

Impacts of climate change – What impacts does climate change have?

Climate change brought about by the anthropogenic greenhouse effect impacts people as well as plants, animals, and ecosystems.

The climate is a complex system involving the interaction of many factors. It is influenced by natural factors that have nothing to do with the anthropogenic greenhouse effect. These factors partially amplify the impacts, for example, large volcanic eruptions and solar activity. Moreover, individual weather events cannot be directly attributed to current climate change. However, it can be statistically demonstrated that global warming increases the likelihood of extreme weather events. The IPCC Sixth Assessment Report of 2021 states that “widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have occurred.” Extreme weather events such as severe storms, heavy rainfall events, floods, heat waves, and droughts occur more often as a result. Since the beginning of the 20th century, global average sea levels have risen by more than 15 cm. Estimates for further rises range between 25 cm and over 1 m by 2100.

Side note: What is the IPCC?

The Intergovernmental Panel on Climate Change (IPCC) is an international institution that regularly compiles and evaluates information on the current state of climate research. The IPCC regularly issues assessment reports with the results of these evaluations. However, the reports also contain summaries for policymakers. The IPCC reports are becoming more urgent, and in 2018 the IPCC published a special report on limiting global warming to 1.5°C. This report describes the global impacts of climate change. The impacts of global warming by +2°C compared to the pre-industrial level – a former climate goal of the community of states – are compared with the impacts of global warming by +1.5°C; the +1.5°C goal was previously set in the Paris Agreement.

The IPCC special report now provides the scientific basis for reasons why global warming should be limited to maximum +1.5°C.

The IPCC can demonstrate developments and future scenarios based on solid scientific research. It is not possible to predict with certainty how the climate will develop. The specific way in which the impacts of climate change continue to develop depends greatly on governmental decisions and human behavior. Measures must be taken both to limit CO₂ emissions and to adapt to the consequences of climate change.

Impacts of climate change and possibilities for adaptation

Direct and indirect impacts of climate change are being recognized increasingly frequently. The average surface temperature has risen all over the world, but some regions are warming up more than others. Warming is greatest in the Arctic, and it is greater on land than in oceans. Certain regions are affected worse by the impacts of climate change than others. The severity also depends on exposure, sensitivity, and the ability of regions and communities to adapt. Measures to adapt must therefore be implemented locally and regionally, and the local population must be involved and made aware.

Basically, the impacts at +2°C are stronger than at +1.5°C, which also means that a greater number of measures to adapt will be necessary at +2°C.

Impacts of climate change are named, and some are briefly explained below.

Direct impacts of climate change

Rising temperatures

- Rising high temperatures
- Rising low temperatures

Melting ice

- Retreat of Arctic sea ice and snow cover; as a result, not as much solar radiation is reflected back into space, land and oceans are exposed, and they also no longer reflect as much solar radiation. All this in turn leads to greater warming.
- Glacier loss and glacier retreat with the same effects as mentioned above
- Thawing permafrost, which leads to release of the greenhouse gases CO₂ and methane contained in the permafrost

Impacts on oceans

- Higher ocean temperatures and consequently lower oxygen levels in the water, since warmer water cannot bind as much oxygen. Until now, CO₂ emissions are stored primarily by algae in the oceans. The algae absorb CO₂, grow, and take the captured CO₂ with them into deep waters when they die. When the oxygen content of oceans drops, fewer algae grow, and thus less CO₂ is stored.
- Ocean acidification due to increased HCO₃ concentrations (bicarbonate) in water as a result of increased CO₂ concentrations, since CO₂ dissolves in water. Calcifying organisms such as corals, mussels, and starfish are especially jeopardized as a consequence. Coral bleaching is one impact of ocean acidification. When corals die, the habitat for many living organisms in the coral reefs is lost.
- Rising sea levels because glaciers and continental ice sheets melt and warming oceans expand

Extreme weather events

- Increase in heavy precipitation (heavy rain and hail)
- Increase in the proportion of intense tropical cyclones
- Increase in aridity and drought
- Increase in heat waves

Indirect impacts

The direct impacts listed also have indirect impacts on ecosystems, animal and human habitats, and society.

Ecosystems

- Loss of biodiversity due to flora and fauna's limited ability and speed to adapt
- Change in the structure of ecosystems
- Further spread of pests and pathogens

Effects on society

- Increase in hunger and water crises, especially in developing countries
- Existential threats due to floods and forest fires
- Health risks due to the increase in the frequency and intensity of heat waves
- Economic consequences for remedying the damages due to climate change

- Necessity to adapt in all sectors (for example, agriculture, forestry, energy industry, infrastructure, tourism, etc.)

