

Emission pathways towards 2°C

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14 September 2009

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1 Introduction

Many countries have established or advocated an agreement on a long-term goal for the maximum increase in global average temperature as compared to pre-industrial times to limit adverse impacts of climate change.

Many countries have supported that the global mean temperature increase (relative to pre-industrial level) should not exceed 2°C. To their judgement, this is the maximum to still allow adaptation to climate change for many human systems at globally acceptable economic, social and environmental costs. However, the ability of many natural ecosystems to adapt to rapid climate change is limited and may be already exceeded before a 2°C temperature increase is reached. However, a global mean temperature increase greater than 2°C will expectedly result in increasingly costly adaptation. Impacts are likely to exceed the adaptive capacity of many systems. It is judged to be an unacceptably high risk of large scale irreversible effects.

In July 2009, the Major Economies Forum, consisting of parties responsible for about 80% of current annual greenhouse gas emissions, agreed upon a declaration on the urgency of action on climate change:

“We recognize the scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2 degrees C. In this regard and in the context of the ultimate objective of the Convention and the Bali Action Plan, we will work between now and Copenhagen, with each other and under the Convention, to identify a global goal for substantially reducing global emissions by 2050. Progress toward the global goal would be regularly reviewed, noting the importance of frequent, comprehensive, and accurate inventories.”

How does the statement on 2°C link to the global goal for substantially reducing global emissions by 2050? In other words: what would a 2°C limit imply in terms of reducing global emissions of greenhouse gases? This paper presents the actual status of scientific research and models that translate the 2°C limit into global greenhouse gas emissions.

First, the essentials in the cause-and-effect chain of climate change are presented as a prelude to understand how global emissions developments link to an increase in global temperature. Next, the possible developments in emissions are distilled from the

temperature limit. Finally, the paper provides some general insight in the size of the efforts and the basic mechanisms to share the effort.

2 Links between emissions and temperature increase

Greenhouse gases are a driver of global average temperature. Several gases contribute to the increase of the earth's surface temperature, of which carbon dioxide (CO₂) is the most important. Essentially, the greenhouse gases keep the solar heat in the atmosphere. The larger their concentration in the atmosphere is, the higher the temperature. The balanced concentration of these gases in the atmosphere (measured in parts per million, ppm) is disturbed by anthropogenic emissions (measured in tonnes of carbon dioxide equivalent, tCO₂eq).

Emissions or emission reductions are reflected in temperature changes only with a delay. Most greenhouse gases stay in the atmosphere for many decades (order of magnitude 100 years) after their emission. This means that an emission or a reduction in emissions does not immediately result in a full temperature effect. The maximum temperature effect of an emission of CO₂ occurs with a delay of around 20 years.

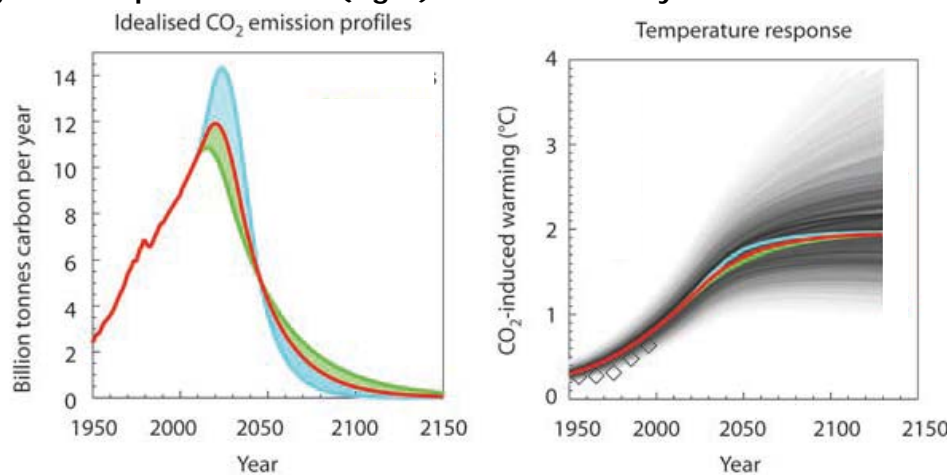
The total amount of greenhouse gases emitted is much more important for the full temperature effect than the timing of emissions. This effect is due to the long residence time of the greenhouse gases in the atmosphere. It means that it is the *cumulative emissions* that determine the level of global temperature increase. Hence, one particular global temperature effect can be achieved along different global emission pathways, as long as they accumulate to roughly the same total amount of emissions. Figure 1 (left) illustrates this: if the world allows emissions to reach a higher or a later peak, the subsequent emission reductions have to be steeper to achieve the same climate effect compared to a case where emissions peak earlier or lower. Very high emissions in early years could also be compensated by net removals of CO₂ from the atmosphere at the end of the century – provided that such technological options are available by then.

