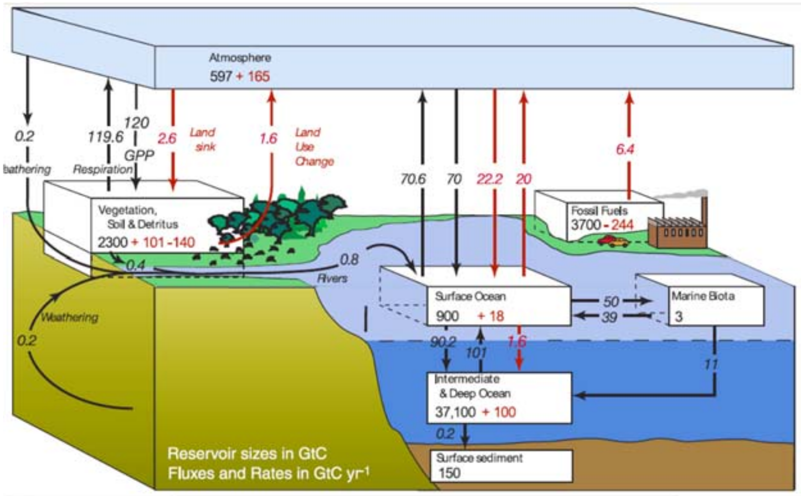
Carbon dioxide CO_2 as an essential gas for life on earth CO_2 from the earth's interior is released by active but also inactive volcanoes and in turn absorbed by the soil, water and rocks as well as plants. Living organisms (bacteria, animals and humans) breathe in oxygen and breathe out CO_2 again. Plants and algae (phytoplankton), the cornerstone of the food chain, take in CO_2 and exhale O_2. This process is called photosynthesis. CO_2 is therefore an essential gas for life on earth.

The composition of air: 78% nitrogen, 21% oxygen, 0.93% noble gases, 0.04% CO_2

The global carbon cycle

The figure depicts the global carbon cycle. The average annual fluxes are given in gigatons of carbon per year ((GtC)/a). (data basis from 1750-1994; modified after [1])

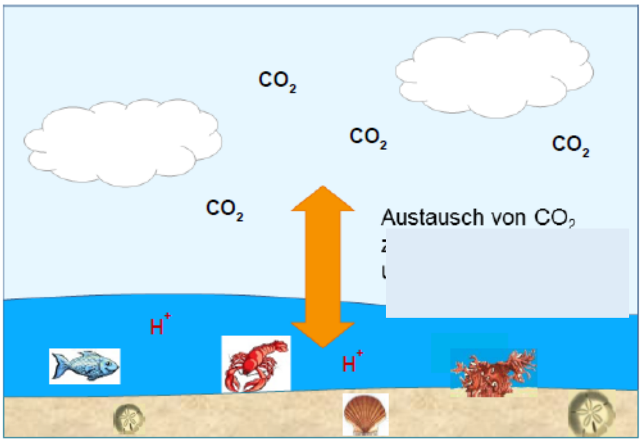
Black arrows and numerical values indicate pre-industrial flows; shown in red are the added "anthropogenic, i.e. man-made" flows.



Oceans as huge CO_2 reservoirs

CO_2 from the atmosphere - but also from sediments and shell limestone - dissolves in seawater, where it forms the medium-strong "carbonic acid". This splits in the water into hydrogen carbonate ions and protons, which are responsible for the acid effect and can lower the pH value of the water. The equation is:

