Questions and answers

about climate change and what's to be done

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This document is the product of many hours of research to help me understand those aspects of climate change that I felt were particularly important for grasping the nature and magnitude of the risks associated with climate change and, above all, the things we can do as voters, activists and consumers to reduce these risks. Climate change is an incredibly complex issue that has emerged very quickly as a key threat to human progress and, some would say, human existence. New knowledge is emerging all the time. It is often difficult to make sense of the information that is available. In fact, I initiated the systematic research reflected in this document partly because I was frustrated by many apparent contradictions and gaps. For instance, the promotion of reforestation as a solution by, in particular, organisations selling carbon offsets didn't seem to tally with what I knew about plants. Carbon footprint calculators available on the internet did not seem to be telling the whole story. In general, I was continually frustrated by an insufficient sense of what the magnitudes are: I came across information about useful things to do, but seldom did I find even rough information on *how large* the impact of these actions would be. Why the issue of population size hardly ever featured in the literature on climate change troubled me.

Concerns around climate change should of course form part of a wider concern around human welfare, equity and sustainability. I have tried to make this clear in the document, even if the main focus is on climate change. I would not want to convey the message that climate change should absorb all our social and environmental awareness energies. Fortunately, actions to reduce climate change often overlap rather neatly with actions that promote social and economic equality, employment, healthy eating habits, a focus on happiness and animal welfare.

You may want to go through the questions (listed below) to see which questions interest you, and just read the answers to them. The document is more or less designed to allow that, though there are some backward references. Or you could read from beginning to end. I think I have been quite good at listing my references, to encourage you to delve deeper where the topic interests you. The document is deliberately written from a developing country perspective, and South Africa-specific content appears in boxes. Years appearing at the end of each question indicate when the contents were last updated.

Note that some but not all of the questions have been answered. The unanswered ones are listed here to provide an indication of what's coming, and what seems important.

1 Briefly, what is anthropogenic climate change? 2009

Climate change is anthropogenic when it is brought about by humans, and not factors such as sunspots. Very briefly, emissions of greenhouse gases, in particular carbon dioxide and methane, by human activities trap more heat from the sun in the Earth's atmosphere and cause global warming. The rise in atmospheric temperatures causes rainfall and wind patterns to change, and this is then climate change. Climate change, in turn, causes other changes such as sea level changes, and changes in plant cover, which themselves impact on the climate.

Temperatures and the climate would change even without humans. The Earth has moved in and out of a number of ice ages which have caused the climate across the globe to change drastically. For instance, between the middle of the last ice age, around 21,000 years ago, and the beginning of the twentieth century, the average temperature increased by around 5 degrees Celsius. Even without anthropogenic climate change, we would be seeing a gradual increase in temperatures now, because the Earth is still warming after the last ice age.

What makes anthropogenic climate change so remarkable, is its speed. The increase we have experienced in the twentieth century is ten times faster than the natural increase following the middle of the previous ice age[1]. And this increase is currently speeding up. The average temperature of the atmosphere has increased by about 0.7 degrees Celsius during the last 100 years[2]. Most of this warming took place during the second half of the twentieth century. But anthropogenic climate change is even more remarkable if we consider what is happening to carbon dioxide concentrations in the atmosphere – more on this in Question 5 below.

What needs some explaining is the idea of average temperature. This is the average across many places across the surface of the Earth. Different groups of scientists use different approaches when it comes to selecting these places (some include more sea places, for instance), but they all come to more or less the same result of the 0.7 degrees Celsius increase in the last 100 years. But this is an average, and different regions of the Earth have experienced rather different increases. Generally, increases have been greater in the Polar Regions (especially the northern Polar Region), and less the closer one gets to the Equator. But there are a lot of exceptions to this pattern. For instance, temperatures around northern Botswana are increasing at an unusually fast pace, in fact as fast as in northern Germany (generally Europe is experiencing faster temperature increases than Africa)[3].

There are thousands of scientists working on climate change statistics (as one might expect, mainly from developed countries). In the past, it has at times been difficult for the non-specialist to make sense of opposing findings. This is less of an issue today, as there is increasing unanimity around how anthropogenic climate change works, and what its effects are (partly because there is less disinformation – see Question 3 below). The Intergovernmental Panel on Climate Change (IPCC), which is based in Geneva, has for many years brought together scientists from around the (largely developed) world and published findings that a sufficiently large number of scientists can agree on in its voluminous Assessment Reports (over 3,000 pages in 2007). The IPCC reports are often accused of being too timid because of the consensus approach used[4], but they provide a wealth of information nonetheless.

In South Africa, temperature increases seem to be greater the further north one goes (this runs against the general pattern of smaller changes the closer one gets to the Equator). In the south of the country, the temperature is currently increasing by about 0.1 degrees Celsius every ten

[1] IPCC, 2007: 451.
[2] Ibid: 252.
[3] Ibid: 253.
[4] Flannery, 2005: 246.

years, whilst in Limpopo Province the figure is around 0.3 degrees Celsius[5]. With regard to rainfall, there is some uncertainty. The Department of Environmental Affairs and Tourism (DEAT) indicates that the summer rainfall areas are likely to suffer the greatest fall in rainfall, whilst a map in the IPCC's Fourth Assessment Report seems to indicate that the loss in rainfall is most serious in the Western Cape winter rainfall area[6].

Three researchers from South Africa were amongst the more than 500 researchers who contributed toward the IPCC's Fourth Assessment Report[7].

[5] IPCC, 2007: 253; Department of Environmental Affairs and Tourism, 2004: 2.
[6] Ibid: 256; Department of Environmental Affairs and Tourism, 2004: 2.
[7] IPCC, 2007: 955.

2 What could happen to us and our children? 2009

The forecasts regarding what will happen to humanity as a whole, and to specific nations and classes of people as a result of climate change are varied. One fairly useful distinction is that between the alarmist forecasts, and the cautiously and conditionally optimistic ones.

A rather prominent example of an alarmist prognosis is a report produced for the United States Department of Defense in 2003 to gauge the impact of climate change on US national security[8]. This report is based on the premise that there would be a sudden acceleration in climate change effects, perhaps as early as 2020, which would bring about an increase in temperatures in tropical areas of around 2 degrees Celsius in just ten years, and a *drop* in the temperatures of Europe and parts of the United States of as much as 3 degrees, also in a ten year period. The temperature drops would be the result of changes in North Atlantic ocean currents brought about by the initial rise in temperatures. This is a possibility that has been widely studied, though the IPCC concludes that these abrupt changes are unlikely to occur in the 21st century, though they could occur in the following century[9]. The US report envisages food and water shortages, and disruptions to energy supplies, the latter caused largely by storms. These phenomena are likely to provoke wars and to pose a major security threat to the US. The mere fact that this kind of information is to some extent informing policy, not just in the US but elsewhere, is a part of the impact of climate change, regardless of whether worst case climate scenarios are realised or not. (The 2004 US movie *The day after tomorrow* is based on a fictional and disastrous chain of events in New York not unlike those envisaged in the report.)

The IPCC's reports, whilst less alarmist, do predict serious problems, even with changes in government policies and human behaviour. For instance, though most IPCC scenarios indicate an increase in the average global temperature during the 21st century of at least 2 degrees Celsius (relative to pre-industrial times), such an increase is associated with several major problems, such as aggravated food and water shortages for millions of people[10]. A report released by the British Government, the so-called Stern Review, offers the following warning[11]:

> The evidence shows that ignoring climate change will eventually damage economic growth. Our actions over the coming few decades could create risks of major disruption to economic and social activity, later in this century and in the next, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes. Tackling climate change is the pro-growth strategy for the longer term, and it can be done in a way that does not cap the aspirations for growth of rich or poor countries. The earlier effective action is taken, the less costly it will be.

The 2007 UNDP Human Development Report, which focuses specifically on climate change effects, explains how climate change raises the risk that poverty reduction gains in the last couple of decades could be undone[12].

People around the world have already begun to feel the impact of climate change. The World Health Organization (WHO), in its 2002 World Health Report, estimated that 154,000 deaths worldwide in 2000 could be attributed to climate change, in the form of diarrhoea, flood injury, malaria and malnutrition (undoubtedly most deaths would have been in developing

8 Schwartz and Randall, 2003.
9 IPCC, 2007: 774.
10 Ibid: 790; IPCC, 2007b, 230.
11 Stern, 2006: 2.
12 UNDP, 2007.

countries)[13]. A 2008 Oxfam on Uganda report argues that climate change has already begun to diminish yields from coffee plantations, which are vital for the Ugandan economy, and that over the next three to four decades climate change will render coffee cultivation impossible in virtually all of Uganda[14]. The Australian scientist Tim Flannery, in his book *The weather makers*, argues, with reference to detailed climate modelling being undertaken, that the conflict in Darfur is mainly the result of conflicts over land that has become unable to support the population as it did in the past, and that this is attributable to anthropogenic climate change[15]. Flannery points to one of the consequences of climate change, denialism:

> The Sahelian climate shift is emblematic of the situation faced by the world as a whole, for in it we see the West focusing on religion and politics as the problem, rather than the well-documented and evident environmental catastrophe that is its ultimate cause[16].

It should perhaps be added that Flannery is very much a mainstream scientist. In 2007 he was handed the Australian of the Year award by Australian Prime Minister John Howard, despite Howard's own longstanding denialist position on climate change.

We cannot be sure of how climate change will affect ourselves, and coming generations. But it seems certain food and water scarcity will become exacerbated for many people, especially for those who are poor or who live just above the poverty line. And considering that anthropogenic climate change has largely been brought about by societies that are better off, there will be large political and moral pressure on these societies to assist others to cope with this new problem. In short, climate change will have an impact on the economics and politics of essentially all societies across the globe.

In South Africa, the official strategy on how to deal with climate change mentions a number of problems the country can expect to experience. The most serious of these is probably a drop in agricultural yields, for instance in the maize crop, related to changes in rainfall patterns. Because this will be felt in neighbouring countries too, South Africa can expect to see a rise in the number of economic refugees arriving in the country. Additional problems would be water shortages and an enlargement of malaria areas[17].

