

## Frequently Asked Questions

**FAQ 12.3 | What Would Happen to Future Climate if We Stopped Emissions Today?**

*Stopping emissions today is a scenario that is not plausible, but it is one of several idealized cases that provide insight into the response of the climate system and carbon cycle. As a result of the multiple time scales in the climate system, the relation between change in emissions and climate response is quite complex, with some changes still occurring long after emissions ceased. Models and process understanding show that as a result of the large ocean inertia and the long lifetime of many greenhouse gases, primarily carbon dioxide, much of the warming would persist for centuries after greenhouse gas emissions have stopped.*

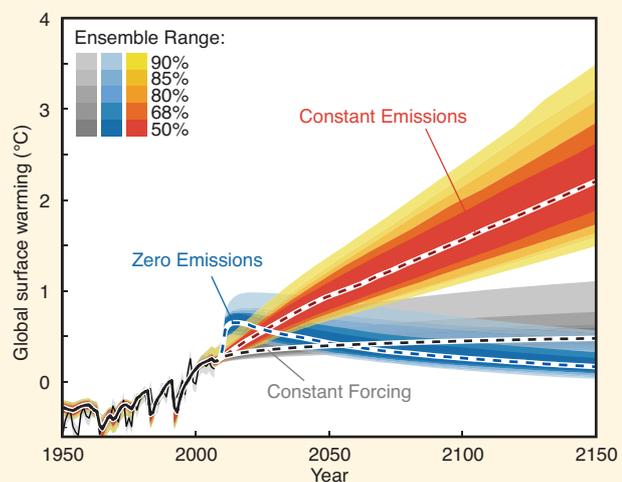
When emitted in the atmosphere, greenhouse gases get removed through chemical reactions with other reactive components or, in the case of carbon dioxide (CO<sub>2</sub>), get exchanged with the ocean and the land. These processes characterize the lifetime of the gas in the atmosphere, defined as the time it takes for a concentration pulse to decrease by a factor of  $e$  (2.71). How long greenhouse gases and aerosols persist in the atmosphere varies over a wide range, from days to thousands of years. For example, aerosols have a lifetime of weeks, methane (CH<sub>4</sub>) of about 10 years, nitrous oxide (N<sub>2</sub>O) of about 100 years and hexafluoroethane (C<sub>2</sub>F<sub>6</sub>) of about 10,000 years. CO<sub>2</sub> is more complicated as it is removed from the atmosphere through multiple physical and biogeochemical processes in the ocean and the land; all operating at different time scales. For an emission pulse of about 1000 PgC, about half is removed within a few decades, but the remaining fraction stays in the atmosphere for much longer. About 15 to 40% of the CO<sub>2</sub> pulse is still in the atmosphere after 1000 years.

As a result of the significant lifetimes of major anthropogenic greenhouse gases, the increased atmospheric concentration due to past emissions will persist long after emissions are ceased. Concentration of greenhouse gases would not return immediately to their pre-industrial levels if emissions were halted. Methane concentration would return to values close to pre-industrial level in about 50 years, N<sub>2</sub>O concentrations would need several centuries, while CO<sub>2</sub> would essentially never come back to its pre-industrial level on time scales relevant for our society. Changes in emissions of short-lived species like aerosols on the other hand would result in nearly instantaneous changes in their concentrations.

The climate system response to the greenhouse gases and aerosols forcing is characterized by an inertia, driven mainly by the ocean. The ocean has a very large capacity of absorbing heat and a slow mixing between the surface and the deep ocean. This means that it will take several centuries for the whole ocean to warm up and to reach equilibrium with the altered radiative forcing. The surface ocean (and hence the continents) will continue to warm until it reaches a surface temperature in equilibrium with this new radiative forcing. The AR4 showed that if concentration of greenhouse gases were held constant at present day level, the Earth surface would still continue to warm by about 0.6°C over the 21st century relative to the year 2000. This is the climate commitment to current concentrations (or constant composition commitment), shown in grey in FAQ 12.3, Figure 1. Constant emissions at current levels would further increase the atmospheric concentration and result in much more warming than observed so far (FAQ 12.3, Figure 1, red lines).

Even if anthropogenic greenhouse gas emissions were halted now, the radiative forcing due to these long-lived greenhouse gases concentrations would only slowly decrease in the future, at a rate determined by the lifetime of the gas (see above). Moreover, the

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**FAQ 12.3, Figure 1 |** Projections based on the energy balance carbon cycle model Model for the Assessment of Greenhouse Gas-Induced Climate Change (MAGICC) for constant atmospheric composition (constant forcing, grey), constant emissions (red) and zero future emissions (blue) starting in 2010, with estimates of uncertainty. Figure adapted from Hare and Meinshausen (2006) based on the calibration of a simple carbon cycle climate model to all Coupled Model Intercomparison Project Phase 3 (CMIP3) and Coupled Climate Carbon Cycle Model Intercomparison Project (C4MIP) models (Meinshausen et al., 2011a; Meinshausen et al., 2011b). Results are based on a full transient simulation starting from pre-industrial and using all radiative forcing components. The thin black line and shading denote the observed warming and uncertainty.