$$CO_2 + H_20 \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$$



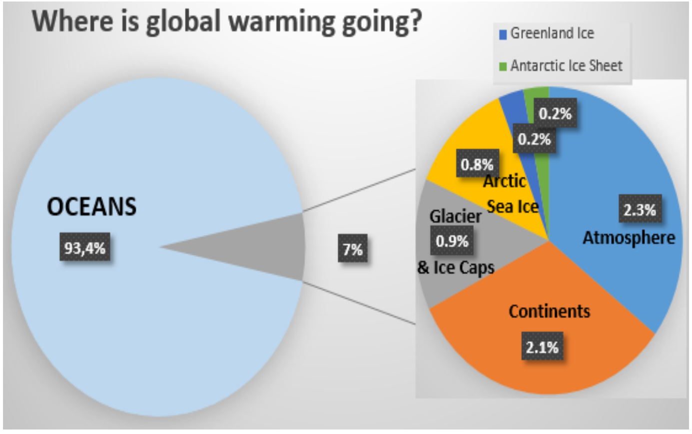
The hydrogen carbonate anion acts as a so-called buffer ion, i.e., as a base, it binds protons in the event of an excess and decomposes back into H_2O and CO_2, which then escapes into the atmosphere.
The amount of CO_2 that can be dissolved in the water depends on the pressure and temperature. The higher the pressure and the colder the water, the more CO_2 can dissolve.
Air pressure on Earth is a fairly constant quantity. Temperature, however, has changed repeatedly throughout Earth's history and is likely to continue to do so. In the long term, higher temperatures in the oceans mean that less CO_2 can be dissolved, the CO_2 outgases into the atmosphere, and the concentration there increases. Currently, the mean temperature of the oceans, like that of the near-surface atmosphere, is 15°C.

Thus, the oceans represent a very important storage for CO_2 and an influencing factor on the climate. However, the real "acidification effect" caused by atmospheric CO_2 is very small, since the dilution effect is enormous due to the large water volume of the oceans. Wastewater discharges and the input of pesticides and nutrient surpluses of nitrates and phosphates as well as SO_2 in the form of acid rain also have a major influence on ocean acidification.

See also S. Solomon, *The physical science basis: Contribution of Working Group I*, Climate change 2007 contribution of ... to the Fourth assessment report of the Intergovernmental Panel on Climate Change, Vol. 1, Cambridge Univ. Press, Cambridge [et al.] 2007.

Effects on the climate

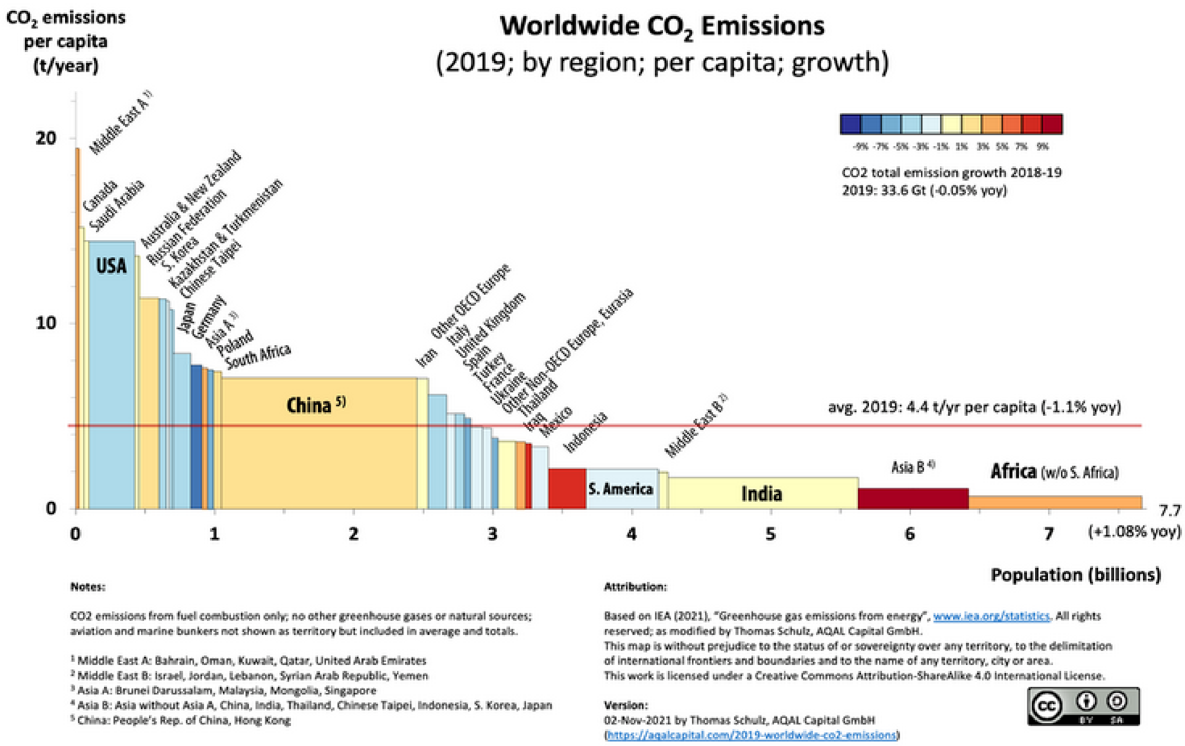
The effect of carbon dioxide and other greenhouse gases on the climate is not only negative for life on earth. After all, without these gases, the average temperature on Earth would not be +15 °C, but about -18 °C. The extent to which the quantities of CO_2 released by humans since the Industrial Revolution have actually changed the climate is still subject to uncertainty, given the short measurement times of often only a few decades and because of the complicated processes that control the Earth's climate.