[13] WHO, 2002: 67 and 72.
[14] Oxfam, 2008.
[15] Flannery, 2005: 125-126.
[16] It is ironic that on the same educational website that Al Gore uses to disseminate a lesson plan based on his climate change film, *An inconvenient truth*, is a lesson plan on the conflict in Darfur that paints the typical picture of a political and ethnic conflict, with no reference to the environmental factors Flannery refers to. See http://prod.takepart.com/social_network/action/ait/studyguides.html.
[17] DEAT, 2004.

3 How long have we known about this problem? 2009

Just as in the tobacco industry legal culpability for damages is partly dependent on the point at which those who profit from the industry became aware of the health consequences of smoking, so it is possible to argue that culpability for climate change effects is linked to when we became aware of the effect of human behaviour on the climate.

So when did we become aware? The answer depends on the level of certainty one wants, but a plausible (and perhaps conservative) answer seems be 1985. Before that, some scientists had argued that greenhouse gas emissions were leading to damaging climate change, but there were also scientists that refuted this. Perhaps the earliest clear scientific statement that human-induced global warming was taking place was that by the Swedish scientist Arrhenius (who won a Nobel Prize in 1903). He did not see the phenomenon as damaging, however, largely because he could find nothing personally wrong with a Sweden that was a few degrees warmer. Arrhenius's position is in fact indicative of what lies behind some of the indifference or even populist denialism we have seen in the climate change field – those most responsible for the emissions that cause climate change tend to live in countries with unpleasantly cold winters.

In 1985, an international scientific conference in Villach, Austria, organised by the United Nations Environmental Programme (UNEP), concluded that greenhouse gas emissions posed grave dangers for human society[18]. From that point forward, it became much more difficult to plead ignorance, or justify inaction. The 1992 United Nations Conference on Environment and Development (the 'Earth Summit') in Rio de Janeiro reaffirmed the risks associated with climate change, and the message has been repeated with increasing frequency since then by a number of conferences, and the IPCC's Assessment Reports.

An especially curious phenomenon was the surge in scientific and quasi-scientific writings *post*-1985 that claimed the dangers of climate change were greatly exaggerated, and that reducing emissions was not necessary. It has been widely demonstrated that these claims enjoyed disproportionate publicity due to backing from lobby groups with an interest in the coal and oil industries[19]. Today these claims enjoy little support, but through the confusion they sowed they have succeeded in delaying decisive responses to the climate change problem. As Flannery puts it, the concerned lobby groups 'have already bought themselves two decades of fat profits, but the costs to the rest of us have been astronomical. Another decade of such profits may cost us the Earth'[20].

[18] See for instance *Chronology of the climate change issue* at http://www.hks.harvard.edu/sl/docs/SL_Apdx2B.3_CCchronology.pdf.
[19] Flannery, 2005: 239; Monbiot, 2006: 20.
[20] Flannery, 2005: 245.

4 What about other social and environmental problems? 2009

The attention span of many people, especially those potentially most able to do something about climate change, is already stretched, and it is often difficult for them to 'get into' this new issue. Many, especially those in developing countries, are not sure there is much one can do, or is obliged to do, if one is from a developing country. Many ask whether paying more attention to climate change means paying less attention to developing the country and alleviating poverty.

Below, are four reasons why even those of us in developing countries should pay attention to climate change.

Firstly, climate change and poverty alleviation will become increasingly intertwined. Over the past decades the world has been relatively successful at tackling poverty – figures differ, but the United Nations Development Programme estimates the percentage of people living in poverty declined from 29% to 18% in the 1990 to 2004 period[21]. This has been achieved largely through integrating millions of people into a particular type of market economy, where environmental costs were often ignored. This rather myopic approach has worked so far, but increasingly it will not. Climate change risks pushing millions back into poverty as agricultural output (amongst other things) is adversely affected. Moreover, the more people move into a formal and high-emissions economy, the more we aggravate the climate change problem. Climate change affects the way we tackle poverty, because it implies tackling some fundamentals of the formal economy into which we want to elevate the poor. The UNDP emphasises the importance of information and education in the paradigm shift that must take place[22]:

> In thinking about the steps that may be taken to halt environmental destruction we have to search for constructive human intervention. For example, greater levels of female education and women's employment can help to reduce fertility rates, which in the long run can reduce the pressure on global warming and the increasing destruction of natural habitats. Similarly, the spread of school education and improvements in its quality can make us more environmentally conscious. Better communication and a richer media can make us more aware of the need for environment-oriented thinking.

Secondly, delaying action on climate change is not like delaying action on other issues. Most environmental issues we have faced have not come with the irreversibility of climate change. The big exception is the ozone hole challenge, which humanity dealt with fairly decisively, leading some to portray that response as a mini-rehearsal for the response needed to the much larger problem of climate change[23]. If we deplete the fish stocks from a part of the ocean, it is not too difficult to allow stocks to replenish themselves. In other words, the damage can to a large extent be undone. Polluted rivers can to a large extent be de-polluted. However, the climate change problem is such that few even bother to contemplate the return to the temperature trajectory we were enjoying before the onset of anthropogenic climate change. Rather, we ask at which higher level of temperature we can stop the anthropogenic increase. It is not a question of undoing the damage, but rather of limiting it.

Thirdly, action on climate change to a fairly large degree boils down to *not doing certain things* in one's private life. This is especially true for the economically advantaged in our societies. Climate change is not a problem that lends itself well to the attitude of letting government sort out the problem 'out there', because so much of the problem is 'in here', in

[21] UNDP, 2007: 24.
[22] Ibid: 29.
[23] Flannery, 2005: 213.

our homes and in our (especially the middle class's) consumption patterns. As the journalist George Monbiot puts it:

> The problem is compounded by the fact that the connection between cause and effect seems so improbable. By turning on the lights, filling the kettle, taking the children to school, driving to the shops, we are condemning other people to death. We never chose to do this. We do not see ourselves as killers[24].

The climate change debates have tended to use countries as the unit of analysis. This is sensible for a number of reasons, but it also tends to distract attention from the role of individuals and households. The average US citizen may release thirteen times more greenhouse gases in a year than the average Indian citizen, but an upper middle class Indian household is likely to emit much more than a household from the around 13% of the US population that is officially considered poor. High emitters, no matter where they live, have a special obligation to worry about their impact on climate change. One should note that this argument for making emissions reductions an issue in developing countries too is very different to that used, for instance, by US President Bush Junior in the Kyoto Protocol context[25]. That argument says that it is the *total* emissions of India (a quarter that of the US) that places a special responsibility on Indians to reduce emissions (and that has justified a failure to do the same in the US). The US undoubtedly carries a much larger responsibility than India to do something about climate change. However, this cannot justify inaction by the Indian household fortunate enough to afford the high-emissions lifestyle of the middle class US household. Both, it can be argued, have similar responsibilities.

Fourthly, many minds will need to be applied to complex and new international negotiations. The logical outcome is for climate change to lead to a complex system of agreements between countries around the distribution of emissions reductions responsibilities, responsibilities for researching new technologies, and international payments for damages attributable to climate change. This system could well dwarf the current World Trade Organisation (WTO) system in complexity. Currently, developing countries are disadvantaged in the WTO system partly because they lack enough trained technocrats who can deal with the economic and trade complexities. Developing countries need to minimise their disadvantage in the emerging climate change and greenhouse gas emissions system by building up intellectual capacity in this area.

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[24] Monbiot, 2006: 22.

[25] The Kyoto Protocol (United Nations, 1998) is an international agreement adopted in 1997 on what governments should do to deal with anthropogenic climate change. The agreement expires in 2012. More details appear in sections 14, **Error! Reference source not found.** and 17.

5 What are the basic emissions statistics one should understand? 2009

There are many complex statistics in the climate change debates. However, two relatively easy statistics stand out as being especially important for an understanding of the key debates about the politics of climate change. The abbreviated names for the two are **ppm CO_2-equivalent** and **CO_2-equivalent emissions per capita**.

ppm CO_2-equivalent (parts per million carbon dioxide equivalent in the atmosphere)

The amount or concentration of carbon dioxide (this is the gas we breathe out) in the atmosphere remained highly stable up till about 150 years ago at around 285 parts per million[26], meaning that in terms of volume, 285 in every 1,000,000 parts, or 0.028%, of the atmosphere consisted of carbon dioxide (or CO_2). In the climate change context, one is concerned not only with CO_2, but also with another five gases that are emitted by humans and which contribute to rising temperatures. These other five gases are (in descending order of impact on anthropogenic climate change): methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)[27]. There are other minor gases in addition to these six, but the six mentioned here are the ones usually dealt with in the international agreements such as the Kyoto Protocol. The gases other than CO_2 are commonly converted to a CO_2-equivalent volume that takes into account their impact on global warming. We thus have 'ppm CO_2' and 'ppm CO_2-equivalent'. Here are the values for these statistics up till 2000[28]:

	1850	*1900*	*1950*	*2000*
ppm CO_2	285	300	310	365
ppm CO_2-equivalent	290	310	330	410

Perhaps the single most alarming climate change fact is that the 365 value for ppm CO_2 in 2000 (which had reached around 383 by 2008[29]) was already higher than it had been for the previous 650,000 years. The Earth is entering into a period of virtually unprecedented greenhouse gas concentrations. The lack of natural precedents in the Earth's history (at least in the last 650,000 years) obviously makes it more difficult for scientists to predict where we are heading.

The ppm CO_2-*equivalent* statistic is clearly the most useful one to keep track of if one wants to know the extent to which atmospheric changes are affecting climate change. Obviously one should take care not to confuse the two statistics shown in the previous table!

tons of CO_2-equivalent emissions per capita (tons of carbon dioxide equivalent emissions per capita per annum)

If we take the human-induced emissions of greenhouse gases in a country, express them in terms of the effect of tons of CO_2, and divide this amount by the population of the country, then we get 'tons of CO_2-equivalent emissions per capita' for the country. This is the average greenhouse gas emissions per person in the population.

