High Noon for 2°C

Introduction: The growing alliance

The world's nations agreed to "prevent dangerous anthropogenic interference with the climate system" (Art. 2 of the United Nations Framework Convention on Climate Change[1]) back in 1992. Until recently, most nations had not agreed what that meant, however. Over the past year, the group of countries that have agreed on a specific goal, namely to limit global warming to below 2°C or 1.5°C, has grown enormously: it now comprises 133 countries[2]. In June 2009 even the US agreed to the G8 target of limiting global warming to 2°C. Overall, the total group of countries calling for warming to be limited to 2°C degree or less accounts for about 75 per cent of global energy and industry-related CO_2 emissions[3] and about 80 per cent of the global population[4] in 2005.

Good news for the UN Climate Convention negotiations?

It is good news, because such warming limit scan be directly translated into how much emissions we can still afford without crossing that threshold. The size of the overall emission cake is thus defined, although how that cake is divided between the countries and over what time frame is now the issue on the negotiation table. But this is where the good news ends.

While calling for 2°C, countries are still claiming for themselves too large a slice of the cake. In other words, the pledges on the table for the UN Climate Convention negotiation do not take us where we need to be heading: Straight towards a near-zero carbon future towards the end of the century.

This factsheet aims to shed some light on the 2°C target (Section 1) and our chances of keeping warming below this. We begin by briefly examining the debate on whether we are bound to exceed 2°C (Section 2). Then we look at what this level means for the overall size of the emission cake – our allowed emissions budget (Section 3), before touching on how we could divide the cake (Section 4). Finally we look at the current state of the negotiations, i.e. what the current pledges from countries add up to (Section 5).

Section 1: Background on 2°C

The origins of 2°C

Based on the available scientific evidence of severe regional impacts in the late 1980s an Advisory Group formed by the World Meteorological Organization, the International Council of Scientific Union, and the United Nations Environment Program recommended 2°C global mean surface warming from pre-industrial levels as "an upper limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly "[5]. Further on, the German Advisory Council on Global Change[6] recommended a 2°C target based on the idea that warming should be kept within limits known from recent warm periods (interglacials). In 1996 after consideration of the IPCC Second Assessment Report (SAR)[7], which highlighted the severe impacts that can be expected for warming levels above 2°C, the European Union first established its 2°C target[8].

Is 2°C a Scientific target?

Is 2°C a scientific target or an un scientific one? Neither. It is a policy target based on science, much like a speed limit for car traffic. Any such target is a value judgment made by policy makers, and hopefully, informed by science in regard to the consequences if we did not limit global warming to below 2°C. With growing scientific insight, as assessed in the Fourth IPCC Assessment Report(AR4), it is hard to conclude anything else but that preventing "dangerous anthropogenic interference with the climate system" means limiting global mean warming to no more than 2°C, and likely much less.

On the one hand, some legitimately claimthat today's climate change impacts are already dangerous (e.g. remember the heat wave victims in Europe in 2003[9,10]). Even though we have only thus far faced a relatively mild global warming of 0.8°C, we have observed unprecedented mass coral bleaching events caused by unusually high sea temperatures[11], unprecedented heat waves and an increase in the most intense and destructive tropical cyclones linked to rising sea surface temperatures[12].

Given the information in the IPCC AR4, and what has been observed and projected since then, a value system that would call for any goal warmer than 2°C, seems to border on the absurd. Not labelling impacts as the complete extinction of coral reefs, even more severe droughts in the Mediterranean area[13], an abrupt transition to semi-arid state in the South-West USA[14], probably more intense cyclones[15], or the near certainty of multi-metre sea level rise in the long-term[16] as "dangerous" would certainly be a value judgement. But such a judgment would however most likely not be shared by most people.

2°C is not a safe level

Of course, 2°C is not a "safe level". That is why 80 of the most vulnerable developing countries are calling for global warming to be limited to below 1.5°C instead of below 2°C. This group comprises the Alliance of Small Island States (AOSIS) and the group of Least Developed Countries (LDC) that are most vulnerable to climate change. For the seacountries, a global warming of 2°C is projected to cause unacceptable damage. Long-term sea level rise is likely to end the history of many of the low-lying islands, even at 2°C warming.

