WBGU
Wissenschaftlicher Beirat Globale Umweltveränderungen
German Advisory Council on Global Change

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Climate change: Why 2°C?

The effects of climate change are already noticeable in every part of the world, and they will increase further. These changes entail serious risks for our societies. Humankind now has only a small time window in which to meet the challenge of climate change and take steps to limit the global rise in temperature to a maximum of 2°C.

WBGU's messages in brief

- It is scientifically proven that rising levels of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere cause global warming.
- The consequences include rising sea levels, an increase in extreme weather events, accelerated loss of species and ecosystems, and acidification of the oceans. Tipping events in the climate system, such as the abrupt cessation of ocean currents, may have catastrophic and irreversible ecological results.
- Climate change can jeopardize the water supply and food production; it poses health risks, may accelerate migration and can lead to security problems. It thus has the potential to trigger major social and economic crises.
- Global warming of more than 2°C would pose unprecedented challenges for our civilization and therefore represents 'dangerous interference with the climate system'. To prevent this, cumulative CO_2 emissions to 2050 need to be capped at 750 Gt.

The global CO_2 budget

Limiting the mean global temperature rise to 2°C requires a radical reduction of greenhouse gas emissions. Model results show that there is a two-thirds probability that warming can be kept within the 2°C guard rail if aggregate CO_2 emissions from fossil fuels until 2050 do not exceed 750 Gt. WBGU proposes that such a cap on the quantity of CO_2 from fossil sources to be emitted until 2050 should be agreed as an internationally binding limit. CO_2 emissions from land use, such as those arising from progressive deforestation, must also be reduced, as must emissions of other greenhouse gases. Post-2050 emissions will need to be reduced further until they reach zero.

How strong is human influence on the climate?

Because of the amount of greenhouse gases that humans have already emitted, the present composition of the atmosphere would in the long term lead to global warming of 1.3°C. On account of the inertia of the climate system, warming of only around 0.8°C is observable so far.

It is scientifically proven that a rise of CO_2 and other greenhouse gases in the atmosphere leads to global warming. Since the late 1950s it has been confirmed that the atmospheric concentration of CO_2 is increasing as a result of emissions caused by humans (anthropogenic emissions). Since the pre-industrial era it has risen from 280 ppm (a ratio of 280 parts of the atmosphere per million) to 384 ppm. This is by far the highest concentration for at least two million years.

Natural causes may also exert additional influence on the climate. For example, over the past 25 years a slight decrease in the brightness of the sun, identified by satellite readings, has had a cooling effect. However, natural causes over this period have only a very minor impact compared with the effect of anthropogenic greenhouse gas emissions. Around 85% of warming since 1900 and almost 100% of warming since 1980 has been caused by human activity.

What is the connection between emissions and rising temperatures?

Human-induced greenhouse gas emissions have already significantly altered our planet's radiative balance. At present, the warming effect of greenhouse gases is still partly compensated by the cooling effect of regional air pollution.

The factor that determines mean global temperature is the balance between the sun's insolation and radiation emitted by Earth; a change in this balance is known as radiative forcing. This is analogous to the temperature in a house, which is determined by the output of the heating system and the heat losses that escape the house.

So far human activities have increased Earth's radiative forcing by 1.6 Watts per m². The rise in concentration of CO_2 accounts for +1.7 W per m² of this, other greenhouse gases contribute a further +1.3 W per m². Particulate air pollution produces a cooling effect of -1.4 W per m². As well as cooling aerosol particles such as sulphates, the atmosphere also contains warming soot particles; nevertheless, all particles on aggregate produce a net cooling. This effect thus currently compensates for almost half of the 'programmed' global warming caused by greenhouse gases. While the greenhouse gases are very long-lived, the cooling substances are relatively short-lived. A reduction in air pollution, while in itself desirable, would therefore rapidly exacerbate the problem of global warming, so that greenhouse gas emissions will then have to be reduced even more drastically.

Climate sensitivity is a measure of the temperature changes that result from radiative forcing. The best estimate of climate sensitivity amounts to 0.8°C per W per m². This equates to warming of 3°C with a doubling of the atmospheric CO_2 concentration.

In the long term, radiative forcing at the current level of 1.6 W per m² will thus produce 1.3°C of warming. So far warming of only 0.8°C has been observable, because the thermal inertia of the oceans delays the full effect by several decades.

How quickly will temperatures rise?

Further warming will mainly be determined by future anthropogenic emissions. These depend in part on population trends and economic growth, but can be reduced by mitigation measures.