For example, the human-induced activities in the United Kingdom produce around 690 million metric tons of carbon dioxide, plus CO_2-equivalent emissions, every year. The population of the United Kingdom is about 60 million. If we divide the first value by the

[26] IPCC, 2007: 135; Stern, 2006: 4.
[27] United Nations, 1998: 19; IPCC, 2007b: 103.
[28] Stern, 2006: 4.
[29] See http://www.esrl.noaa.gov/gmd/ccgg/trends/.

second, we get 11.5 tons of greenhouse gases (considered in terms CO_2 effects). If we consider India, on the other hand, we take total emissions in one year of around 1,570 million tons of CO_2-equivalent (so in total India emits more than the United Kingdom) and divide this by the population of 1,050 million, giving us 1.5 tons of emissions per average Indian (meaning the average Indian has a much smaller impact on climate change than the average Briton). The average human being emits around 7.3 tons of CO_2-equivalent emissions per year. These statistics all pertain to 2000 – more recent figures are less complete[30].

How should we think of one ton of CO_2 emissions? A ton is 1,000 kg, or the mass of a small car. In the form of a gas, a ton of pure carbon dioxide occupies around 500 cubic metres, or the space within a large 150 square metre flat. But that ton of CO_2 diluted in the atmosphere takes up about 1.4 million square metres, or more or less the space inside five large indoor stadiums. This is one ton. The average Briton, for instance, would be responsible for filling up 55 indoor stadiums with diluted carbon dioxide (or equivalents) in one year.

What do the emissions figures quoted above (like 7.3 tons per capita for the globe) include? Around 77% is actual carbon dioxide, and the rest is the other five 'Kyoto gases' expressed as CO_2-equivalent emissions (and the other five are dominated by methane, which accounts for 14%, and nitrous oxide, accounting for 8%, meaning the remaining three account for only 1%). Table 1 in Appendix A gives a breakdown by activity. The well-known industrial, transport and energy activities are included. But so is land use change. For instance, cutting down a forest releases carbon dioxide into the atmosphere when dead plant matter decays. If some of the wood from the trees is used for, say, furniture, then the decay can be delayed a bit (eventually wooden chairs get thrown away and decay), but inevitably a large proportion of vegetation that is killed by human activity decays fairly soon afterwards. Emissions produced by land use change are included in the figures above, but it is worth keeping in mind that they are not always included in per capita emissions figures that are published. The above figures also attribute emissions produced *inbetween* countries, when ships or aeroplanes move between countries, to particular countries. Commonly, these emissions, known as 'international bunker' emissions, are excluded from per capita figures. The figures quoted above are in fact the most complete there are. The best place to go to for these kinds of figures is probably the Climate Analysis Indicator Tool, or CAIT, at http://cait.wri.org.

What about the carbon dioxide emitted when the seven billion or so human bodies on the planet convert oxygen to carbon dioxide in the process of breathing? These emissions are in fact not included in any listing of total human-induced greenhouse gas emissions. The average human produces around 0.3 metric tons of carbon dioxide by just breathing[31]. Strictly, we should add this 0.3 to the 7.3 quoted above. But the carbon dioxide produced through breathing (like carbon dioxide produced by burning firewood) is to a large degree linked to processes that absorb carbon dioxide from the atmosphere, such as growing food (which gives us the carbon we exhale) or growing trees for firewood. So in a sense emissions produced by breathing are cancelled by carbon absorbing processes – the same can't be said of the coal power stations that give us our electricity.

In 2000, CO_2-equivalent emissions from South Africa came to 455 million tons[32]. This works out to about 10.3 tons per capita (this puts the country at position 19 of 182 countries). This is a high figure, but as is explained elsewhere in this document, per capita responsibility for emissions in South Africa is very unequally distributed, and a large part of our emissions are linked to minerals that are used in other countries.

[30] World Resources Institute, 2008.
[31] See http://micpohling.wordpress.com/2007/03/27/math-how-much-co2-is-emitted-by-human-on-earth-annually/.
[32] World Resources Institute, 2008.

6 What about cumulative emissions from the past? 2010

The 7.3 tons per human being per annum average referred to in the previous question translates into just over 44 billion tons of CO_2-equivalent emissions per year. These are figures applicable to 2000 – today, thanks largely to population growth and growth in the standard of living of people, they would be higher. One might think that the amount of greenhouse gases in the atmosphere would increase every year by the amount emitted by humans, for instance the 44 billion tons in 2000. However, the amount is less than that because somehow nature (the oceans and plant cover on land) have actually been absorbing more carbon dioxide in response to the greater amount of carbon dioxide in the atmosphere. It's as if nature has been helping us, by slowing down anthropogenic climate change. But nature cannot absorb all the additional carbon emitted by humans, and it is likely that nature's ability to assist, even in this limited way, will decline as oceans and plants become saturated with carbon[33].

So by how much does the amount of CO_2-equivalent emissions in the atmosphere increase each year? By about 20 billion tons (in 2000). In other words, currently about half of the emissions sent out into the atmosphere by humans is being removed[34]. This re-absorption is essentially nature at work. As we saw in the previous question, human changes to plant cover may also result in some removal of emissions (but that is taken into account in the calculation of the 44 billion tons).

However, even if some emissions are removed by nature, it is clear that countries that have been emitting large amounts for a longer period of time, carry a greater responsibility for of the anthropogenic greenhouse gases currently in the atmosphere. The next table makes a comparison between country responsibility using annual emissions (in 2000) and cumulative emissions (1850 to 2000)[35].

	% of world total	
	2000 only	*1850-2000 (cumulative)*
United States	21	29
European Union	14	27
Russia	6	8
China	15	8
Japan	4	4
India	6	2
Rest of world	34	22
TOTAL	100	100

It must be noted that cumulative figures are difficult to obtain, as historical records are not good, and there is some controversy over the figures. The figures in the second column above cover only carbon dioxide emissions (and not other gases, and not the effects of land use change). Moreover, these figures do not take into account removals from the atmosphere by nature (though one should keep in mind that these removals do come at an environmental price, in particular they result in a higher carbon dioxide content in the oceans, which in turn

[33] IPCC, 2007: 515 provides a useful diagram representing anthropogenic and pre-anthropogenic (i.e. natural) carbon flows in the planet. Note, however, that this diagram refers to billions of tons (gigatons) of carbon, and not billions of tons of carbon dioxide (a ton of carbon translates into about 3.664 tons of carbon dioxide – see for instance http://cdiac.ornl.gov/pns/convert.html#3).
[34] Calculated on the basis of IPCC, 2007: 146. The removal rate of around half is confirmed by the carbon figures in IPCC, 2007: 515.
[35] Baumert, Herzog and Pershing, 2005: 12, 32.

makes the oceans more acidic and affects marine life[36]). The first column reflects total CO_2-equivalent emissions, including the effects of land use. Despite these accounting problems, scientists believe that the general pattern in the table holds true, namely that countries that have been industrialised for a long period of time (such as the EU countries) come out as more responsible if you count historical emissions, whilst countries that have been industrialised for a shorter period of time (such as China) come out as less responsible if you factor in historical emissions.

Whether you view South Africa's emissions in terms of current emissions, or cumulative emissions over time, makes little difference. Either way, South Africa is responsible for around 1.2% of anthropogenic greenhouse gases in the atmosphere[37]. South Africa's population, however, is only about 0.7% of the world's population.

[36] IPCC, 2007: 529.
[37] Baumert, Herzog and Pershing, 2005: 12, 32.

7 How do we know how much countries are emitting? 2010

The Kyoto Protocol[38] obliges 41 'Annex I countries' (essentially developed countries) to provide annual emissions inventories to the UNFCCC[39]. Other countries are encouraged to do the same, but are not obliged to. The detailed rules on how emissions inventories should be compiled are provided by the IPCC in a voluminous set of manuals[40], and by an additional guideline document produced by the UNFCCC itself[41]. An important part of the reporting rules is the accounting categories to be used. The IPCC-specified structure starts with four 'sectors' at the highest level, and goes down by as much as three additional levels, in some cases. Altogether, there are 232 bottom level accounting categories, specified in around 70 pages of tables, so the framework is a rather detailed one (though not all 232 categories would be relevant for all countries, because not all countries have all types of emissions)[42]. Brief definitions for the four sectors (energy; industrial processes and product use; agriculture, forestry and other land use; waste) and their first level of sub-categories are provided in Appendix A below.

The IPCC manuals furthermore specify three different methods for arriving at inventory figures. The methods are of differing levels of sophistication, and which one a country chooses depends largely on what data are available. All three methodologies follow a simple principle, however, which is to take 'activity data', such as total distance travelled by a particular aircraft type in domestic flights, and multiply this by a relevant 'emissions factor'. Analysts in the country must find the activity data, and the IPCC stipulates standard emissions factors that all countries should use.

How well do countries comply with these reporting rules? It is worth emphasising that producing national greenhouse gas inventories is not an easy job. A huge amount of activity data must be collected from many different organisations within the country. For instance, information from coal-driven power stations relating to coal type, coal use, and the efficiency and age of equipment are needed. Nearly all the data were originally recorded for some purpose other than greenhouse gas reporting, so their reliability for the inventory process must be carefully assessed. The IPCC manuals recognise that it is far from an exact science, and require countries to conduct an 'uncertainty assessment' on how wrong the final emissions figures may be. A look at a national inventory report of a country such as the United Kingdom, which has above average capacity for this kind of work, provides an idea of the magnitude of the task, and the extent of uncertainties. The 2008 UK report is over 500 pages long[43].

The Annex I countries all submit their annual national inventory reports to the UNFCCC – even the United States does, despite not having ratified the Kyoto Protocol. Amongst the 154 non-Annex I countries (essentially developing countries) which have ratified the Kyoto Protocol, 131 have submitted at least one greenhouse gas inventory to the UNFCCC[44]. As is to be expected, the non-Annex I country inventories are generally less detailed, mostly provide a picture for one year only (only seven countries have submitted more than one report), and were compiled with fewer resources.

[38] United Nations, 1998.
[39] United Nations Framework Convention on Climate Change. The offices of this organisation are based in the building in Bonn, Germany, where the post-World War II Marshall Plan was signed.
[40] IPCC, 2006.
[41] UNFCCC, 2004.
[42] The full accounting structure can be downloaded from http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_8x_Ch8_An2_ReportingTables.pdf.
[43] United Kingdom: DEFRA, 2008.
[44] See http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php.