At this level of warming, if not before, Arctic summer sea ice is likely to disappear, and with it unique ecosystems and ice-dependent species such as the Polar bear. We cannot rule out the possibility that accelerated melting of the Greenland ice sheet and disintegration of the West Antarctic ice sheet could be triggered below 2°C, inundating populous riverdeltas and low-lying coastal areas around the earth in coming centuries. Limiting global warming to below 2°C would certainly help to avoid the worst of impacts. Hence, 2°C is often thought to be the threshold, beyond which we would face unmanageable risks.

Section 2: Can 2°C be avoided?

GHG concentrations are already at around 450 ppm CO_2 eq, how can we avoid 2°C?

The atmosphere is already loaded with greenhouse gases –sufficiently so that a warming of 2°C is likely to result if two conditions are met: Firstly, that greenhouse gas concentrations stay at today's levels, and secondly, that all cooling agents, i.e. aerosols, are eliminated.

The question is then, are we already committed to 2°C? No, we are not and the following paragraphs explain why. The total of all anthropogenic warming and cooling influences on the climate determines the global average temperature. The figure of 450 ppm CO_2 eq only includes the warming effects of the greenhouse gases CO_2, CH_4, N_2O, and various types of fluorocarbons, including HFCs, but not the cooling effect of aerosols. The effect of aerosols is to reduce the combined climate changing effects of all GHGs to close to the effects of CO_2 alone – around 385 ppm CO_2eq.

If we were to reduce all emissions instantly, then concentrations would fall again. In the case of CO_2, a substantial amount would still be redistributed to the oceans and the biosphere. For other gases, finite atmospheric lifetimes would result in their concentrations slowly falling back to the natural background levels.

Therefore, a commitment is probably best defined by the emission scenario that leads to the highest possible rate of reductions that is considered economically, and technically feasible without causing major disruptions to energy services, for example. The resulting "committed" concentrations will thus first increase above today's levels, but then fall again below these in the long term. In other words, we are not committed to stay at or above today's greenhouse gas concentrations. It is a choice.

Even if the aerosol cooling shield is taken away in the longer term (since this is very advisable for multiple reasons, primarily air quality), the resulting warming does not have to exceed 2°C[17]. The lower scenarios assessed in the IPCC Fourth Assessment Report, for example, all greatly diminish the emissions of aerosols up to the middle of the century, and yet these lower scenarios are able to limit maximal warming to below 2°C (Table 3.10 of IPCC AR4, WG III[18]).
Figure 1 also shows GHG concentrations and global mean warming for a scenario that includes substantial removal of cooling air pollutants in parallel with the substitution of fossil fuels and technological innovation. Following the upper band of the emission reduction goal endorsed by the G8, in this scenario global Kyoto GHG emissions are halved by 2050, as in Schellnhuber, 2008[17]. This is virtually certain to overshoot the 450 ppm CO_2 eq line (even including the aerosol effect), while there is about a one-in-three probability, or slightly higher, of exceeding the 2°C target.

Finally, we are basically bound to exceed 450 ppm CO_2 eq (even including cooling agents) for some decades.
Only if global emissions start to fall immediately by roughly 7 per cent annually, would the net forcing stay below that of 450ppm CO_2 eq. As shown in Figure 1, this concentration overshoot does not have to result in exceeding 2°C temperature levels. The phenomenon is similar to cranking up the thermostat on a kitchen oven to 220°C, with the greenhouse gas concentrations being the thermostat. If the oven is turned down fast enough the actual temperature in the oven will never reach 220°C.

In summary, there is no reason for complacency. To ensure a safe climate future in the long term, we will have to turnback the atmospheric CO_2 eq concentrations. The first and most important requirement to halt any further increase inconcentrations is to lower emissions again. The peak has to be reached as soon as possible in order to get on a downward path – at least from 2015 on wards[21]. Only if global emissions