Climate gas	Global warming potential (GWP)	Sources	Atmospheric dwell time	Rise in the atmosphere
Water as gas (H2O(g))	< 1	water evaporation	low	unknown
Carbon dioxide (CO2)	1	combustion of fossil fuels, power plants, heating, fire clearance, land fills, vehicles, people & animal breathing	< 150 years	+ 35%
Nitrous oxide (N2O)	296	nitrogen fertilization, rice cultivation, burn of bio mass, fire clearance, land fill, traffic	114 years	+ 10%
Methane (CH4)	23	agriculture (rice cultivation), land fills, livestock, combustion of fossile fuels, swamps & wetlands	12 years	+ 120%
Halogenated Hydrocarbons (i.e. FCKW)	20	propellant gas in spray cans, solvents, coolants, foaming agents	> 1.000 years	not natural
Ozone (O3) at ground level		from nitrogen oxides and tph with the aid of uv radiation		
Sulfurhexafluoride (SF6)	20		32.000 years	not natural

Climate-relevant gas emissions include CO_2 as well as other gases. Methane and nitrous oxide in particular make a much greater contribution to the greenhouse effect (GWP = Global Warming Potential) and thus to the composition of the air in the atmosphere than CO_2. Halogenated hydrocarbons have a particularly harmful effect on the ozone layer, which adsorbs the sun's harmful UV radiation. For this reason, they are now banned in many areas of application.

The graph below conveys global CO_2 emissions by country and population for 2019.



Soil and plants - "A gigantic reservoir" - Only 30% of the earth's surface consists of land mass, and only part of this is covered by plants; one third of this area is made up of deserts and high mountains with no vegetation worth mentioning. Nevertheless, soil and plants act as gigantic carbon reservoirs worldwide. Under special geological conditions, coal, oil, gas and gas hydrates are formed from living and dead matter. These are the fossil energy raw materials that have led to an increase in the CO_2 concentration in the atmosphere through intensive use over the last 100 years.

Photosynthesis - Plants absorb CO_2 from the atmosphere as part of photosynthesis and use sunlight to convert it into oxygen, which is released into the atmosphere, and glucose:

$$6\ CO_2 + 6\ H_2O \leftrightarrow C_6H_{12}O_6 + 6\ O_2$$

From this it is clear that it is by no means detrimental to plants if the CO_2 content of the air increases. Thus, plants in greenhouses are irrigated, fertilized and often fumigated with CO_2 to increase its partial pressure in the air in order to achieve higher yields through increased photosynthetic activity. This is 0.038 vol. % in air and about 0.08 vol. % in greenhouses due to CO_2 addition.
As soon as a plant dies, it can no longer perform photosynthesis. It is then decomposed by microorganisms, which release the bound CO_2 back into the atmosphere as part of their respiration. The natural death of plants is intensified by large-scale clearing of forests.

