The role of atmospheric gases in causing climate change and global warming

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This is a resume of a chapter of a book, Climate Change: Observed Impacts on Planet Earth, 2nd ed. (ed. Trevor M Letcher), to be published by Elsevier in ca. September 2015. As allowed by the contract between myself and the publisher, this resume constitutes only ca. 10% of the original chapter, and can therefore be published on Open Access websites such as the University of Birmingham PURE site (https://pure.bham.ac.uk/admin/login.xhtml).

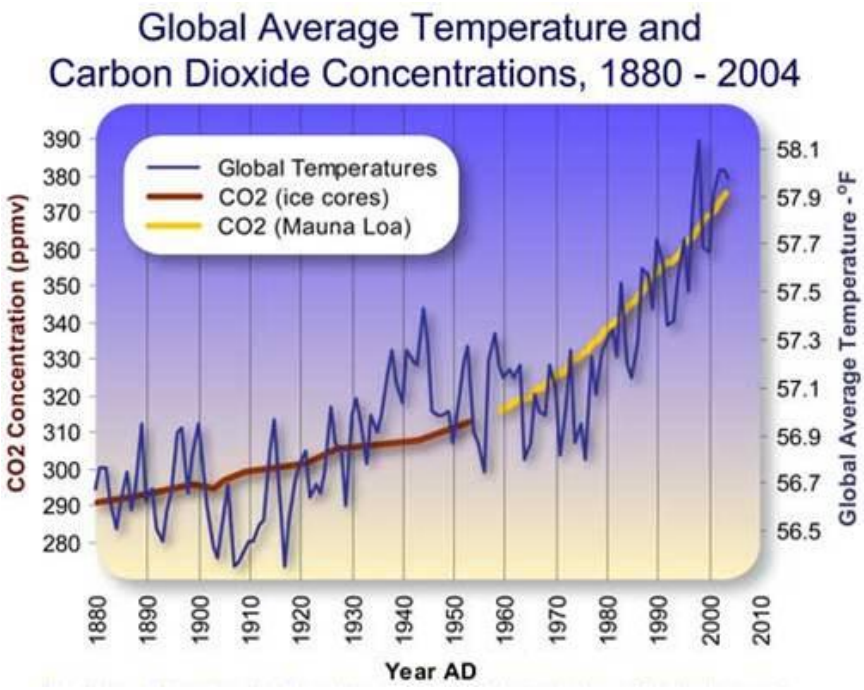
Abstract: Evidence that person-made carbon emissions are contributing to the increasing temperature of the Earth grows stronger by the year. Following publication in 2013 of the United Nations Intergovernmental Panel on Climate Change 5th Assessment Report, data for the dominant secondary greenhouse gases are reviewed and updated. I suggest that methane emissions are every bit as serious a problem as carbon dioxide emissions, and the fact remains stark that we must face up to population issues over the next century if we are to limit the increase in temperature to a manageable 2 ^{o}C. I suggest that targets for CO_2 and greenhouse gas emissions expressed as % reductions per country are bland and do not connect with the general public. Rather, following MacKay in 2009, I suggest that absolute numbers per person are used instead; this may resonate better with the individual, and the scale of the problem to be addressed will become better understood. Within the UK, ideas for possible changes in legislation and adaptions to lifestyle are suggested.

1. *Introduction*: A major misconception of science is that it confirms certainty on any issue. This is rare, and therein lies the problem with increasing CO_2 concentrations in our atmosphere and global warming. We cannot *prove* that the increasing CO_2 concentrations over the last two centuries correlates with what many people believe is an increase in the average temperature of Planet Earth, +0.85 ^{o}C or K over the last 130 years [1]. The Figure shows the data plotted together as a function of time [2], but there is simply not the *resolution* to prove or disprove a positive correlation between the two sets of data. Indeed, being devil's advocate, if the axes labels were removed and the graphs only were displayed, most scientists would surely say that the two datasets displayed on the *y*-axis might be correlated as whatever the *x*-axis represents increases, but they could not prove it. Therefore, to say that there is a definite proven correlation between CO_2 concentrations and T_{earth} as t increases is wrong. Be re-assured, these are not the opening sentences of another climate sceptic, far from it. I am an academic working in vacuum-UV photophysics of gas-phase molecules with an interest in atmospheric science. I do not support the (tongue-in-cheek?) assertion of Ball that the chemistry community has its higher percentage of sceptics than the average [3], but I do understand why sceptics question the 'proven correlation' between CO_2 concentration and global temperature; the evidence is not there.