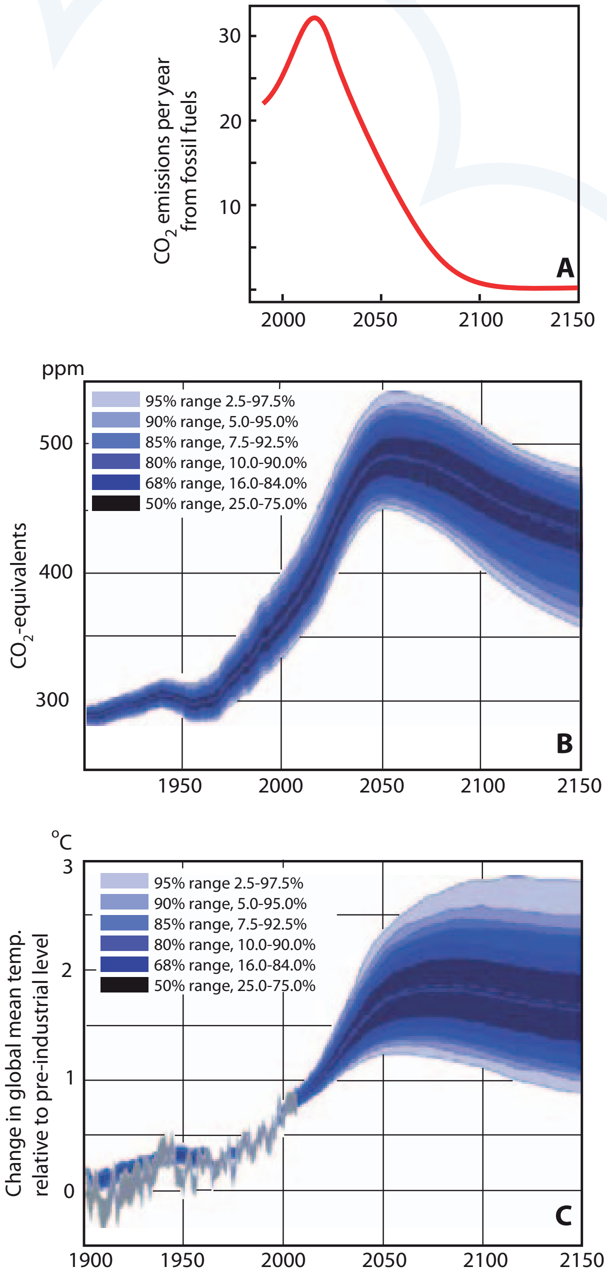

Figure 1.
A: CO2 emissions from fossil fuels under a mitigation scenario assuming halved global Kyoto GHG emissions by 2050 relative to 2000 levels (Schellnhuber, 2008)17.

B: Resulting GHG concentrations + aerosol effects translated into CO2 eq concentrations. Calculations are based on the reduced complexity carbon cycle model MAGICC6.019. Uncertainty ranges are calculated applying the statistical methodology introduced by Meinshausen et al., 200920 (also see Appendix).

C: Resulting changes in global mean temperature relative to pre-industrial levels.

are there after reduced sufficiently quickly, can we also stop the further rise in global mean temperatures. To halt the rise in sea level, there is simply no other way than to remove CO_2 from the atmosphere. Only these "negative" emissions will then allow us in the long term to return to CO_2 concentration levels below 350 ppm CO_2, as proposed by Hansen et al., 2008[22] – with some chance at least of limiting the rise in sea levels.

Would it be worth while to focus on the short-lived warming agents?

There is one additional very important aspect with respect to aerosols: Although overall they are estimated to have a cooling effect (-1.4 W/m^2 according to Ramanathan and Carmichael, 2008[25] and -1.2 W/m^2 according to IPCC AR4WG I[23]), black carbon (BC) is one component with a pronounced warming effect (+0.20 (0.05, 0.35) W/m^2 solely from fossil fuel BC (IPCC AR4 WG I[23]); +0.9(0.65, 1.15) W/m^2 according to Ramanathan and Carmichael, 2008, including other sources as biomass burning). Thus, reducing black carbon emissions will help to reduce global warming. These black carbon emissions mainly stem from cooking with biofuels, fossil fuel combustion (especially diesel and coal), and biomass burning associated with deforestation and crop residue burning. Therefore reducing black carbon emissions would not only have tremendous benefits in terms of increasing (indoor) air quality. Because black carbon on snow can decrease the albedo of snow and ice-covered areas, reducing black carbon emissions can be particularly beneficial for Himalayan glaciers or Arctic ecosystems.