The right half of Figure 1 illustrates the temperature response induced by the emission pathways in the left half of Figure 1. All three emission pathways lead to a temperature increase of 2°C by the end of the century.

For a given pathway of global emissions, scientific models can only provide a probability of meeting a certain temperature limit. Scientific models include several uncertainties along the cause-and-effect chain from emissions to temperature increase. Although thoroughly tested, every model contains its own uncertainties. For instance, there are uncertainties in the model that describe how greenhouse gases are removed from the atmosphere, or how the climate system reacts to increased concentrations. Transposing global emission levels to a temperature effect will always

lead to probabilistic statements. These probabilistic statements are however quite robust. The shaded area in the right half of Figure 1 illustrates that the resulting temperature could be well above or well below the 2°C limit. These three pathways all have an overall 50% probability of meeting the 2°C limit.

Figure 1. Illustrative global emission pathways (left) that lead to the same longterm temperature limit (right) with uncertainty as shaded area



Source: Allen et al. 2009

3 Illustrative pathways towards 2°C

The total amount of allowed emissions to meet the 2°C limit is limited.

Reversing the cause-and-effect chain and back-tracking from the 2°C requirement, scientists have executed a large number of emission scenarios in the last couple of years. Scientific literature concludes that emissions could accumulate to roughly 2000 billion tonnes of CO₂ equivalents (GtCO₂eq) between the year 2000 to 2050, in order to have a 50% chance to meet the 2°C. A maximum of 1500 GtCO₂eq would increase the probability to stay below 2°C to 75%.

Urgent action is needed. Global emissions from 2000 to 2010 will account for roughly 500 GtCO₂eq, which is a quarter of the allowed emissions until 2050 for a 50% chance and a third of the allowed emissions for a 75% chance. Every year at current emissions (roughly 50 GtCO₂eq) consumes a significant share of the available amount until 2050.

Four generic options for global emission pathways consistent with the 2°C limit are available. Figure 2 presents four representative emission pathways

consistent with the 2°C limit. A common denominator is that they all require urgent deviation from the current reference development.

- The "immediate action" pathway assumes global emissions to peak as soon as 2011 and then decline at 6% per year. Such a scenario would ensure that the 2°C limit is met with a 75% chance.
- The "accelerated action" pathway allows for a later peak in global emissions (2013), but requires significantly faster action later in the century, a decline of 10% per year. It will also meet the 2°C limit with a 75% chance.
- If a steep decline is not achieved, the "steady decline" pathway follows a constant 3% decrease per year for many decades. The slower emission decline will decrease the probability of meeting the 2°C limit to 50%.
- If the peak is delayed until 2017, the "guardrail" pathway could occur. In this case reductions as large as 8% per year will have to occur to meet the 2°C limit with a 50% chance.

The parameters for the four illustrative pathways are provided in Table 1.

The annual reductions required to meet the pathways are ambitious. Achieving steep reduction rates would possibly require early retirement of capital invested in present technologies. It would also require fast market introduction of new technologies. Delaying the year when global emissions peak would lead to even more ambitious reduction rates. It would also narrow the options to adjust the pathway once new scientific information becomes available.