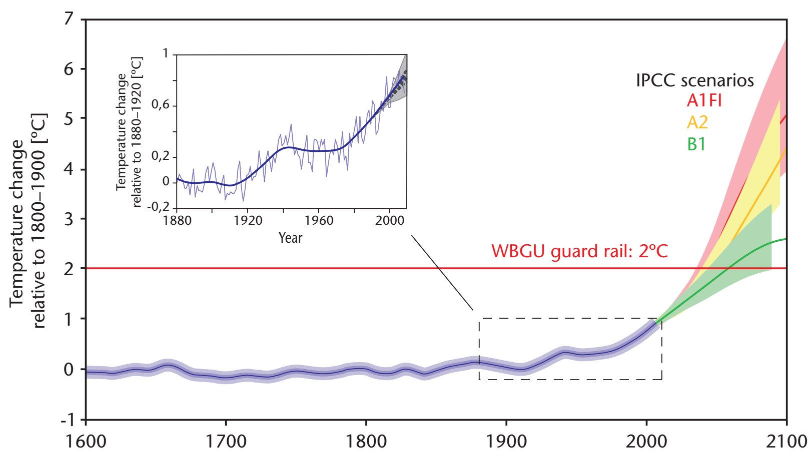

Figure 1
Three different emission scenarios are shown (B1, A2 and A1FI); the coloured areas are the associated climatological uncertainty ranges. Without successful climate change mitigation, the 2°C guard rail will be exceeded even under the most optimistic emission scenario (B1). Inset: Comparison of observed temperatures with projections of 2001.
Source: WBGU, modified after Rahmstorf et al., 2007

Making plausible assumptions for future emissions, climate researchers can estimate the range within which the global rise in temperature will occur. Their findings show that with high greenhouse gas emissions, the mean global temperature may rise 3–7°C above the pre-industrial level by 2100 (Fig. 1). Scenarios based on lower emissions still result in a temperature rise of 2–3°C. Only an ambitious and effective policy of climate change mitigation can keep global warming below 2°C. The temperature rise over continents and particularly in the polar regions is above the global average.

Human culture has evolved during recent millennia in a relatively stable world climate. The global temperature has fluctuated by significantly less than 1°C in the past 2000 years. Our infrastructure is not prepared for a swift and pronounced change in climate.

What is the effect of climate change on nature?

Even with the moderate warming of 0.8°C that has so far been measured, the effects of climate change are already noticeable in every part of the world. Unchecked climate change outside the 2°C guard rail entails great risk. The negative consequences would pose unprecedented challenges for humankind.

Global warming has the following tangible consequences:

- The **sea level rises** due to the thermal expansion of sea water and the influx of meltwater into the oceans; the warmer it becomes, the faster the sea level rises. Since 1880, the global sea level has risen by around 20 cm. It could, however, rise by 50–150 cm by 2100 and by several metres by 2300. Destabilization of the ice sheets in Greenland and the Antarctic would result in an irreversible rise in sea level over many centuries.
- An increase in **extreme weather events**, such as heatwaves, droughts, extreme rainfall events, floods and tropical storms, has already been observed in many regions. A further rise of these extreme weather events is to be expected.
- Progressive global warming in excess of 2°C threatens to accelerate the **loss of genetic, species and ecosystem diversity**, since many regions of the world will enter climatic conditions not experienced for several million years. This would place an intolerable strain on nature's adaptive and regenerative capacity.
- Anthropogenic CO_2 emissions are already causing measurable **acidification of the oceans**. This disrupts the growth of important calcifying marine organisms such as corals.
- A number of **tipping elements** have been identified within the climate system. Triggering these tipping elements may lead to catastrophic ecological consequences. Among the most significant risks are the abrupt cessation of ocean currents, dieback of the Amazon rainforest, changes in the monsoon system and destabilization of large ice masses.

What is the effect of climate change on societies?

Climate change has the potential to trigger major social and economic crises. Poor populations are especially at risk, but wealthy nations are not immune. Temperature rises above 2°C will be particularly difficult to cope with.

If climate change continues unabated, the following impacts must be anticipated:

- The **water supply** in many places will be jeopardized by weather extremes, altered precipitation patterns and glacial retreat.
- **Food production** is expected to decline worldwide if warming of 2–4°C occurs, not least because of the increase in droughts and soil degradation. This has the potential to trigger regional food crises and undermine the economic productivity of affected states.
- Warming of more than 2°C increases the risk of triggering an irreversible sea-level rise of several metres within the next few centuries. **Islands, densely populated coastal regions and megacities** such as London, Mumbai and New York, together with their infrastructure and cultural assets, would be at direct risk.
- Warming intensifies **health risks** through the possible spread of infectious diseases and circulatory disorders (heatwaves) and the dangers posed by extreme weather events.
- The **economic potential** of many countries – especially in the agriculture, forestry and fisheries sector – is adversely affected by climate change, both directly and indirectly. Likewise, global warming accelerates the loss of biodiversity and corresponding ecosystem services, which will give rise to substantial economic costs worldwide.
- Climate change thus endangers the natural life-support systems on which many people in almost all parts of the world depend. The consequences of unabated climate change would overstretch many countries' adaptive capacity, contribute to political and economic destabilization and trigger additional **environmental migration**. Increasingly, therefore, climate change is becoming a **security risk**.