2. *Myths about the greenhouse effect*: The general public is confused. Some misunderstandings are caused by scientists making increasingly vehement claims on both sides of the argument, some by unwise comments by political leaders who should know better, and some by genuine myths that have been allowed to grow into the public conscience over decades. I highlight three myths. The first is that the greenhouse effect is all 'bad news'. Nothing could be further from the truth. Indeed, without the greenhouse effect, the average temperature of Planet Earth would be that of a Siberian winter, ~255 K or –16 ^{o}C. The second is that the greenhouse effect and ozone depletion, if not quite the same phenomenon, have similar scientific explanations and causes. Again, totally false. The third, and perhaps the most serious, is that *weather* and *climate* are the same phenomenon. They are not. The former is a short-term prediction on which we base daily actions, the latter is a long-term prediction of what might happen decades of years in the future.

3. *The physical chemistry of greenhouse gases*: I described the physical chemistry of greenhouse gases in detail for the 1st edition of Climate Change, published in 2009 [4]. I concentrated on pure science and properties of a greenhouse gas that made it *effective* in the atmosphere. I stressed that CO_2 was not the only (secondary) greenhouse gas of concern, but CH_4 could potentially be just as serious. In this 2nd edition, I contend that, whilst absolute proof is impossible, the evidence that person-made carbon emissions *are* the dominant contributors to the increasing T_{earth} grows stronger by the year, and this threat must be taken very seriously [5]. The UN Intergovernmental Panel on Climate Change Assessment Reports track the increase in concentrations of all long-lived greenhouse gases, and these facts are surely unchallengeable. The net radiative forcing of the atmosphere due to such gases (CO_2, CH_4, O_3, SF_6, perfluorocarbons *etc.*) is growing steadily; 2.43 ± 0.24 W m^{-2} from the 3rd IPCC report of 1998, 2.63 ± 0.25 W m^{-2} from the 4th of 2007, and now 2.83 ± 0.29 W m^{-2} from the 5th of 2013 [6], with the predominant contributors being CO_2 (*ca.* 60%) and CH_4 (*ca.* 18%). Furthermore, the increasing concentration of CO_2 shows no sign of slowing down, with the current level at the emotive level of ~400 parts per million by volume (ppmv). There is nothing special about this number, but the view of most climate scientists is that if this value gets close to 500 ppmv the earth's atmosphere will have reached the point of no return, and it will be almost impossible to stabilise T_{earth}; this is called the *runaway* greenhouse effect. If the above evidence and predictions are shown to be wrong, then Climate (Non-) Change will be the biggest scientific hoax of all time.

4. *Time for action*: I believe the evidence is as strong as it ever can be, and it is time for action. Times are changing, and there are many examples of excellent practice emerging at an individual level in the UK. For example, conservation of energy through double glazing and roof insulation of the housing stock, generation of solar electricity through photovoltaic panels, the trend to drive more fuel-efficient cars (and



perhaps electric cars will be the norm in 50 years time), and the increase in bicycles and walking as a long-term lifestyle change are just four examples. But these examples only scratch the surface, and inevitably it is the educated *converted* class who are taking these actions. Although it goes against the instincts of politicians of all colours to *'tell people how to live their lives'*, I fear that is exactly what they must do, and some national policies must be imposed. From secondary schooldays, we are told to break down a seemingly-insuperable problem into bite-size chunks. That is my approach; start easy, and work towards the more difficult. Policies in (i) and (ii) below therefore would be some suggestions to whatever political parties are in power in the UK to roll out over the two decades.

(i) ***Easy to implement and solve*** : In 2009, MacKay estimated that, on average every person in the UK used 125 kWh of energy per day [7]. Any policy advocated cannot possibly apply to every person, and in general the young, old, disabled and infirm will be exempted. That said, he estimates that that wearing more clothes and reducing thermostats by a few degrees everywhere might reduce this figure by about 20; stopping flying might cause a reduction of 35; modifying means of transport within the UK by driving less and biking / walking more might reduce by about 20; avoiding packaging and the buying of clutter, however defined, might cause a huge reduction of 20; and becoming vegetarian might cause a reduction of 10 such units. These are all big percentage changes, even though there are huge errors in the numbers estimated. These are *individual* decisions that every one of us should think about, but national changes in law could evolve. I suggest therefore the following:

- A reduction in the minimum working temperature for employees by at least 2 ^{o}C,
- A review of health and safety legislation with regard to packaging of food,

- Abolition of Sunday trading,
- Domestic air travel be priced out of the market,
- Simultaneously, a huge expansion in rail travel, and safe cycle routes in all towns and cities,
- A reversal of the 1988 Education Act, so that school children *must* attend their local school,
- Huge investment in technology to make much 1:1 business travel for meetings un-necessary.