The UNFCCC enters what emissions values are available into a database which is publicly available[45]. Analysing this database makes it clear how unreliable country totals can be. One extreme error stands out in a 2008 download, namely the large and negative emissions total for Guinea Bissau. The value for Guinea Bissau implies that in 1994 alone, through human-induced carbon absorption (for instance through the planting of new forests), the country was able to cancel out one-third of the emissions from the rest of the world. Though one may wish that reducing global emissions were this easy, the Guinea Bissau figure is clearly an error, and should caution us about the reliability of figures submitted to the UNFCCC.

There are organisations that verify the figures submitted to the UNFCCC, and provide (where necessary) adjusted figures. One such organisation that stands out is the World Resources Institute (WRI), based in Washington. The WRI maintains a useful online database, the Climate Indicators Analysis Tool (or CAIT), which includes a cleaned up version of the UNFCCC country database[46]. Cleaning occurs based on non-UNFCCC data such as those of CDIAC[47] (which in turn calculates emissions using international statistics on energy production) and of FAO[48] (which collects data on land use change around the world). The global emissions figures appearing in Appendix A are from CAIT. A comparison of CAIT and UNFCCC figures reveals that overall developing (non-Annex I) countries under-report their emissions by about 22% (the figure is around 3% for Annex I countries). At the same time, the percentage of countries with large errors (of over 20%) is about the same for Annex I countries, and non-Annex I countries[49]. The problem is simply that those non-Annex I countries that do make mistakes, make especially large mistakes. Of course this is all assuming that CAIT is right. For the world, CAIT arrives at emissions totals which are about 8% higher than what the inventory submissions to UNFCCC suggest. In this document, CAIT figures have generally been used.

Emissions resulting from changes in land use, for instance deforestation and reforestation, stand out as being particularly difficult to estimate, because the methodology is so complex, and because they occur largely in developing countries in the tropics, where environmental accounting and controls are typically weak. Land use change emissions are said to account for almost one-fifth of total emissions, but the emissions figures could be out by as much as 40%[50].

South Africa, specifically the Department of Environmental Affairs and Tourism (DEAT), has submitted a greenhouse gas inventory report to the UNFCCC once, in 2000. That report describes the country's emissions in 1990 and 1994, so it actually contains two inventories. The inventory itself occupies just 11 pages (against the 500 pages in the UK report). Total emissions are reported for three main gases – carbon dioxide, methane and nitrous oxide – and these figures tally exactly with what CAIT publishes, so one can assume they are regarded as sufficiently accurate by the WRI analysts. Figures given in Appendix A below are largely based on the 1994 DEAT figures. The issue of the accuracy of land use change figures is not prominent in the case of South Africa, as this category accounts for only 5% of total emissions, and the land use figure is negative, indicating carbon is being absorbed through the emergence of more carbon-intensive vegetation.

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[45] See http://unfccc.int/di/FlexibleQueries/Setup.do.
[46] See http://cait.wri.org/cait-unfccc.php.
[47] Carbion Dioxide Information Analysis Center (http://cdiac.ornl.gov).
[48] Food and Agriculture Organization (http://www.fao.org/).
[49] The comparison across the two datasets was made for the most recent year available in both.
[50] Houghton, 2003: 380.

8 Can't countries (and companies) lie about their emissions? $_{2010}$

When it comes to Annex I (developed) countries, the UNFCCC ensures that there is a rigorous audit of the submitted emissions inventories, which includes having auditors visit the reporting country and examine source data[51]. In the previous section we saw that UNFCCC figures and CAIT estimates differ by only 3% on average for Annex I countries, suggesting that these figures are rather accurate. Non-Annex I countries, on the other hand, are barely audited at all by the UNFCCC.

Under the Kyoto Protocol, the incentive to lie about one's emissions seems to apply to Annex I countries only, in other words those countries that are obliged to reduce their emissions. These countries could arguably gain political points, or save on the economic cost of reducing emissions, by under-stating their emissions. There is no punishment, for instance in the form of a fine, if countries do lie. So the cost of being found out is a bad reputation. On the surface then, it seems as if there might be an incentive to cheat the system.

However, if one looks carefully at how the system works, the opportunities to cheat seem fairly limited. The Kyoto targets are expressed in terms of percentage reductions in emissions relative to a base year. Specifically, on average Annex I countries have to achieve a level of emissions in 2012 that is 5% lower than their 1990 levels. This means that the emphasis of the UNFCCC experts and auditors is very much on seeing that the methodology for measuring the emissions does not change from year to year. This makes things more difficult for potential cheaters. Moreover, the biggest emission types, in particular emissions from the burning of fossil fuels, are the ones where it easiest for auditors to catch out any wrongdoing. Cheating is most possible in those areas accounting for smaller emission amounts (at least in developed countries).

There are some loopholes for cheating that special mechanisms outlined in the Kyoto Protocol create, which is one of the reasons why these mechanisms have not been universally popular[52]. As an example, the Clean Development Mechanism (CDM) allows an Annex I country to fund a project in a non-Annex I country aimed at reducing emissions in the latter, and to count the reduced emissions in the non-Annex I country as an emissions credit when it comes to reaching the Kyoto targets. The project may only be counted as a CDM project if it wouldn't have taken place anyway. The question is, of course, how one can be sure of this last point. Annex I country funding could simply be displacing funding that the non-Annex I country would have undertaken anyway. The cheating that may result would not take the form of a lie, but it could involve playing the system nonetheless. (CDM credits are not counted in Annex I inventory reports. There are some CDM statistics on the UNFCCC website.)

The post-Kyoto emissions regime that must extend beyond 2012 will almost certainly include much more stringent emissions reductions targets than Kyoto for developed countries (the EU has already tentatively made a commitment towards reducing emissions by 20% relative to the 1990 baseline by 2020) and, for the first time, emissions targets for developing countries. This will undoubtedly raise the stakes of the emissions statistics, and there are likely to be much more worrying about who is cheating.

It is important to view the emissions numbers in their political context, however. Even if some countries may be unable to report accurately on their emissions, or may willingly distort figures, there is more than enough knowledge about emissions for us to work out which

[51] See Swart, Bergamaschi, Pulles and Raes, 2007: 537. It is worth noting, however, that reports by these auditors seem not to be available on the UNFCCC website, so one cannot conclude what the impact is of the audits on statistical adjustments.

[52] There are three Kyoto mechanisms: emissions trading; clean development mechanism (CDM); joint implementation.

countries and sectors require the most urgent reductions, and the information systems we currently have, though not perfect, are good enough to identify who takes their reductions targets seriously, and who does not. The numbers debate is important, but it is not the most important climate change debate. In comparison, the debate around how one morally assigns responsibility to different societies is a much larger and vexing one.

What about lying companies? The arguments that apply to countries apply to a large extent to companies too. Moreover, if governments take national emissions seriously, they are likely to enforce honest reporting and emissions reductions in the private sector.

9 Is someone tallying country reports with what's in the air? 2010

The UNFCCC country-specific reporting system, and the parallel verification processes by organisations such as WRI, are based on activity data, such as data on the utilisation of coal. Such measurement is sometimes said to follow a bottom-up approach. An obvious question is whether we can obtain more accurate information on greenhouse gas emissions from measuring what is in the atmosphere, in other words through a top-down approach. There are two areas of enquiry here. On the one hand, we can measure the levels of greenhouse gases in the air and see whether this agrees with the UNFCCC-type statistics on how much is emitted each year. On the other hand, we can, perhaps, monitor what's going on in the atmosphere and conclude which industries, cities and countries are responsible for what levels of emissions.

The first analysis should be relatively easy, at least as far as the atmospheric measurements are concerned. The 'ppm CO_2-equivalent' statistic for the globe discussed under question 5 above is a highly reliable statistic obtained by several national and international organisations. As an example, one research body from the US receives flasks of captured air from all over the world on a regular basis and analyses the carbon dioxide content of the samples[53]. The difficulty lies in assessing whether the UNFCCC emissions figures are in line with the concentrations of carbon dioxide (and other greenhouse gases) in the atmosphere. It was indicated under question 6 above that around half of the carbon dioxide emitted by human activity is re-absorbed by the earth (including the oceans). Scientists are currently not able to explain where all of the re-absorbed carbon dioxide goes. The puzzle is sometimes referred to as the 'missing sink' puzzle – a sink is any mechanism whereby carbon dioxide is re-absorbed out of the atmosphere[54]. These uncertainties clearly make it more difficult to ascertain the accuracy of the UNFCCC emissions statistics on the basis of trends in the concentration of greenhouse gases in the atmosphere. In other words, it is difficult to reconcile bottom-up with top-down statistics. For the non-specialist, obtaining clarity on this matter seems not to be that easy, partly because the matter appears to have been insufficiently studied and documented. Perhaps the most significant reassurance lies in the fact that the IPCC is able to reconcile bottom-up carbon dioxide emissions resulting from fossil fuel burning and cement production within the overall carbon cycle of the Earth[55].