Figure 2. Generic global emission pathways with different likelihood of limiting global temperature increase to 2°C

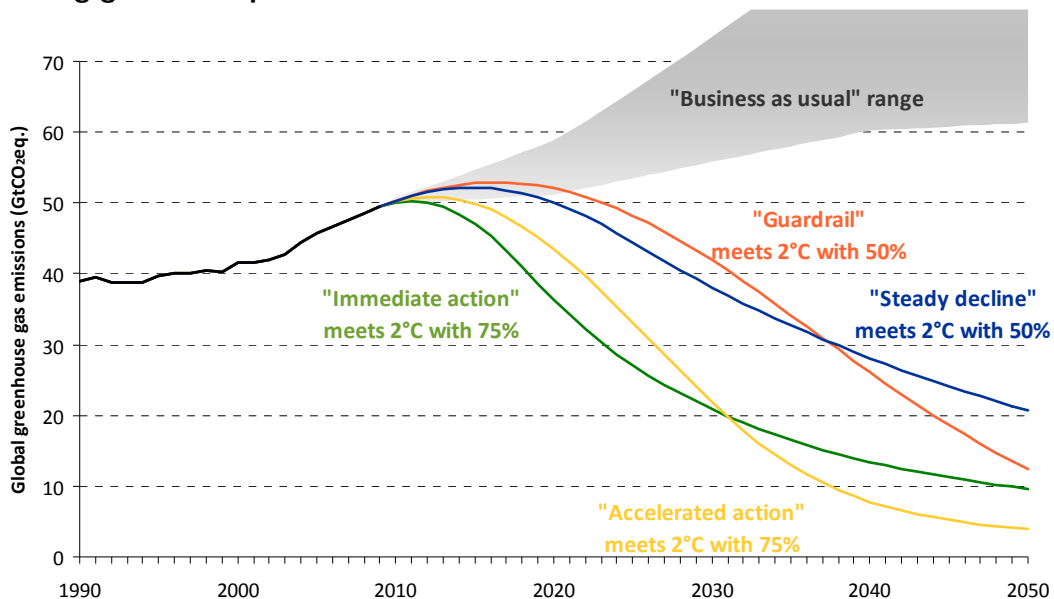


Table 1. Parameters of the generic global emission pathways of Figure 2.

	Probability of meeting 2°C	Year of peak	Maximum decline (% per year)	Global emission level (relative to 1990 level)			Cumulative emissions 2000 to 2050 (GtCO ₂ eq)
				2020	2030	2050	
Immediate action	75%	2011	6%	-7%	-46%	-75%	1500
Accelerated Action	75%	2013	10%	12%	-44%	-90%	1500
Steady decline	50%	2015	3%	29%	-2%	-47%	2000
Guardrail	50%	2017	8%	34%	8%	-68%	2000

Agreements about global emission reductions consistent with the 2°C limit could take various forms. With the 2°C limit as a prerequisite, a political agreement on pathways could have different shapes.

- Firstly, the total cumulative emissions allowed until 2050 could be agreed. A robust statement is that the cumulative anthropogenic greenhouse gas emissions from all sources between 2000 and 2050 need to be at least below 2000 GtCO₂eq.
- One step into more detail, the agreement could focus on the year when global emissions should peak. From the scientific analysis it is robust that this year has to be well before 2020.
- One step beyond that, global emission levels in 2020, 2030 and/or 2050 can be agreed. The global emission levels in 2020, 2030 and 2050 may vary between the emission pathways. It is however robust that the global greenhouse gas emissions from all sources will at least have to be halved by 2050 compared to 1990, probably reduced even further.

Note: Besides the greenhouse gases originating from combustion and industry, also greenhouse gas emissions from forests (CO₂) and agriculture (non-CO₂) exist. These emissions are substantial but uncertain. They are covered in the analysis above.

4 Sharing the reduction effort

The location of the emission reduction can be independent of the source of its financing. Because most greenhouse gases stay in the atmosphere for a long time, they can travel all over the world. A reduction anywhere on the globe helps to stop the increase in the atmospheric concentration of greenhouse gases. The challenge of meeting the 2°C limit is so large, that emissions need to be reduced wherever possible, hence in all countries. A separate question is: who will contribute to the costs of emission reductions? Sharing the costs could be based on the basis of the principle of common but differentiated responsibilities.