However, none of these reductions should be made at the expense of focussing less on the main long-term culprit, CO_2. If short-lived species, such as black carbon and methane, as well as HFCs, are reduced in exchange for more emissions of gases with a long atmospheric residence time, a disservice is done to the climate. That is because in the longer term, when climate change is going to be magnitudes more dramatic than today, only the long-lived emissions of today count.

That is not to say that black carbon should not be reduced. On the contrary, reducing air pollution, extending the lifetime of Himalayan glaciers that supply water, and slowing current warming in the Arctic, are sufficient reasons to act swiftly. Tackling short-lived forcing agents is however not a substitute for CO_2 reductions. It is also important to recall that moving to an energy system that has very low CO_2 emissions will rapidly reduce black carbon emissions, however there is little or no synergy in the other direction. In other words moving fast on CO_2 will mean it is easier to move faster on black carbon.

Forcing	2005 Radiative forcing (W/m^2)	Best-estimate CO_2 equivalence concentration (ppm), if all below agents are included one by one[24].
CO_2	1.66 (1.49, 1.83)	380 CO_2 270
Methane (CH_4)	0.48 (0.43, 0.53)	415 CO_2eq (CO_2 + CH_4) 350
N_2O	0.16 (0.14, 0.18)	427 CO_2eq 500
Halocarbons	0.34 (0.31, 0.37)	455 CO_2eq 270
Tropospheric ozone	0.35 (0.25, 0.65)	486 CO_2eq 200
Stratospheric ozone	-0.05 (-0.15, 0.05)	482 CO_2eq
Land use	-0.20 (-0.40, 0.00)	464 CO_2eq
Black carbon on snow	0.10 (-0.00, 0.20)	473 CO_2eq
Direct effect of aerosols	-0.50 (0.90, -0.10)	431 CO_2eq
Indirect effect of aerosols	-0.70 (-1.81, -0.30)	378 CO_2eq

Table 1. Today's anthropogenic impact on the atmosphere. The human-induced radiative forcing agents, with the major culprit CO_2, are listed on the left, their radiative forcing (the measure of how much those agents contribute to warming) is listed in the middle column (taken from Table 2.12 in IPCC AR4, WG I[23]) and the corresponding best-estimate CO_2 equivalence concentration is listed on the right.

Section 3: The size of the cake

– what are the allowed emissions?

Many surprises in store for unique experimentsTranslating a target of 2°C or 1.5°C into guidelines for global emission reduction targets over the coming decades is one of our most important and urgent tasks. We have to answer the question of what ceiling must be placed on emissions to keep global mean warming below these limits. It is this number which then allows an assessment of the targets. But unfortunately determining this number is not trivial: Whilst there is certainty about the fact that human-induced greenhouse gas emissions can and have caused global warming[26] it is not possible to predict the exact amount of warming that would result even for a certain emission trajectory. This depends on many factors such as: the amount of CO_2 taken up or released by the terrestrial biosphere and the oceans; the strength of radiative forcing associated with the concentrations of CO_2 and other greenhouse gases remaining in the atmosphere; and the cooling effect of aerosols and the fraction of warming that is buffered by the oceans. However, there has recently been a lot of progress in quantifying the se uncertainties.

As with any unique experiments, and we are currently performing a big one with the Earth's climate, there are going to be surprises in store. In the history of humanity, the climate has never been pushed to warming levels that we are heading for. We cannot be certain that large positive feedback mechanisms such as the release of methane hydrate from the ocean floor as the seas warm up, are not going to bea major source of warming that will haunt us in the future. We cannot be certain about how exactly the carbon cycle reacts across the span of Earth's diverse ecosystems. But there are certainties as well. We know for certain that the climate will warm, and with 2°C warming it is clear that more terrestrial, freshwater and marine species are at risk than at anytime in the recent geological past[27].

Risk management approach – quantifying allowable emissions

Given these uncertainties, climate change policies have to be seen as a risk management technique. As in so many other policy areas, we not only have to state the target, but also how certain we want to be of achieving it. The question hence becomes: "What is the allowed amount of emissions, if we want to keep global warming below 1.5°C or 2°C with a probability of X %?" For each emission path there will be acertain risk of exceeding a given temperature target due to the uncertainties of the projections – without even accounting for the potentially strong feedbacks mentioned above. Deciding on possible emission pathways is uncertain, as are most political decisions. But a lot of effort is spent in quantifying and reducing the uncertainties related to this special question.