The second atmospheric measurement challenge is much harder, and much more costly. If we could fix monitoring devices all over the atmosphere, over every industry in every country, one would probably obtain very good top-down measures for determining where the greenhouse gas emissions were coming from, before they got mixed in the atmosphere. There are a few local monitoring devices of this kind[56], but extending the system across the globe would be so costly and would involve so much coordination that the option of fixed monitoring devices is not considered a viable option currently. Instead, the focus amongst scientists is on a satellite-based top-down system for monitoring emissions. This option uses spectrometry (the reading of light). Because greenhouse gases influence very slightly the light that is reflected in the atmosphere, it is possible to use data on light to determine, to some extent, where the greatest low altitude concentrations of greenhouse gases are, and hence where the gases are coming from. The translation of the light data to localised emissions data is very complex because the analysis must take into account cloud cover and atmospheric disturbances. But the methodology is sufficiently advanced to have yielded results. Data

[53] IPCC, 2007: 138.
[54] Ibid: 520.
[55] Ibid: 515-516. The reconciliation is not explicit. But the 6.4 gigatons of carbon in Figure 7.3, when multiplied by the conversion factor 3.664 (see question 6 in this document), gives 23.4 gigatons of carbon dioxide, which is close to the global total published by the UNFCCC and CAIT (keep in mind that this is carbon dioxide only from just fossil fuel burning and cement production).
[56] Goede, Burrows and Buchwitz, 2007: 26.

collected by the European EVERGREEN satellite, launched in 2002, has permitted the calculation of top-down figures for methane emissions down to the level of world regions (not individual countries) which agree rather well with the UNFCCC's bottom-up figures (though there are some interesting deviations, such as a higher than expected level of emissions from tropical areas using the top-down approach)[57]. The Japanese Greenhouse Gases Observing Satellite, or GOSAT, is the world's first satellite dedicated to monitoring greenhouse gases. It focuses on carbon dioxide and methane, which account for around 90% of the overall greenhouse effect. A serious setback to obtaining better emissions data occurred in 2009, when the US's new satellite-based Orbiting Carbon Observatory (OCO) came apart and was destroyed during its launch due to technical failure[58].

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[57] Ibid: 28.

[58] http://www.nasa.gov/mission_pages/oco/mission/index.html.

10 What about emissions resulting from the production of export goods? $_{2011}$

The IPCC method for calculating annual emissions for a country ignores international trade. A look at the emissions totals for oil producing countries reveals how problematic this can be. Extracting oil is a dirty business, partly due to the process of flaring whereby what is considered excess gas is burnt. This largely explains why the top three emitters in the world in the world in per capita terms – Qatar, United Arab Emirates and Kuwait – are oil producing countries[59]. A third of the CO_2 reported in Norway's emissions inventory comes from activities associated with the export of oil[60]. It seems logical to argue that reducing emissions associated with oil production is a responsibility that should be shared by those countries exporting the oil, but also those countries importing it. Specifically, those importing oil could reduce emissions, at home and in the producing countries, by using less of it. Yet the current international system to reduce emissions focuses almost exclusively on the producing country, and not on where the consumers are. This brings about the added problem that a society can appear to be taking steps against climate change by moving its high-emitting industries to other countries, when this obviously has no impact on global emissions, even if the national emissions of the country concerned drop.

An alternative to the IPCC's production-based national emissions figures are consumption-based national figures, where the emissions associated with what the people of a country consume in a year are considered, regardless of whether goods are produced locally or abroad. Consumption-based figures, which are far more difficult to obtain than production-based figures, have been calculated for some countries, and for CO_2 only (CO_2 accounts for around 77% of the total greenhouse gas effect[61]). As the next table indicates, in general more developed countries have higher consumption-based figures, whilst the opposite tends to apply for developing countries. Generally, developed countries such as Japan produce goods which are cleaner to produce whilst developing countries such as China produce goods which involve more emissions. However, the figures in the table suggest that there are many exceptions to this general pattern (for instance Mexico and Australia)[62].

	CO_2 emissions (million tons) in ±2004		
	Production-based statistic (A)	*Consumption-based statistics (B)*	*Difference of B from A*
Japan	1,295	1,545	19%
France	420	483	15%
Mexico	445	494	11%
Germany	888	950	7%
United States	5,855	6,146	5%
United Kingdom	582	596	3%
Canada	630	644	2%
Brazil	2,184	2,182	0%
India	1,190	1,138	-4%
Australia	384	361	-6%
South Africa	354	289	-18%
Russia	1,619	1,315	-19%
China	5,013	3,858	-23%

[59] World Resources Institute, 2008.
[60] Baumert, Herzog and Pershing, 2005: 48.
[61] Ibid.: 5.
[62] Values were obtained by putting together trade-related figures from Atkinson et al (2010: 26) and Ahmad and Wyckoff (2003: 8) and 2004 overall carbon emissions figures (including land use and international bunkers) from World Resources Institute (2010).

Why is it so difficult to obtain consumption-based figures? Above all, the data required for such figures are not widely available. Three types of data are needed: input-output ('IO') tables indicating how industries within one country use each others' products; international trade statistics broken down by product; emissions per industry within each country. Because all countries are ultimately inter-connected through trade, the national consumption-based figures, unlike the production-based ones, must be calculated within one international model, and cannot be calculated separately by country. It is the first data type, input-output tables, which is the most difficult to obtain. In recent years the Global Trade Analysis Project (GTAP) has facilitated things by bringing together national IO tables within a standard format. Currently 106 countries (of around 190 countries in total) are covered. Better coverage depends ultimately on more widespread compilation of input-output tables by national statistical agencies.

It is argued by some that a hybrid between the production-based and consumption-based approaches is needed when national emissions figures used for setting targets are compiled. According to this argument, it is ethically correct for both producers and consumers to take shared responsibility for emissions (producers do, after all, benefit from the emissions in the form of job creation and tax revenue). It is also argued that it would be impractical to try and exert all the pressure on consumers. Some direct pressure on producers to reduce their emissions is also necessary. A number of analysts have suggested formulas that would split the emissions across producers and consumers, whilst avoiding the problem of double-counting[63]. However, these hybrid approaches have been even less explored than purely consumption-based approaches.

As the above table indicates, the official CO_2 emissions figures for South Africa are 'too high' by about 18% if one uses the criterion that only emissions associated with what South Africans consume should be counted. Details of this, for instance by industry, are not provided by the analysts concerned[64]. But a quick analysis of the last supply and use tables (these tables are used to compile IO figures) produced by Stats SA, for 2002, provide some answers[65]. For instance, 11% of the electricity generated in South Africa is associated with mining products that are exported to the rest of the world. As Table 1 in Appendix A indicates, electricity generation is responsible for around 25% of South Africa's emissions (using the production-based method). This means that around 3% of South Africa's emissions are associated with electricity needed for minerals exported.

Stats SA has indicated that new supply and use tables will be published during 2010. This will provide an opportunity to refresh the figures on exported (and imported) emissions.

[63] See for instance Lenzen et al (2006: 15).
[64] Atkinson et al, 2010.
[65] Statistics South Africa (2006).

11 What do personal emissions calculators found on the internet tell me? $_{2011}$

There are many carbon footprint calculators on the internet that claim to estimate your emissions. For instance, the World Resources Institute, a US-based think tank, provides one[66], as does Carbon Footprint, a UK company selling environmental products[67] and the US Environmental Protection Agency (EPA)[68]. Most available carbon footprint calculators are rather simple and concentrate on requesting information relating to your travelling within a year (for instance kilometres flown, and type of car and kilometres driven), and electricity consumption (typically in kilowatt-hours), and then providing you with a calculated carbon dioxide emissions statistic per year. As an example, the EPA calculator requests information on the household's car use, household energy use (in terms of electricity, natural gas, fuel oil and propane consumption) and whether recycling of household waste occurs. Unlike many other emissions calculators, the EPA calculator does not request information on the use of public transport, including kilometres flown. Typical input data for a four-person household would result in a 'total estimated emissions' value of around 38 tons of carbon dioxide, or 9.5 tons per person. What is useful in the case of the EPA calculator is that it encourages users to test different scenarios where they achieve emissions reductions through different changes to their lifestyle.

Emissions calculators tend to be region-specific. Different countries and different regions within countries will, for instance, have electricity with a different carbon footprint per kilowatt-hour, depending on how the electricity is generated.

The 9.5 ton per capita value given by the EPA calculator is well below the average US carbon dioxide emissions value obtained if official emissions data are used. Those data provide a per capita value of around 20 tons per capita[69]. The difference between the two arises largely because the EPA emissions calculator, like virtually all such calculators on the internet, excludes emissions associated with a large range of goods and services consumed, including food bought in the supermarket, accommodation in holiday hotels, house renovations and educational services used. Even public goods that households do not actively seek to consume, such as policing and defence, should be counted within an all-inclusive emissions total for the household or individual. Another thing that the EPA calculator, and virtually all other calculators, ignore is CO_2-equivalent emissions of gases such as methane. These emissions raise the 20 ton figure mentioned earlier to a total of around 25 tons.

Why does someone not produce an emissions calculator that allows people to calculate their total emissions in a way that the value would correspond to what is reported in the UNFCCC system? This is good question, because producing such an emissions calculator would not be that difficult, though obviously one would need to make certain assumptions, for instance around how to spread the emissions produced by the US military across ordinary Americans (should rich Americans be considered as greater consumers of this service, for example?).

One rather good calculator that attempts to fill the typical is unfortunately only available in Norwegian. It is made available by the Norwegian public broadcaster (NRK) and has been developed by a group at a university in Trondheim[70]. It is such an exceptional tool that it warrants some special attention. The table below provides results from the tool, assuming a typical four-person household (the tool provides typical Norwegian values as default values). Direct emissions, which are calculated on the basis of physical inputs such as kilometres flown and are in the case of most calculators the only emissions considered, account for only

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[66] http://www.safeclimate.net/calculator/
[67] http://www.carbonfootprint.com/calculator.aspx
[68] http://www.epa.gov/climatechange/emissions/ind_calculator.html
[69] http://cait.wri.org
[70] http://www.nrk.no/norge2020/

29% of overall CO_2 emissions (3,021 over 10,414). Indirect emissions, which account for the remainder, are calculated using estimates of monthly expenditure in Norwegian Kroner (NOK). Not only does the calculator translate expenditure to emissions, it breaks the emissions down by whether they occurred in Norway, in the EU, or in the rest of the world. In this sense the calculator is even more inclusive than the official emissions per capita figures, which exclude imported emissions (see question 10 above). The official 2007 carbon dioxide emissions per capita figure for Norway is around 9 tons, which is well above the approximately 5 tons one gets if one excludes the EU and rest of world values from the following table. Part of the explanation for this discrepancy would be that the calculator is not designed to count emissions that Norway *exports*. As an oil producer and exporter, these emissions would be large in the case of Norway and would be included in the official average figure following the UNFCCC method.