The soil as a carbon store - Just as in the ocean, gigantic amounts of carbon are stored in the soil and in the plants that grow on it. But here, too, the binding of CO_2 is not permanent. The gas can be outgassed from the soil both by a drop in pressure in the atmosphere and by an increase in temperature. This effect is particularly pronounced for permafrost soils (i.e. permafrost) and peatlands. Climatic changes directly affect vegetation and thus the CO_2 balance. Sealing of soil surfaces leads to the fact that soil formation and thus also CO_2 fixation are stopped or at least strongly hindered.

Another important factor influencing CO_2 storage in the soil is agricultural use. Under normal cultivation, soils contain large amounts of dead matter (humus and humic substances), which temporarily stores carbon and makes the soils fertile. Over time, this carbon is slowly degraded with the release of CO_2 . At the end of this microbiological degradation, all humic substances are converted back into inorganic matter, i.e. CO_2 and other inorganic compounds. Therefore, to counteract this loss, soils require a constant supply of new humus. Soil use that harvests all living matter from fields, as is the case with the production of crops for biofuel, for example, will therefore have negative consequences for soils in the medium and long term. The decrease in organic carbon content reduces the fertility of soils.

Storage and use of CO_2 - There are many different options for the capture and subsequent storage of CO_2 (CCS) - both in the oceans and on the continents. However, none of the options can be considered ideal, either because permanence cannot be ensured or because of high costs. By means of CCU, i.e. the capture and subsequent use of CO_2 , the gas can be utilized and thus transformed from a "pollutant" to a "raw material".

AB 1 Characteristics of the personal CO_2-Footprint

What is the CO_2-Footprint?

The CO_2 *carbon footprint* records the amount of CO_2 emissions caused by a production process, a product or a person in a given period of time. This CO_2 balance shows how one stands on average: With a large footprint, above-average emissions are caused; a small footprint, on the other hand, implies a climate-friendly life.

If you want to know what your$_2$ personal carbon footprint looks like, you can calculate it with the help of calculators. This requires some information on electricity consumption, heating requirements, consumer behavior, eating habits and transport. The CO_2 footprint is a one-dimensional approach to life cycle assessment. The CO_2 footprint model was developed by Wackernagel and Rees in 1994.

➔ Here is the link to the calculator https://www.carbonfootprint.com/calculator.aspx

For example, a regionally harvested **apple** certainly has a better carbon footprint than one from New Zealand or Chile. Or is it not?
Surely this is true for a few months after harvest. Because the apple comes after the harvest in the cold storage and is stored there at +0°C. This costs energy. The longer the apple is stored there, the more energy is consumed.
If the apples are in cold storage for more than half a year, the apple from Chile (i.e. from the southern hemisphere, where it has just been freshly harvested and has not been in cold storage for long) can have a better CO_2 balance than the domestic apple.

Opportunities: Humans can best reduce their carbon footprint by:

- drives less or chooses a significantly more economical model the next time they buy a car.
- or gets into the habit of a more economical driving style.
- reduced the temperature in the house by 1-2 degrees.
- his house well insulated.
- chooses its vacation destinations closer to home.

and heeded the following rules when it comes to food:

- fresh is usually better than processed
- local or regional is better than imported from overseas when it is freshly harvested
- less meat is more climate-friendly than more meat
- if meat, then no red meat
- **"organic"** is not in principle better than "**non-organic"**, not even for meat

There is particularly great potential for CO_2 savings in housing and mobility.
They exceed the CO_2 savings from food many times over.