There are four recent studies (Meinshausen et al., 2009[21] and Allen et al, 2009[28], Matthews et al. 2009[29] and Zickfeldet al. 2009[30]) which take a very comprehensive approach to quantifying the current uncertainties related to the question of what are the "allowed amounts" of global emissions. We focus here on the methodology which includes all greenhouse gases (Meinshausen et al., 2009).

Given any specific emission path, a reduced complexity carbon cycle climate model was used to estimate the probability of exceeding a global mean warming of 2°C in the 21st century. Therefore a large number of model runs were executed based on different sets of model input parameters varied within their uncertainty ranges. More details of the methodology are given in the Appendix.

Calculating these exceedance probabilities for a large number of emission profiles tells us that:

- Generally, exceedance probabilities depend on cumulative emissions, i.e. emissions summed up over a long time period, not on the specific emission profile.
- If we accept an exceedance probability of 25 per cent the cumulative CO_2 emissions from fossil sources and land use changes have to be limited to 1,000 Gt CO_2. If we are willing to accept a probability of even 50 per cent of warming exceeding 2°C, the limit is reached at 1,440 Gt CO_2.

We cannot afford to burn today's reserves.

But what do the numbers 1,000 Gt CO_2 and 1,440 Gt CO_2 mean, respectively? Is there any hope that fossil fuel reserves are exhausted before reaching these limits? The answer is no. Burning the known economically recoverable oil, gas and coal reserves vastly exceeds the "allowed emissions" that will keep global warming below 2°C: Known CO_2 emissions from 2000 until now (2009) already total more than 300 Gt CO_2. Thus, we only have an allowance of less than 700 Gt CO_2 left if we are to retain a "likely" 31 chance (75 per cent) of keeping global warming below 2°C. Given that the amount of economically recoverable fossil fuel reserves is about 2,800 Gt CO_2 [32,33], this is less than a quarter. Based on today's emission rates of 36.3 Gt CO_2/yr, the budget of 1000 Gt CO_2 will be exhausted by 2027. Furthermore, keep in mind that the overall resource estimates, including the unconventional sources, are probably many times larger than the economically recoverable reserves.

But using CCS will allow us to burn all fossil fuels!?

The short answer is no, and here is why: Carbon Capture- and Sequestration (CCS) is an important technology; it is worthwhile supporting and important to make it available on a commercial scale, with sound solutions to resolve issues like permanence, leakage, transport etc. And yes, it is true: If the burning of fossil fuels in a coal power plant is combined with CCS, then that power plant is going to be carbon neutral.

So why then is CCS not a lifesaver for the coal industry? In order to achieve safe climate levels in the long term, e.g.a return to 350 ppm CO_2 concentrations, we will have to reduce all emissions basically to zero before the end of the century, and it is likely that CO_2 emissions will need to beclose to zero shortly after mid-century. In fact, to prevent further sea level rise or ongoing ocean acidification, there is no way around negative CO_2 emissions. These negative emissions are for example possible with the combination of biomass power plants and CCS. Thus, we can simply not afford to waste the available geological storage sites for carbon dioxide from coal power plants, but will have to use them to suck carbon from the atmosphere. For these large point sources, such as power plants, carbon neutrality is simply not going to be good enough.

What does 2°C mean for 2050 emission levels?

Generally, one year's emissions do not provide enough information about cumulative emissions to deduce exceedance probabilities. High or low emissions in 2050 may be levelled off by especially low or high emissions in previous years. But given that we are discussing "plausible" real world emission pathways, emissions in 2050 actually become a robust indicator of exceedance probabilities. Given the default assumptions about climate sensitivity *(see Appendix)*, it turns out that halving global emissions by 2050 relative to 1990 levels is not enough to achieve a 2°C target with a very high likelihood. There is still a one-third risk of exceeding 2°C. As mentioned, this analysis makes assumptions about what a "plausible pathway" could look like. This basically comes down to "smooth" trajectories with maximum reduction rates of six per cent per year in the region with the strongest emission cuts, i.e. OECD. There are some sketches of pathways in the international arena that assume ever-increasing global emissions until 2030, and then crashing emission