Results from the NRK Norwegian carbon emissions calculator

	NOK	*Kilograms of carbon dioxide*				*kg per NOK*
		Within Norway	*Within EU*	*In rest of world*	*Total*	
Direct emissions						
Heating					69	
Car					1,157	
Electricity					754	
Flights					1,041	
Indirect emissions						
Entertainment	2,663	94	53	33	180	0.068
Public transport (not flying)	733	66	17	38	121	0.165
Furniture and appliances	9,711	516	286	367	1,169	0.120
Heating	1,664	154	138	110	402	0.242
Renovation	3,609	243	199	236	678	0.188
Home loan payment	5,031	207	47	71	325	0.065
Clothing and shoes	2,746	180	88	155	423	0.154
Groceries	5,271	399	142	165	706	0.134
Other indirect	8,188	199	66	103	368	0.045
Totals for direct					3,021	
Totals for indirect	39,616	2,058	1,036	1,278	7,393	
Overall total					10,414	

The last column in the above table is useful insofar as it can provide guidance on what to spend one's money on if one wants to reduce one's carbon footprint. It is best to spend one's money on the house one wants, rather than on renovating a house one is not happy with. Spending money on local entertainment such as restaurants is over twice as clean as spending one's money on new clothing or shoes.

Googling 'carbon calculator site:za' takes one to a few South African carbon footprint calculators, including those of the NGO Food & Trees for Africa and Nedbank. These calculators suffer the typical limitations described above. One calculator that stands out is that of Project 90 by 2030[71], which takes the form of a downloadable Excel file, so one can see the background calculations, and takes into account non-CO_2 emissions (though not the indirect emissions taken into account by the NRK calculator).

[71] http://www.90x2030.org.za

12 What exactly does the footprint idea refer to? $_{2011}$

The carbon footprint referred to under question 11 above is a loose adaptation of a more formal and all-embracing concept: the ‘ecological footprint’. Wikipedia has a good description of this ecological footprint. Here the focus is on some critiques of this concept, in particular insofar as it attempts to deal with CO_2 emissions (currently it completely excludes other greenhouse gases).

The ecological footprint is strongly associated with two researchers, Rees (Canadian) and Wackernagel (Swiss), and two organisations, the Global Footprint Network (GFN, works on the methodology) and the WWF (does much of the dissemination of the global and country statistics[72]).

The basic ecological footprint idea is an attractive one and can be thought of as follows. At a local level, one could ask oneself whether a particular community is ecologically sustainable, in other words whether it could go on existing forever without, for instance, exhausting the nutrients in its croplands and depleting its fishing grounds. However, with trade and greenhouse emissions, it is impossible to answer the question at a local level in the modern world. It may have been possible before industrialisation, but not today. Today, we need to ask the same question at a global level: If the world’s population stopped growing and we lived like we did today, would we be able to sustain our existence forever? If the answer is no, then by how much would you need to reduce the population of the world (assuming you reduce all communities by the same proportion) before you reach a point where the world would be sustainable? If you have to halve the world’s population, then you can say that the world’s ecological footprint is 2.0. The other way of thinking about this is to say that in order for the current population to be sustained (at current lifestyles, which of course includes lifestyles of poverty), it would be necessary to double the size of the planet. In other words, we would need two planets. There are many problems with the ecological footprint, especially when you try measuring it, but the basic concept is an appealingly simple one.

GFN’s ecological footprint is based on six categories of land: cropland, grazing land, fishing ground, forest land, built-up land and ‘uptake land to accommodate the carbon footprint’[73]. For all six land types, an ecological footprint for each country and the world as a whole is calculated. This is the land that is needed for current levels of consumption. Trade is taken into account. So oranges grown in South Africa and consumed in Germany are considered when Germany’s cropland requirement is calculated. In the case of the uptake land, CO_2 emissions are converted to the amount of forest land that would be needed to absorb the carbon (the problems with this are discussed below). With respect to the five land types other than the uptake land, the available land per country and globally are calculated. This is called ‘biocapacity’. The ecological footprint divided by the biocapacity provides the ‘overshoot’, or the use of extra land that one does not have. The global ratio was 1.5 in the 2010 WWF report, meaning we needed 1.5 planets to live sustainably, or that the overshoot was half a planet. Actually, it is only in the case of forest land (which includes uptake land) and fishing grounds that an overshoot can occur. It is assumed that you cannot use, say, more grazing land than you have. So over-grazing is not taken into account in the model (a basis for one of many criticisms of the model, some of which are admitted by the modellers themselves as reasonable things to ignore to reduce complexity). Apart from the ratio of ecological footprint to biocapacity, another important statistic produced by the model is ‘global hectares’ needed per person, for instance for the average American, to satisfy current levels of consumption. This allows one to make comparisons, for instance between countries. A person’s global hectare needs cover needs with respect to the six land types. Each of the six land types is

[72] WWF, 2008 and 2010.
[73] Ewing *et al*, 2010: 1. See also Kitzes *et al* (2008).

weighted so that, for instance, a weighted hectare of fishing ground produces more or less as much food as a weighted hectare of cropland.

If one looks at the figures released by the WWF, there are a few things that may seem confusing at first sight. The total global hectares of biocapacity don't equal either the Earth's total land area nor land plus water. This is not because of the weighting system, but because some land, such as Antarctica, is excluded and some but not all sea is included as fishing grounds. If one looks at the trend since 1961, the average non-carbon ecological footprint of each person actually declined. This was largely as a result of greater productivity, in particular the Green Revolution. Of course this should raise concerns about the absence of soil depletion as a factor in the model. On the other hand, the per capita ecological footprint with respect to carbon, or the uptake land, increased fivefold since 1961. Clearly, greenhouse gas emissions is a predominant sustainability concern. In fact, the 0.5 planet overshoot mentioned above is due largely to the need for uptake land. If we could ignore CO_2, we would in fact just need 0.7 of a planet, in other words human life would still be sustainable. In fact, all of the five non-carbon land types display no overshoot, not even fishing grounds, which may seem somewhat surprising if one considers how commonly the over-fishing argument is heard[74].

Many researchers like the ecological footprint as an educational concept, but would argue that it has been inaccurately used by governments. Currently, many local and city governments in Europe and Australia publish their jurisdiction's ecological footprint[75]. With respect to the carbon uptake land, the big problem is that the model seems to signal that if you have enough forest land absorbing the CO_2 you emit, then you can emit fairly large quantities of CO_2 and still have a sustainable world. Specifically, the WWF numbers suggest that if we halve CO_2 emissions, we would have enough forests to do the absorbing. What this ignores, is that forests only absorb significant amounts of carbon when they are growing. Once they mature, after some decades, they absorb about as much carbon as they emit. In fact, the existing mature forests of the world are not net absorbers of carbon, at least not in any significant way. So the uptake land part of the ecological footprint gives a false sense of possible sustainability. In reality, once forests mature you have no uptake any more and you would need to plant new forests, but then of course you would run out of land to plant forests. One option would be to cut down the mature forests and store the wood somewhere. But this is not what the WWF argues. What ought to be made clearer is that the uptake land in the ecological footprint is not re-usable in the way that, say, cropland is. The very serious confusions around what forests can and cannot do are dealt with further when carbon offsets are considered under question 16.

Overall, South Africa uses 2.0 times as many ecological hectares as it actually has (this compares to the global ratio of 1.5). This relatively poor sustainability for South Africa is mainly due to the uptake land needed to absorb carbon emissions according to the model. With respect to the other five land types, South Africa has worse ratios than the world for two land types: cropland and forests. In the case of grazing land and fishing ground, South Africa is more sustainable than the world as a whole.

[74] Calculations based on the '2010 Data Tables' spreadsheet found at http://www.footprintnetwork.org/images/uploads/2010_NFA_data_tables.xls. The same data are explained rather well in the *Living Planet Report 2010* (WWF, 2010).

[75] McManus and Haughton, 2006.

13 To what extent are people's emissions proportional to their income?

14 By how much do we need to cut emissions?

15 What can individuals do?

16 If I buy carbon offsets when I fly, is that a good thing? 2012

Carbon offsets are sold by some airlines to travellers who want to be able to say that their trip was a carbon neutral one. Prices vary. For instance, carbon offsets for a flight from Amsterdam to Barcelona could cost anywhere between EUR 2 and 37[76]. To understand how sensible these carbon offsets are it is necessary explain a few background issues. Clarifying these issues also make it easier to understand how offsets are used in other industries.

A carbon offset is, in a sense, a promise that one buys, usually through an intermediary, to reduce CO_2 emissions by a certain amount by a certain future date. The future date of the promise, or voucher, is referred to as the 'retirement date'. The money one pays for the carbon offset goes to an organisation that uses the money to emit less greenhouse gases than it would otherwise have done, for instance through investment in clean energy solutions. The money may also go towards reforestation, which results in the absorption of CO_2 from the atmosphere. One buys carbon offsets to compensate for one's own emissions, which one is either unable or unwilling to reduce.

Carbon offsets are one type of carbon credit. Another type is allowances. Organisations or whole countries may be subject to legal emissions limits, or allowances. If, say, one organisation is able to emit even less than what its allowance dictates, it may be possible for the organisation to sell its unused allowance to another organisation that is not able to remain within its allowance. The purchasing organisation would pay for the allowance by raising its price, for instance the price of the electricity it sells in the case of an energy company[77]. These traded allowances, like carbon offsets, are carbon credits.

It is estimated that carbon offsets reduced the emission of carbon dioxide by 283 million tons in 2009[78]. About 75% of this occurred through mechanisms of the Clean Development Mechanism of the Kyoto Protocol, meaning through emissions reductions projects in developing countries. The value of each ton of reduced emissions in 2009 was around USD 12. We can differentiate between voluntary carbon offsets and compliance carbon offsets. The airline carbon offsets would be voluntary, because the traveller decides whether to purchase the offset. Another example would be someone choosing a bank that pays carbon offsets in order to be carbon neutral, or a net non-emitter. Carbon neutrality may be a way of attracting clients to a company. On the compliance side, a company subject to emissions restrictions which is not able to remain within its allowance could, depending on the prevailing laws, have two options: either the company could buy unused allowances from someone else, or it could buy carbon offsets. Voluntary carbon offsets accounted for 46 million tons of CO_2 in 2009, or 0.1% of global emissions (the figure would be 0.6% if one included compliance offsets). The impact of these offsets is thus still quite small. In the airline industry, carbon offsets accounted for around just 200,000 tons of CO_2 in 2005, or only 1 in 4,000 parts of the total emissions of commercial air travel[79].