I believe that the changes above are relatively easy to make, they may lose the Government in power some votes, but ultimately I believe they, *and many others,* have to be made to control carbon emissions.

(ii) ***Moderately difficult to implement*** : All developed countries should move rapidly to a system of taxation whereby the principle of *'polluter pays'* becomes paramount. A carbon credit card would then result in which a premium is paid for excess use of domestic gas and electricity, for petrol and use of the roads, and certainly for air travel. This idea was muted by the UK Government ten years ago, but was quickly dropped like a hot potato when public reaction was negative, to say the least, from the first day.

A different issue concerns food production, *what* we eat, and *where* the food comes from. For the last sixty five years since the end of rationing, I suggest that the principle that the customer has a paramount right to food at the cheapest price has swept aside any environmental consequences. We now understand that this comes at a price; excess use of fossil fuels for un-necessary transportation of food. We could then address what we eat. Cattle use limited land for grazing, and perhaps we should reduce meat consumption, if not become vegetarians of whatever strictness; a policy effectively advocated by MacKay [7], thereby also reducing methane emissions. Perhaps vegetarianism is a half-way cop out, and more people should become vegan. The growth of genetically-modified crops must surely be allowed to continue, as I do not believe that the perceived risks have materialised. We may then reduce our dependency on cattle for food.

5. ***Very difficult problems to solve***: The population of the planet dominates this category. The figures are stark. Fifty years ago the population was 3.3 billion (3.3×10^9), today it is 7.3 billion, and is predicted to rise to ~11 billion by AD 2100, with the large majority of growth expected in Africa [8]. Currently, 75% of the world's population live in Asia and Africa, and this figure may grow to 82% by the end of the century. Conversely, the population of Europe is predicted to fall from its current level of 11% (or 0.74 billion) to 6% (or 0.64 billion). Everyone will need housing and feeding. CO_2 and CH_4 together contribute ~81% of the total radiative forcing of long-lived secondary greenhouse gases, but it is too simplistic to say that reduction of CO_2 levels will be the complete solution. In simple terms, I believe that CO_2 levels in the atmosphere correlate loosely with lifestyle of the population, and with serious effort, especially in the developed world,

huge reductions are possible; examples are given above. However, I believe that CH_4 poses just as serious a threat as CO_2, simply because this level will be much harder to reduce; a major component of methane emissions correlates *strongly* with the number of animal livestock which itself is dependent on the population of the planet.

Thus population control on a world-wide scale must be openly discussed and the subject cannot be avoided if we are to control methane emissions. If there is one, the message from the West is mixed. Europe and the US / Canada have always believed in the absolute right of individuals to make their choice of family size independent of the State, but it is easy to see how their Governments could exert influence by limiting financial access to the State for families above a certain size. That said, no Government wants population levels to drop too much because of loss of revenue from taxation; Japan is currently worried about how few children are being born, over thirty years after introducing its one-child-per-family policy China is becoming increasingly concerned who will look after their elderly, and Denmark is almost bribing couples to have more children. Conversely, at least in public, the leaders of the Catholic Church, comprising ~15% of the world's population, will not discuss world population, believing in the absolute sanctity of life and refusal to accept any form of contraception. The situation is a mess, but any solutions must start with Asia and Africa because projected increases here are the greatest.

Controlling world population levels is a huge area of policy that calls for inter-Government agreements at all levels. For all its faults and decreasing respect with which it is viewed, I see no alternative to the United Nations as the global organisation to lead on such issues, and surely this should be their major policy directive for the next few decades. The issue of person-made climate change / global warming cannot be separated from that of world population, and true leadership at the world level is needed to bring about this change in public perception and subsequent action.

[1] BBC4, Horizon, *Climate Change by Numbers* (2015).

[2] http://cdiac.esd.ornl.gov/ftp/trends/co2

[3] P. Ball, http://www.rsc.org/chemistryworld/2013/10/climate-sceptic-global-warming-chemist

[4] R. P. Tuckett, 'Climate Change : observed impacts on planet earth' (2009), 1st edition, Chapter 1, Elsevier, ISBN: 978-0-444-53301-2.

[5] R. P. Tuckett, 'Climate Change : observed impacts on planet earth' (2015), 2nd edition, Chapter 24, Elsevier.

[6] Intergovernmental Panel on Climate Change (IPCC), 5th Assessment Report (2013), Working Group 1, Chapters 1, 2 and 8, Cambridge University Press.

[7] D. J. C. MacKay, 'Sustainable energy – without the hot air', (2009), UIT Cambridge UK, ISBN: 978-0-9544529-3-3.

[8] *e.g.* http://esa.un.org/wpp, http://www.worldometers.info/world-population