USA	**-80%**	-85%	**-90%**	-93%
EU27	-73%	**-80%**	-87%	**-90%**
Non-OECD	48%	10%	-26%	-45%
OECD	-72%	-79%	-86%	-90%
WORLD	-9%	-32%	-55%	-66%
AVERAGE PER CAPITA ($tCO_2eq/cap/yr$)	3.04	2.26	1.52	1.13

Table 2. Relationship between 2050 absolute emission levels relative to 1990 – assuming equal per capita emissions of Kyoto GHG excl. LULUCF (CRF36+MATCH37) in 2050. Numbers are based on Medium Growth UN 2008 Population projections. [38]

reduction rates between 2040 and 2050. We admire the optimism underlying those pathways, i.e. that it is feasible to achieve the very steep reduction rates withsome miracle technology in the future. The IPCC Fourth Assessment report did not share that optimism either, when it concluded that for the lower stabilisation categories a peaking of global emissions by 2015 is pivotal. However, even if emission levels were halved by 2050 after such a crash trajectory, the exceedance probabilities would be greater than merely a third – simply because the cumulative emissions over the first half of the 21st century are going to be too high.

Section 4: Sharing the "allowed" emission budget

How we should share the "allowed" emission budget among the countries of the world in a fair manner is at the core of the climate negotiations. For example, some developing countries point out the large historical contributions to emissions. Without even having to look backward, the current per capita emissions in industrialised countries are still significantly higher than per capita emissions in developing countries. In 2005, per capita emissions of greenhouse gases reached 23.5 t CO_2 eq for the USA, 10.5t CO_2 eq for the EU-27, 5.4 t CO_2 eq for China, and 1.65 t CO_2 eq for India[34,35,36].

For any fair solution to avoid the worst climate impacts, the effort of reducing emissions has to be primarily shouldered by those emitting most on a per capita basis, which have the capacity to act, and contributed most to historical emissions, i.e. the climate change we face today. This is the group of OECD countries. Clearly, however, without leveling off emission in developing countries, such as China, by 2020, we will not be able to contain global emissions within the allowable remaining budget. Hence, not only is domestic action required by all countries, major finance and technological support has to be shouldered by the rich, in order to allow a zero-carbon development path for the poor.

In this article we do not prescribe any particular rules for dividing the remaining amount of allowed emissions associated with a reasonable chance of keeping global warming below 2°C. Rather, we follow a conservative approach in the sense that we do not consider historical emissions but simply assume equal per capita emissions in 2050.

The fairness of such an approach can of course be questioned, rather like asking whether it is fair that those who are drunk at the end of a party should claim an equal share of the last bottle as those who have only had water so far (Nicholas Stern, Bali climate conference, 2007). On the other hand, the political realities seem to suggest that future generations in OECD countries might not be willing to sign up to financial transfers, once their per capita emissions turn to lower levels than those of currently developing countries. Anyway, for illustrative purposes, it is illuminating to sketch a world of equal per capita emission allocations in 2050, as done in table 2.

Based on medium growth population projections (UN2008) we can calculate the resulting reductions in global GHG emissions (expressed in CO_2 eq) given that the USA and the EU 27 reduce their emissions by 2050 by the relative amounts printed in bold. Thus, the first column of Table 2 on page 6, has to be read as follows: If the USA reduce their total (not per capita) emissions by 80 per cent relative to 1990 that means per capita emissions of 3.04 t CO_2 eq. To reach the same per capita emissions in 2050, the EU 27, as a group, has to reduce their total emissions by 73 per cent. For the group of OECD countries this means emission reductions of 72 per cent while emissions are allowed to increase by 48 per cent in the non-OECD countries. But overall this means that global emissions are only reduced by 9 per cent – not enough to have a reasonable chance of staying below 2°C global warming. To limit the exceedance probability to 25 per cent, global emissions have to be reduced by 50 per cent or more. Assuming equal per capita emissions in 2050 this means that the USA has to reduce their emissions by ~90 per cent. For the EU 27 this means reductions of 87 per cent and in this case even the non-OECD countries have to cut their emissions by 26 per cent *(see column 3 of Table 2 on p. 6)*. Average per capita emissions of Kyoto GHG reach 1.52 t CO_2 eq per year under this scenario.