Around 30% of voluntary carbon offsets deal with reducing emissions from deforestation and forest degradation, or REDD[80]. It is worth elaborating on this a bit because of the amount of confusion that often surrounds REDD. Above all, it is important not to think of forests as perpetual absorbers of carbon. It is possible that this notion has arisen because coal and petroleum are sometimes thought to be the remainder of ancient terrestrial forests. The logic would thus go that forests, through photosynthesis, absorb carbon and bury the carbon as

[76] Gössling, Broderick, Ceron, et al, 2007: 235.
[77] Capoor and Ambrosi, 2007: 8.
[78] See Kossoy and Ambrosi (2010: 1). The values for the spot and secondary Kyoto offsets referred to in the source are excluded because these offsets were traded between brokers and not between a broker and a final client.
[79] Gössling, Broderick, Ceron, et al, 2007: 239.
[80] Peters-Stanley, Hamilton, Marcello, et al, 2011: 15.

forests age and new trees sprout. This view would see forests as coal factories slowly converting atmospheric carbon to underground coal. Unfortunately, this is not the case. Both coal and petroleum were formed underwater, coal from dead plant matter and petroleum from dead microorganisms. Forests do absorb carbon, but only when they are young and the overall amount of wood is growing. Once they reach maturity, they become more or less carbon neutral. The amount of carbon absorbed by young forests varies a lot, depending on many factors such as type of forest, but to give a rough idea, the Environmental Protection Agency (EPA) of the USA indicates that a hectare of non-mature forest absorbs around 2.5 tons of carbon per year[81]. That is around a half of the carbon emitted by the average US citizen in a year. To gain a sense of the maximum re-absorption of atmospheric carbon we could achieve through re-forestation, it is useful to consider how much forest has been destroyed in recent times. Between 1850 and 2000 around 156 billion tons of carbon escaped into the atmosphere as a result of deforestation, in particular the burning of wood[82]. This amount of carbon comes to around 20 years of greenhouse gas emissions at current rates. Even this wildly ambitious scenario would thus have a limited impact. The argument that planting forests is a way of justifying air travel and other emissions-intensive activities is a weak one. Amongst other problems, one would soon run out of space to plant new forests.

Carbon offsets are also subject to measurement and cheating problems. It is often difficult to know how much carbon offsetting to purchase because the total emissions of one's activity, for instance one's flight, is not very clear. Analysts have pointed to numerous errors in emissions figures released by airline companies for specific flights[83]. This partly explains the large variance in the price of carbon offsets mentioned above. It is often difficult to verify that the promised emissions reductions occurred, in other words that one obtained what one paid for when purchasing the carbon offset. The opportunities for fraud can be large. Even if a reduction occurred, there is often uncertainty as to whether the reduction would have occurred anyway, without the carbon offsetting scheme, for instance because technologies are continuously changing[84].

To sum up, there is a chance that one will do some good, or at least offset the environmental effects of one's air travel, when buying carbon offsets. But there is also a chance one's carbon offset will have no effect due to problems that have been discussed above. It is impossible to say what one's chances are of doing some good. Importantly, those who sell carbon offsets are likely to exaggerate their benefits and setting the record straight is an important task for activists and governments. If one's air travel is not essential, then perhaps one should *not* fly *and* at the same time one should buy carbon offsets. Even then, one's carbon offsets are unlikely to offset all one's emissions, but there is a good chance that one will offset a part of them.

Sterling Waterford, a Mauritius-based company, claims to have pioneered the selling of carbon derivatives, which are carbon credits made available, between their creation and their retirement, for trading[85]. Investors can thus make a profit if the value of the credit rises. The company has made these carbon derivatives available on the Johannesburg Stock Exchange. Nedbank in South Africa claims that in 2010 it became the first carbon neutral bank in Africa. Annually, Nedbank publishes a report detailing the emissions of the organisation. As one might expect, electricity consumption accounts for around 70% of all emissions[86]. Nedbank achieves its carbon neutrality by buying carbon offsets.

[81] See http://www.epa.gov/sequestration/faq.html.
[82] Houghton, 2003.
[83] Hooper, Daley, Preston, et al, 2008.
[84] Bushnell, 2010.
[85] See http://www.sterlingwaterford.com/pdf/SWSecuritiesBrochure.pdf.
[86] See http://www.nedbankgroup.co.za/pdfs/2011ghg.pdf.

17 What would a fair international order look like?

18 What should governments do?

19 Can birth control help? 2010

Obviously the more people there are on the planet producing and consuming things, the higher will be the greenhouse gas emissions, and the faster the speed of climate change. Yet the climate change literature tends to be astoundingly silent, or at best vague, about this important point.

How large the population challenge is becomes clear if you look back and do some simple calculations using the world's total population and carbon dioxide emissions figures for the period 1950 to 2000. Between 1950 and 2000 total global emissions increased from 5.2 to 23.5 billions of tons. This was partly because there were more people in 2000, and partly because on average each person emitted more in 2000. If population had increased and the average person's emissions had remained fixed the total emissions in 2000 would have been 12.7 billions of tons. But if population had stood still and just the average person's emissions had increased, total emissions in 2000 would have been just 9.6 billion. In many ways then, population increases are a more serious problem than increases in each person's emissions[87].

Let's begin with the few who are saying something meaningful about the issue of population. The *Living Planet* reports of the WWF are rather good at displaying the relationship between population numbers and human utilisation of the environment. The WWF, using the valuable environmental accounting methodology developed by the Global Footprint Network[88], concludes in 2008 that though there are only 2.1 hectares of land available per person, the average person is using 2.7 hectares of land for consumption and for the dumping of waste (including carbon emissions). The 'land' is calculated according to a methodology that takes into account the productivity of land, the ability of the land to absorb emissions, and so on. Clearly, we are living beyond our means, and the reason why we are able to do this is that we currently use up the natural resources of the next generations. Simple arithmetic can tell us that if we wanted to be kind to these next generations, we should be around 5.4 billion human beings, and not 6.9 billion (the UN estimate for 2010). The full calculation is: $6.9 \times 2.1 / 2.7 = 5.4$. The WWF goes as far as arguing for population reduction in developing countries, where the fastest population growth currently occurs, through, for instance, empowering women so that they have greater control over fertility[89]. The Optimum Population Trust[90], a British NGO whose patrons include naturalist David Attenborough, goes a step further and advocates population reduction in all countries, including developed countries. For instance they argue that the optimum population for an environmentally sustainable Britain is between 17 and 27 million, as opposed to the current population of 61 million (which is still increasing). They use the same footprint methodology used by the WWF, but apply a more stringent interpretation.

The mainstream literature on climate change barely acknowledges the issue of population. The IPCC's 2007 *Assessment Report* devotes whole chapters to more climate-friendly strategies with regard to areas such as energy, transport and forestry, but with regard to population states almost in passing that population policy is part of the solution[91]. Al Gore's *An inconvenient truth* film makes no mention of world population as a climate change factor. To understand this mysterious silence one needs to understand the politics around population policies over the last few decades. To put it briefly, since the 1970s it has become virtually a taboo to propose optimum population levels, or population control policies in the documents of the UN, and to a large degree this taboo is also found in individual countries. The taboo is an outcome of a curious and unfortunate mix of factors including religious groups opposing

[87] See the appendix.
[88] www.footprintnetwork.org.
[89] WWF, 2008: 27.
[90] www.optimumpopulation.org.
[91] IPCC, 2007b: 745.

contraception, developing country groups resentful of the argument that only they have a population growth problem, suspicions on the part of certain women's groups around infringements on women's reproductive rights, and economists arguing that fertility reduction can only really come about as a result of economic development[92]. The trend has been unfortunate as it has led to silences where there should be debate. One wonders, for instance, what the future history books will make of the fact that the resolutions emerging from the major 1994 international conference on population in Cairo lacked any reference to the threat of climate change (despite the fact that the Rio Earth Summit had occurred just two years previously), and specifically reject any incentives or disincentives aimed at curbing population growth, arguing that these do not work[93].

The big exception to this silence if of course China's so-called one-child policy – it is actually a 1.5 child policy if one takes into consideration that many people are allowed to have more than one child[94]. What China does is obviously of great importance, considering that around one in five people are Chinese. Chinese officials sometimes refer to their population policy as a factor that has helped in reducing China's impact on climate change[95]. They argue that without this policy there would have been an additional 300 million Chinese. From the official Chinese perspective (which is of course not inclined towards human rights considerations) the policy has worked rather well. Currently 'total fertility', or the number of children the average woman has, is 1.8 in China, which, whilst greater than the 1.5 intended by the policy, is considerably lower than the rate of 3.0 prevailing in the rest of the developing world (the rate in the developed world is 1.6 and in the world as a whole 2.6)[96]. Any rate below 2.0 means that in the long run the population will decline.

A few influential people, such as Chris Rapley, director of the British Antarctic Survey, have called for much more focussed attention on population in the climate change debates[97]. Between the extremes of complete silence on the matter, and coercive interventions by the state, lie a multitude of options that can be explored. At least one study has demonstrated that just awareness that there is a population problem is enough to induce people to lower the number of children they have[98]. The link between the number of children we have and the sustainability of the human race is information that should be available to people who want to make ethical choices. UN projections indicate that the human population will increase from its current 6.9 billion to 9.1 billion by 2050 (this is using the UN's medium projection). If everyone adopted a one-child approach now, the world's population would be just 6.1 billion by 2050, and 2.1 billion by 2100, taking the population back to what it was in 1950. Such a scenario may not be feasible. But deciding what scenarios are possible and desirable ought to become matters for public debate.

What is a sustainable population for South Africa? If one applies the criteria the Optimum Population Trust applies to the UK to South Africa, one gets a range of 18 million to 29 million. This implies that South Africa's present 49 million is too many people if one takes into consideration things like water, arable land and the capacity of vegetation to absorb carbon emissions. The total fertility rate in South Africa is 2.6, in other words below the developing world average, and at the same level as the world average.