What is to be done?

To limit the mean temperature rise to 2°C with a probability of two-thirds, CO_2 emissions from now until the middle of the century must not exceed 750 Gt. At current emissions rates this CO_2 budget will be exhausted within around 25 years – and even sooner if emissions continue to rise.

Global emissions must start to decline as soon as possible – any delay will result in almost unachievable reduction requirements. With an immediate reversal of the trend, global emissions would need to fall to 50–80% below the 1990 level by 2050, with further reductions towards zero emissions thereafter.

Even a slight delay in the reversal of the trend, i.e. postponement of the peak year to 2015, would trigger annual global emissions reduction requirements of up to 5% (from a 2008 baseline) (Fig. 2). The world would then have to achieve in every single year the same emission reductions for which the Kyoto protocol has allowed the industrialized countries full two decades.

Delaying the peak year even further to 2020 could necessitate global emissions reduction rates on an almost unachievable scale of up to 9% per year. There is thus no option but to halt the observed global rise in CO_2 emissions as quickly as possible and switch to emissions reductions on a global scale. Any further delay will drive up the costs of climate change mitigation and result in the 2°C guard rail being exceeded.

In 2006 the Stern Review showed that investment in climate change mitigation now leads to far lower global economic costs and welfare losses than a business-as-usual strategy with unabated climate change. In economic terms it is therefore better to invest in mitigation today rather than in adaptation to dangerous levels of climate change tomorrow.

The analysis reveals the challenge posed by the given scenario – i.e. an extremely pressing problem with rapidly closing windows of opportunity – to international policy-making, in which decisions are usually adopted on the basis of time-consuming consensus. However, unless the international community can swiftly agree the required short- and medium-term emissions reductions and implement them accordingly, it will be left with hardly any climate policy leeway.

In its special report published in 2009, WBGU put forward a proposal for meeting this challenge at the global level: the budget approach defines a global CO_2 emissions budget for the period until 2050 that is subdivided into national emissions budgets. The report also outlines additional institutions and instruments that would play a part in implementation of the scheme, enabling effective climate change mitigation and sustainable development to go hand in hand.

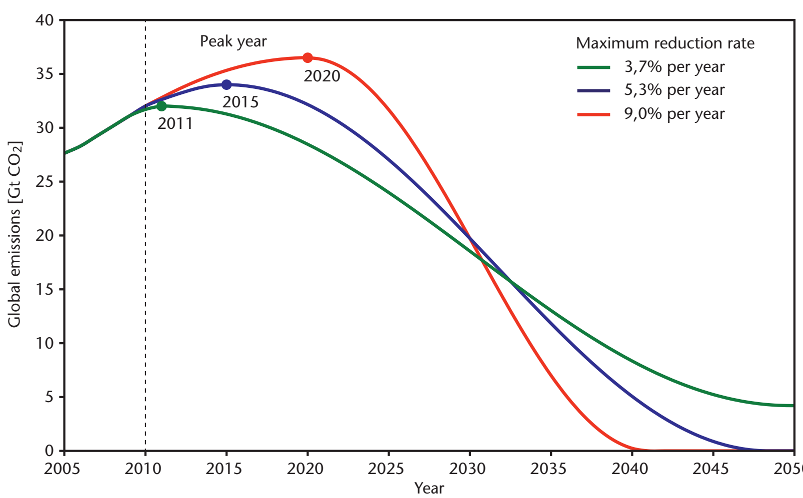

Figure 2
Examples of fictitious global emission pathways for the period 2010–2050 with global CO_2 emissions capped at 750 Gt during this period. At this level, there is a 67% probability of achieving compliance with the 2°C guard rail. The figure shows variants of a global emissions trend with different peak years: 2011 (green), 2015 (blue) and 2020 (red). In order to achieve compliance with these curves, annual reduction rates of 3.7% (green), 5.3% (blue) or 9.0% (red) would be required in the early 2030s (relative to 2008).
Source: WBGU

WBGU
The German Advisory Council on Global Change (WBGU) was established by the German federal government as an independent, scientific advisory body in 1992 in the run-up to the Rio Earth Summit. WBGU is an interdisciplinary body which provides in-depth scientific analyses and derives recommendations for policy action and research.

WBGU's 2009 Special Report, entitled 'Solving the climate dilemma: The budget approach', is available for download at www.wbgu.de.

WBGU Secretariat
Reichpietschufer 60–62
10785 Berlin, Germany
Phone and Fax:
+49 30 263948 0
+49 30 263948 50
Email: wbgu@wbgu.de
Internet: www.wbgu.de

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