## FAQ 12.3 (continued)

climate response of the Earth System to that radiative forcing would be even slower. Global temperature would not respond quickly to the greenhouse gas concentration changes. Eliminating CO<sub>2</sub> emissions only would lead to near constant temperature for many centuries. Eliminating short-lived negative forcings from sulphate aerosols at the same time (e.g., by air pollution reduction measures) would cause a temporary warming of a few tenths of a degree, as shown in blue in FAQ 12.3, Figure 1. Setting all emissions to zero would therefore, after a short warming, lead to a near stabilization of the climate for multiple centuries. This is called the commitment from past emissions (or zero future emission commitment). The concentration of GHG would decrease and hence the radiative forcing as well, but the inertia of the climate system would delay the temperature response.

As a consequence of the large inertia in the climate and carbon cycle, the long-term global temperature is largely controlled by total CO<sub>2</sub> emissions that have accumulated over time, irrespective of the time when they were emitted. Limiting global warming below a given level (e.g., 2°C above pre-industrial) therefore implies a given budget of CO<sub>2</sub>, that is, higher emissions earlier implies stronger reductions later. A higher climate target allows for a higher CO<sub>2</sub> concentration peak, and hence larger cumulative CO<sub>2</sub> emissions (e.g., permitting a delay in the necessary emission reduction).

Global temperature is a useful aggregate number to describe the magnitude of climate change, but not all changes will scale linearly global temperature. Changes in the water cycle for example also depend on the type of forcing (e.g., greenhouse gases, aerosols, land use change), slower components of the Earth system such as sea level rise and ice sheet would take much longer to respond, and there may be critical thresholds or abrupt or irreversible changes in the climate system.

et al., 2008; Rohling et al., 2009; Lunt et al., 2010; Pagani et al., 2010; Schmittner et al., 2011; Rohling and Members, 2012), most but not all based on climate states colder than present, are therefore not necessarily representative for an estimate of climate sensitivity today (see also Sections 5.3.1, 5.3.3.2, Box 5.1). Also it is uncertain on which time scale some of those Earth system feedbacks would become significant.

Equilibrium climate sensitivity undoubtedly remains a key quantity, useful to relate a change in GHGs or other forcings to a global temperature change. But the above caveats imply that estimates based on past climate states very different from today, estimates based on time scales different than those relevant for climate stabilization (e.g., estimates based on climate response to volcanic eruptions), or based on forcings other than GHGs (e.g., spatially non-uniform land cover changes, volcanic eruptions or solar forcing) may differ from the climate sensitivity measuring the climate feedbacks of the Earth system today, and this measure, in turn, may be slightly different from the sensitivity of the Earth in a much warmer state on time scales of millennia. The TCR and the transient climate response to cumulative carbon emissions (TCRE) are often more directly relevant to evaluate short term changes and emission reductions needed for stabilization (see Section 12.5.4).

### 12.5.4 Climate Stabilization and Long-term Climate Targets

This section discusses the relation between emissions and climate targets, in the context of the uncertainties characterizing both the transient and the equilibrium climate responses to emissions. 'Climate targets' considered here are both stabilizing temperature at a specified value and avoiding a warming beyond a predefined threshold.

The latter idea of limiting peak warming is a more general concept than stabilization of temperature or atmospheric CO<sub>2</sub>, and one that is more realistic than an exact climate stabilization which would require perpetual non-zero positive emissions to counteract the otherwise unavoidable long-term slow decrease in global temperature (Matsuno et al., 2012a) (Figure 12.44).

#### 12.5.4.1 Background

The concept of stabilization is strongly linked to the ultimate objective of the UNFCCC, which is 'to achieve [...] stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. Recent policy discussions focussed on a global temperature increase, rather than on GHG concentrations. The most prominent target currently discussed is the 2°C temperature target, that is, to limit global temperature increase relative to pre-industrial times to below 2°C. The 2°C target has been used first by the European Union as a policy target in 1996 but can be traced further back (Jaeger and Jaeger, 2010; Randalls, 2010). Climate impacts however are geographically diverse (Joshi et al., 2011) and sector specific, and no objective threshold defines when dangerous interference is reached. Some changes may be delayed or irreversible, and some impacts are likely to be beneficial. It is thus not possible to define a single critical threshold without value judgments and without assumptions on how to aggregate current and future costs and benefits. Targets other than 2°C have been proposed (e.g., 1.5°C global warming relative to pre-industrial), or targets based on CO<sub>2</sub> concentration levels, for example, 350 ppm (Hansen et al., 2008). The rate of change may also be important (e.g., for adaptation). This section does not advocate or defend any threshold, nor does it judge