Adaptation

To be able to limit the impacts of climate change, people must adapt to the constantly changing conditions. Adaptation to these impacts requires that people plan and implement concrete measures. The first step of this process is to identify possible risks and the susceptibility to damage, thus examination of the question “Which natural and social sectors are affected and jeopardized by climate change, and to what extent?” Concrete measures can be derived based on the answers while considering regional and local requirements such as the risk and the susceptibility to damage and also resilience. The knowledge of the local population can play a key role here. Naturally, the actual ability of the individual sectors to adapt (see below) must also be taken into consideration. By identifying risks and the susceptibility to damage, nations, regions, cities, and communities as well as the private sector and individuals will be empowered to deal with the impacts of climate change and to build up resilience.

Possibilities for structural and physical adaptation

These possibilities include primarily measures of a technological and engineering nature that concern ecosystems.

- Coastal protection: Dikes must be expanded. Coastal protection is being enhanced, and coasts are being protected against erosion, for example, along the German border with the North Sea. Land reclamation measures are also possible, such as enlarging islands in the Maldives using coral sand. Enhanced flood protection is an important topic, as are improved flood warning systems and construction bans in flood-prone areas. Another possibility of coping with floods and rising sea levels is using other construction methods, for example, stilt houses or floating houses.
- Agriculture: Farmers are adjusting and cultivating plants that tolerate heat and aridity better. In some places, however, the warmer climate also allows multiple harvests each year where previously fields could be harvested only once.
- Forestry: More heat-resistant tree varieties are being planted in forests and attempts are being made to replace coniferous forests with mixed forests. This will also make forests more resilient to forest fires.
- Securing the water supply: For example, water can be stored in reservoirs as a precaution.

Possibilities for social adaptation

These possibilities include educational, informational, and behavioral measures.

- Increasing awareness, for example, by implementing climate change education in the education system
- Preserving local and traditional knowledge
- Implementing early warning systems for extreme weather events such as storm surges and hurricanes
- Preparing for climate-induced disasters, for example, through evacuation plans

Possibilities for institutional adaptation

These possibilities include economic measures, laws, and regulations as well as political programs.

- Insurance and relief funds to be covered and able to respond in case of disaster

- Building regulations, for example, banning building in vulnerable areas
- Drafting of national and regional adaptation strategies
- Climate-resilient city planning and development

Tipping points

Scientists are warning that very severe or abrupt climate changes may occur if so-called tipping points are reached. Then irreversible processes will be set in motion that cannot be undone even if global warming were stopped. Climate scientists say that climate changes will then be long-term and severe. If the climate changes begin abruptly, it may be that adaptation measures cannot be taken in time. Therefore, everything should be done so that such tipping points are not reached at all or are reached as late as possible.

Research currently hypothesizes four tipping elements:

1. **Less sea ice at the poles and in Greenland**

When ice melt has reached a critical point, it can no longer be halted, even if global warming were to be stopped in the future. If the Greenland ice melts and the tipping point is reached in the Antarctic, sea levels could rise globally by more than 15 m by 2300.

2. **Logging, slash-and-burn clearing, and fires in primeval forests**

CO₂ is stored in every tree and is released into the atmosphere when the tree is burned. The global climate is impacted when the large primeval forests, especially the Amazon rainforest, emit more CO₂ than they absorb. Furthermore, trees transpire water via their leaves and influence the climate in this way. Less transpiration with fewer trees means less moisture in the air and thus less rain. Many trees cannot cope with drier soil and die off, which can lead to steppization.

3. **Ocean carbon uptake**

The greenhouse effect intensifies when large volumes of CO₂ emissions can no longer be taken up and bound in the ocean but remain in the atmosphere.

4. **Slowing of the Gulf Stream**

One study¹ found that the velocity of the Gulf Stream has already decreased by up to 15 percent. This decrease could be due to increased fresh water flux resulting from melt water and rainfall. Scientists are certain that the Gulf Stream will grow even weaker. However, they cannot yet predict how much weaker it will become or whether it will even collapse. A collapse of the Gulf stream would have grave impacts on the climate in northern and western Europe because the Gulf stream helps keep temperatures mild. Already today, a significant cooling of water in the North Atlantic can be observed.

Whether and when tipping points will be reached cannot be known with certainty. However, the unanimous view is that global warming must be limited to +1.5°C compared to the pre-industrial level because otherwise the probability is great that a tipping point will be reached before the end of this century.

¹ <https://www.nature.com/articles/s41586-018-0006-5>

Caesar L, Rahmstorf S, Robinson A, Feulner G, Saba V (2018): Observed fingerprint of a weakening Atlantic Ocean overturning circulation. Nature 556:191-196.