Only under a scenario where the EU and the rest of OECD as a group reduce emissions allocations by 90 per cent relative to 1990 levels, will it be possible to have both the qual per capita emission allocations by 2050 and global emissions substantially below 50 per cent.

-17% allocations by 2020 for the US might be fair –relative to 1990 levels, not 2005

The Waxman-Markey/HR37 bill is a great step for US legislationon climate change, implying around 17 per cent emission reductions below 2005 by 2020 for its cap including the additional measures[38]. However, it is insufficient in regard to its 2020 targets. Consider for example that EU and US per capita emission allocations should be equalised by 2050, as described above. Assume furthermore that a fair path towards that 2050 target might simply be a straight line, so that the ratio between US and EU 27 per capita emissions steadily diminishes from its current factor of 2.3 to 1 by 2050. Then, if the EU aims for a 90 per cent reduction by 2050, US emissions by 2020 would need to be 17 per cent below 1990 levels –already taking into account the fact that the US population is steadily rising. *See Figure 3.*

Section 5: The big gap

The announcements do not add up to reach the goal

The present UN Climate Convention negotiation are an opportunity, maybe the last one, to set the world on an emissions pathway that turns around before 2015. Currently, emissions are ever increasing, and so is the risk to coral reefs, river deltas, and increasingly drought-struck and water-scarce areas. As the deadline for an UN agreement approaches, industrialised countries have started to put their pledges for future emission reductions on the table. Some developing countries have also put in place or planned policies which would reduce the growth of their emissions. What do all these pledges and climate policy initiative sand proposals mean with respect to achieving the 2°C (1.5°C) target? Are current proposals sufficient to reach that target? Unfortunately, the short answer is no.

US per capita emissions in relative to EU per capita emissions

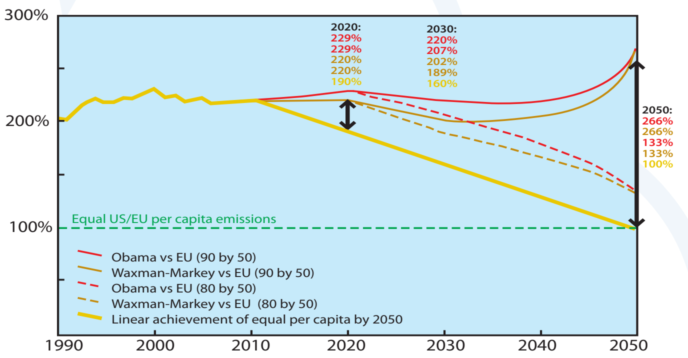

Figure 2. US per capita emissions in proportion to EU per capita emissions assuming that the EU reduces its GHG emissions by 90 per cent (solid lines) or 80 per cent (dashed lines) in 2050 relative to 1990. Ochre line: Linear decrease in proportions reaching from today's levels to equal per capita emissions in 2050. Orange lines: Assuming US emissions follow the Waxman Markey Bill. Red lines: Assuming US emissions follow the proposal by President Obama. (Assuming medium UN population growth projections; Kyoto GHG emissions (excl. LULUCF CO_2);EU27 target -30% rel. to 1990.)