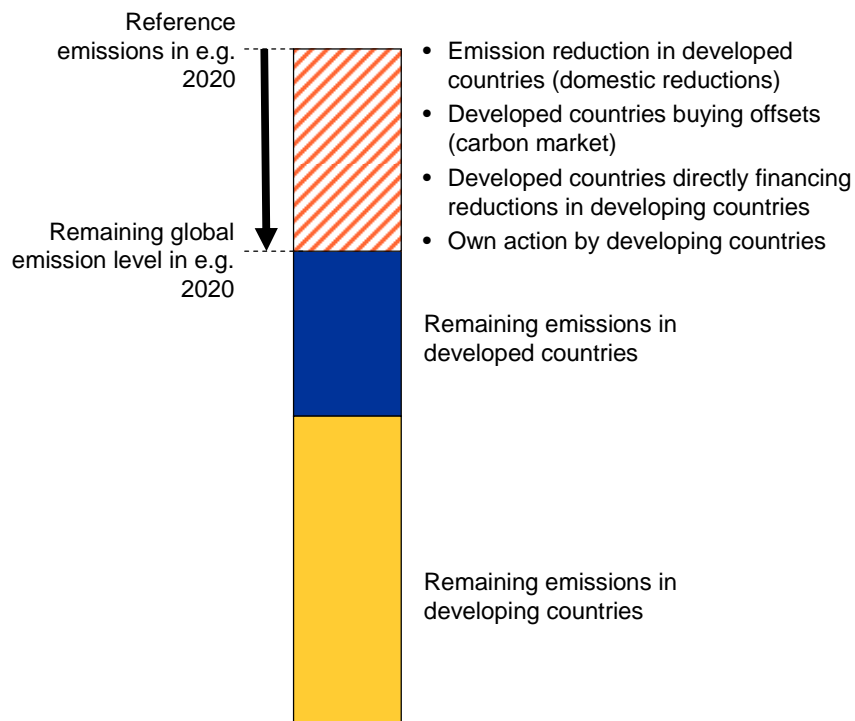
Limiting temperature increases to 2°C is only possible if emissions in developed and in developing countries are mitigated. Scientific models show us

that developed countries need to reduce their emissions substantially, already by 2020. There is still some room for developing countries to increase their emissions, but they also would have to deviate substantially from reference emissions in 2020, peak soon thereafter and decline from then on, even if developed countries' emissions would decrease to a very low level.

Four basic ways of mitigating greenhouse gas emissions and financing the reductions could fit in an international agreement, see also Figure 3:

- Developed countries reduce their own emissions domestically.
- Developed countries finance emissions reductions in developing countries through buying emission offsets. Emission reductions in developing countries can be counted towards the target of the financing developed country. Such use of the “carbon markets” would contribute to financing emission reductions in developing countries and would reduce the global costs of mitigation.
- Developed countries directly finance emissions reductions in developing countries. Developed countries support capacity building or the implementation of specific policies or provide loans or grants for investments in developing countries.
- Developing countries reduce their emissions by own actions.

Figure 3. examples on how emission reductions can be achieved



Appendix A Technical notes

Assumptions

The calculations for Figure 2 include all greenhouse gases covered under the Kyoto Protocol and include international transportation and land-use change and forestry. Historical emission estimates are summed from various sources, including the UNFCCC, IEA, CDIAC and US EPA. We assumed constant growth in emissions from 2007 to 2009. A lower assumption of the growth in that period (e.g. because of the economic recession) would change the resulting pathways slightly. The generic emissions paths start to differentiate as of 2010.

To simulate a time lag between action and emissions, we assumed that the trend of the pathways cannot change more than 0.8 percentage points per year. Pathways are set to result in cumulative emissions of 1500 GtCO₂eq from 2000 to 2050 for 75% chance of meeting 2°C and 2000 GtCO₂eq for a 50% chance based on Meinshausen et al. 2009. The business as usual range is adapted from the IPCC Special Report on Emission Scenarios (IPCC 2000).

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