of CO_2 and we know it is of the order of several decades, while it is of the order of 7 days for SO_2. This makes a big difference in the time evolution of the CO_2 warming and SO_2 cooling effects. Whenever the rate of fossil fuels combustions will decrease, the SO_2 cooling will immediately decrease in a proportional amount, while the CO_2 warming will decrease with a delay which can be qualitatively thought to be of the order of the atmospheric permanence time. This effect has been accounted for by N+C (pp. 177-178) using the value -1.1 W/m^2 for the 2006 aerosol forcing. If we use a value of -2.0 W/m^2 for the aerosol forcing, the decrease of temperature offset has to be corrected accordingly.

5. Results

Our figure compares N+C temperature increases up to 2200 (their model AH(0.03) – black line) with the same results corrected to take into account both the climate sensitivity and the SO_2 offset corrections (blue curve). We note that no correction has been introduced to allow for the long time constants in the natural CO_2 sinks; such a correction would lead to higher temperature values going toward 2100 and further. To show this quantitatively, the red curve represents the corrected one starting from N+C AL(0.022) results. The AL(0.022) model, having a longer time constant, simulates to some extent the presence of long time constant CO_2 sinks and therefore is possibly a closer representation of the real evolution.

According to the corrections in the figure, the temperature rise during this century will very likely reach values of the order of 1.8 °C, if all the available fossil fuels were to be exploited. The global temperature would remain almost constant at such level at least until 2200.



Temperature projections according to CO_2 emission model by N+C and with corrections for climate sensitivity and aerosols offset. Temperature anomalies are relative to 1980-2000 average.

6. Conclusions

We will note here that N+C analysis does not allow for an extreme exploitation of <low quality / high cost / difficult extraction> oils and carbon fuels. Such exploitation will be ultimately limited by the energy return (which shall be substantially larger than 1). Nevertheless any degree of extreme exploitation will raise N+C energy availability scenario, leading to a warming larger than the one presented in this paper.

If we accept a likely warming of the order of 1.8 °C during this century, we agree with some of the **qualitative conclusions** by N+C. The impacts of the warming should not be underscored and will "*require considerable adaptation to minimise environmental and socio-economics impacts*"….. *"Although energy efficiency is of primary importance, it must be supported by behavioural changes that bring about energy conservation*".

From the **quantitative** side, our results show that N+C conclusion *"that the extent of global warming may be acceptable and preferable compared with the socio economic consequences of not exploiting fossil fuel reserves to their full technical potential"* is certainly wrong and could lead to distorted interpretations. Their sentence would have been different, if the climate conclusions by N+C were starting from a ~1.8 °C rather than a 1°C warming.

About the economic part of N+C paper, we report one more sentence from their conclusions: "*The economic impact of our ERC (energy scenario) is a significant divergence from the 20th century equilibrium growth conditions. Stabilisation of human welfare is only achieved under optimistic assumptions with respect to technology change and human behaviour, demanding a paradigm shift in contemporary economic thought*". We add that the shift, the changes in human behaviour and in human attitudes shall be more important when taking into account the corrections we are outlining to N+C temperature growth forecasts.

The fact itself that our results are different (but not in contradiction) from those by N+C, shows strikingly that we need more and urgent research to reduce the uncertainties in our knowledge of the climate system – especially regarding the aerosol contribution to the climate budget. The quoted uncertainties cannot be interpreted by the negationist party as an excuse to negate and set apart as non-existing the relevance of the climatic risk. There is a substantial agreement on part of the present and by N+C results: this part is more than enough to call for immediate action to reduce our CO_2 emissions.

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