US and EU absolute greenhouse gas emissions

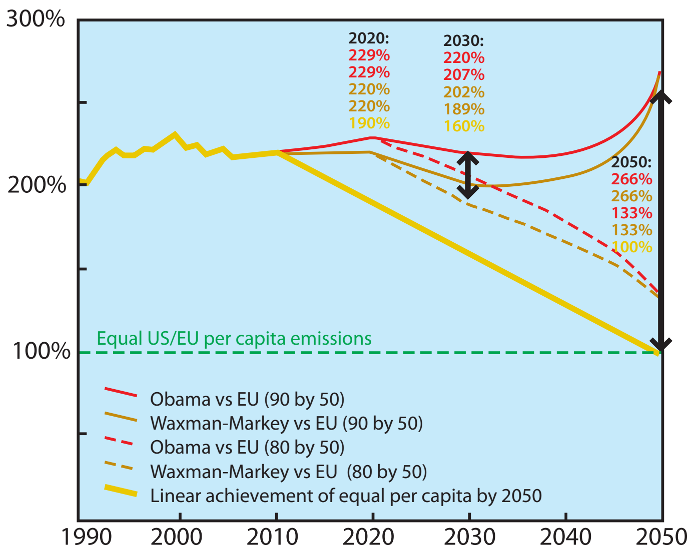

Figure 3. Projections of absolute GHG emissions per year from the US and EU-27 for different scenarios considered in Figure 2 (see legend). Thus, a -17 per cent target by 2020 for the US would be substantially below implied levels of the Waxman/Markey bill (orange line), as shown by the black downward arrow. Considering a hypothetical starting year of per capita convergence at the time of Kyoto (1997), the -17 per cent US reduction by 2020 is relatively "mild", as shown by the black upward arrow. (Kyoto GHG (excl. LULUCF CO_2 emissions); CRF UNFCCC 2008; extended beyond 2009 according to target proposals.)

Looking at global emission reductions, it is necessary to consider the reduction targets or policies of both developed and developing countries. Rogelj et al., 2009[39] have calculated that the overall number of countries for which it was possible to deduce future emissions accounts for about two thirds of the world's population. This group accounts for 76 per cent of global GHG emissions in 2005. Rogelj et al., 2009[39], have compiled all these pledges to create a global emission path up to 2100. Wherever it was not possible to specify a country's position, emissions are assumed to follow a Business As Usual (BAU) scenario up to 2100 (SRESA1B, Nakicenovic and Swart, 2000[40]).

Assuming the best option whenever a range of reductions is specified ("current best scenario") and constant emissions after 2050 whenever a 2050 target was set, Rogelj et al. found that global emissions will increase by 42 per cent relative to 1990 in 2020. In 2050 total emissions are projected to be 80 per cent higher than 1990. Given this there is virtually no chance to limit global warming to 2°C. The exceedance probability reaches 100 per cent, based on the methodology of Meinshausen et al., 2009. Even the risk of exceeding 3°C global warming by 2100 is greater than 50 per cent. Atmospheric CO_2 concentrations are projected to exceed 550 ppm by the middle of the century. This is a level at which coral reefs are predicted to dissolve due to ocean acidification (Silverman et al., 2009)[41].

Conclusion

Thus, while the good news is that countries have 1.5 and 2°C in mind, their current aspirations are simply not sufficient to get there. Closing this gap, i.e. coming up with deep reduction targets, and sufficient financial support for additional reductions in developing countries, is the key challenge for UN Climate Convention negotiation. This challenge is only matched by the attempts of some parties to derail the international architecture under which the mutual trust of nations can flourish. An international agreement that is reduced to a collection of pledges, where each nation plays only according to its own rules and each nation verifies its own achievements, is unlikely to create an atmosphere in which we believe our neighbors are doing their fair share and in which we will bring global emissions to a halt any time soon. It will be rather like living in the Wild West. A hot Wild West.

Appendix

Methods

Our approach to calculating temperatures and GHG concentrations from emission trajectories (Meinshausen et al., 2009)[27] is based on a Bayesian Monte Carlo method that allows us to calculate the probability of exceeding a 2°C target for any given emission path. Probabilities are used to describe the current level of uncertainty associated with the projections. These uncertainties are due to the uncertainties of a large number of model parameters involved in calculating global warming for a given emission paths. The basic idea of the approach is simple: Instead of calculating the global mean warming for one specific emission path and for one set of model input parameters, these parameters are varied within the range currently considered as "possible" or plausible in comparison to observations. Assumptions about these ranges are based on the IPCC AR4 and more recent literature. One of the most important model parameters in projections of global warming is, for example, climate sensitivity. This is defined as the global mean temperature change that occurs in equilibrium under CO_2 doubling. For the results described here, its uncertainty range is determined by the probability distribution found by Frame et al., 2006[42]. This distribution closely resembles the AR4 estimate (best estimate, 3°C; likely range, 2.0–4.5°C). Thus, instead of one projection we finally get a large number of projections. These are compared with observations such as, for example, historical temperature time series, and weighted according to their agreement with these observational constraints. In this way some parameter configurations may be ruled out as they do not fit observations and the overall uncertainty of the projections can be reduced. Based on this weighted set of projections it is finally possible to determine one exceedance probability for the given emissions path. This can be deduced from the fraction of projections that exceed the 2°C warming limit.

Acknowledgement

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References

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