[92] A fascinating account of this is provided by Hodgson and Watkins (1997).
[93] United Nations, 1995.
[94] Gu Baochang, Wang Feng, Guo Zhigang and Zhang Erli (2007).
[95] www.alertnet.org/thenews/newsdesk/L30472039.htm
[96] UNPD, 2009.
[97] Article by Rapley at http://populationandsustainability.org/papers/rapleyarticle.pdf.
[98] Hodgson and Watkins, 1997.

20 What are governments doing?

21 Could the victims take the perpetrators to court?

22 On the personal front, do I need to give up everything I enjoy?

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Appendix A: Emissions information by IPCC category

Table 1: Emissions information by IPCC category [99]

	IPCC sector and category	Global per capita emissions	SA per capita emissions	Activity and consumption description in plain English
1	**Energy**	4.2 (60.8%)	7.4 (82.9%)	
1A1	Energy Industries	1.7 (24.9%)	4.1 (45.4%)	Production of electricity in power stations. Included here is also heating activities in iron and steel plants. Consumers use electricity directly in their homes and indirectly through the electricity needed to produce the goods and services they consume. In SA, about a quarter of the local electricity supply is consumed directly in homes. The rest is consumed in industries.
1A2	Manufacturing Industries and Construction	0.7 (10.6%)	1.3 (14.4%)	Fuel-burning activities occurring in industrial and construction sites, such as on-site generation of electricity through generators. Consumers use the products coming out of these activities.
1A3	Transport	1.0 (14.0%)	1.3 (14.5%)	All transport by road, rail, sea and air, excluding trains powered by grid electricity. International transport is split according to the countries of departure and arrival. Consumers benefit directly through private and public transport, and indirectly through consumption of the goods transported.
1A4a	Commercial /Institutional	0.1 (1.8%)	0.0 (0.2%)	Fuel-burning occurring in shops and offices, in particular on-site generation of electricity through generators. .Consumers benefit through the services they enjoy.

[99] The first column indicates the IPCC sector and category codes (sector names appear in black rows, the non-black rows refer to categories). The global figures (per capita emissions of CO_2-equivalent and percentage of total emissions) are based on information provided in Baumert, Herzog and Pershing (2005). The South African figures are based on the latest available official national inventory of greenhouse gas emissions, which describes the 1994 situation (DEAT, 2000). A population total of 41.5 million was used for South Africa. For both the world and South Africa figures, figures had to be reorganised slightly so that they would align with the categories established in the IPCC's 2006 reporting guidelines.

1A4b	Residential	0.3 (4.3%)	0.2 (2.0%)	Burning of fuels such as wood and paraffin in the home to produce heat. Electrical generators used by homes fall under this category. Consumers, generally poorer ones, benefit directly from this.
1A4c	Agriculture/Forestry/Fishing/Fish Farms	0.1 (1.1%)	0.4 (4.5%)	Fuel-burning activities other than transport in agriculture, forestry and fishing. Consumers benefit largely through the food they buy.
1B	Fugitive emissions from fuels	0.3 (4.0%)	0.2 (1.8%)	Mining of for instance coal causes gases to escape unintentionally from the ground. Accidental coal fires would be included here. We can think of these emissions being linked to the consumer's use of electricity.
2	**Industrial Processes and Product Use**	0.2 (3.4%)	0.7 (8.2%)	
2A	Mineral Industry	0.2 (2.3%)	0.1 (1.4%)	Activities in the mining sector other than fuel-burning. Emissions from cement factories (other than fuel-burning), which are included here, form a large part of this category. Consumers benefit partly through the buildings they use.
2B	Chemical Industry	0.1 (0.9%)	0.1 (1.1%)	Activities in the chemical sector other than fuel-burning.
2C	Metal Industry	0.0 (0.2%)	0.5 (5.6%)	Activities in the metal industry other than fuel-burning. In SA, the iron and steel industry and the aluminium industry are important emitters within this category. Consumers use a variety of products containing metals.
3	**Agriculture, Forestry and Other Land Use**	2.2 (32.3%)	0.4 (4.5%)	
3A1	Enteric Fermentation	0.4 (6.0%)	0.4 (4.8%)	Enteric fermentation, in other words farting and burping, by farm animals, in particular cattle and sheep. Consumers use the meat, milk and wool from these animals.
3A2	Manure Management	0.1 (1.0%)	0.0 (0.4%)	Manure from farm animals, especially where animals are densely accommodated, produces

				emissions.
3B	Land	1.3 (18.3%)	-0.4 (-5.0%)	Largely destruction of forests. Where a country plants more trees than it destroys, the emissions value may be negative, meaning the net result is the absorption of CO_2 from the atmosphere.
3C1b	Biomass Burning in Cropland	0.0 (0.4%)	0.0 (0.0%)	Burning of cropland. This may be intentional.
3C1c	Biomass Burning in Grassland	0.0 (0.4%)	0.0 (0.1%)	Burning of grassland, intended or unintended. Consumers benefit from the productivity of the regenerated grassland after the fire.
3C4	Direct N_2O Emissions from Managed Soils	0.4 (4.2%)	0.4 (4.4%)	Fertilisation of farmlands with nitrogen. This results in the emission of N_2O. Consumers benefit from the farm produce they consume.
4	**Waste**	0.2 (3.6%)	0.4 (4.4%)	
4A	Solid Waste Disposal	0.1 (2.0%)	0.4 (4.1%)	The concentration of large amounts of waste in dumps. Organic waste such as discarded food emits large amounts of methane. Consumers benefit from having such waste removed from their homes.
4D	Wastewater Treatment and Discharge	0.1 (1.6%)	0.0 (0.3%)	Sewerage treatment. This activity also results in the emission of methane.
	TOTAL	6.9 (100.0%)	9.0 (100.0%)	

Appendix B: Population modelling

The role of population in past increases in carbon emissions

The first three rows of the next table give the actual population and carbon emissions occurring in the 1950 period. The last two rows indicate what would have happened in two hypothetical situations, one where population had remained static and only per capita emissions had occurred, and another where per capita emissions had remained static and only population had increased. Population clearly outweighs per capita emissions as a factor contributing towards an increase in total emissions. In fact the population effect was about 1.7 times as large as the per capita emissions effect (7.5 / 4.4).

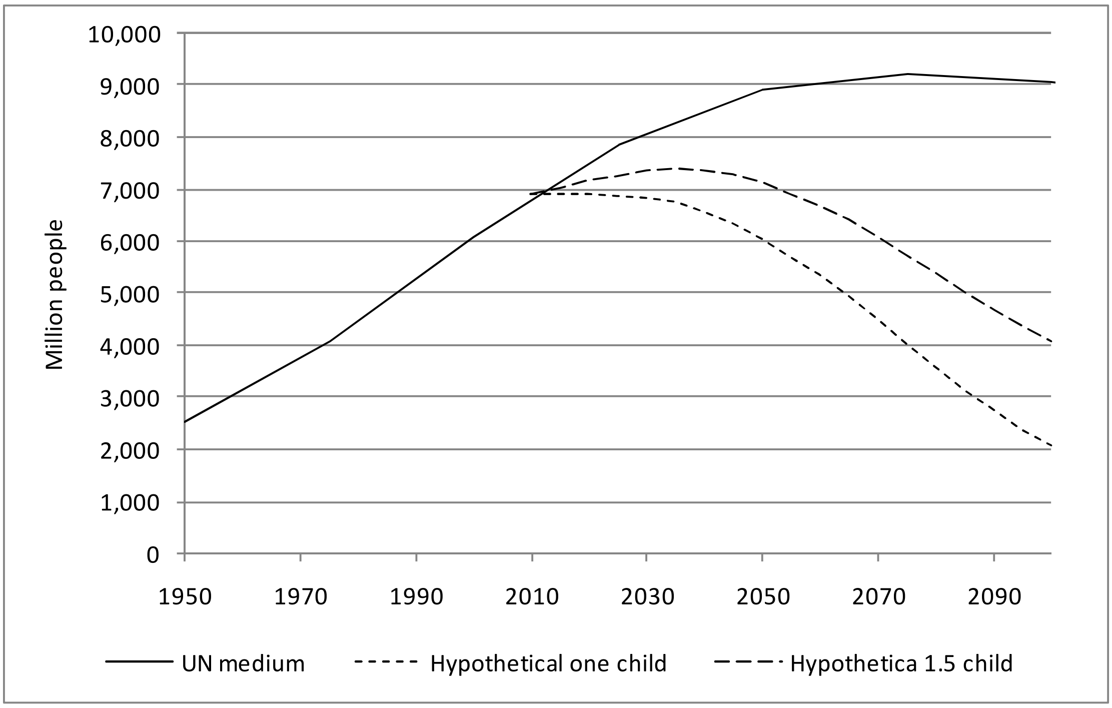
Table 2: Population and annual emissions 1950-2000

	1950	*2000*	*1950-2000 increase*
Total CO_2 emissions (billions of tons)	5.2	23.5	18.3
Population (billions)	2.5	6.1	3.6
Per capita CO_2 emissions (tons)	2.1	3.9	1.8
Total CO_2 emissions with just per capita effect (billions of tons)		9.6	4.4
Total CO_2 emissions with just population effect (billions of tons)		12.7	7.5

Population projections

The next graph illustrates a few population scenarios extending up to 2100. A medium projection published by the UN is given. The one child per woman trend from 2010 to 2100 is calculated using the age-specific and gender-specific mortality rates implicit in the UN's medium population projections for 2010 to 2050 (UNPD, 2009), plus the assumption that after 2050 these mortality rates would remain unchanged. Age-specific fertility rates applicable in 2010 were adjusted downwards so that children per woman was reduced from the 2.5 level of the UN medium trend down to 1.0, and these rates were applied for the whole 2010 to 2100 period. The 1.5 child per woman trend is derived in a similar way.

Figure 1: World population trends 1950-2100



Source: The UN medium trend is from United Nations (2004: 14).