
WTF
QUITTING
WILL IMPROVE
YOUR HEALTH
IS
CLIMATE
CHANGE?
GLETSCHERSTAND
GLACIERPOSITION
1995

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WTF

IS

CLIMATE

CHANGE?

INTRO

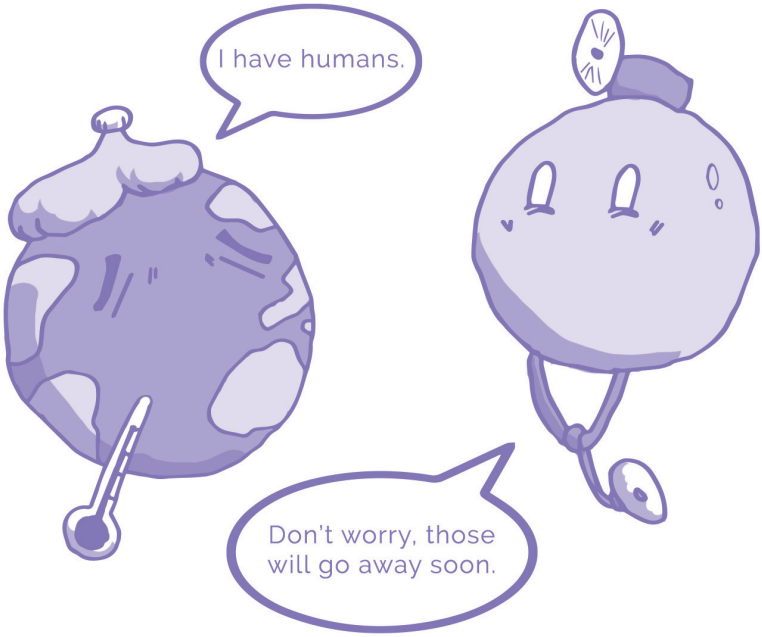
Dear reader,

We are fully aware that you have heard the phrases 'climate change' or 'global warming' very often, and that by now they are very familiar to your ears. Nowadays, these two phrases tend to be overused, so many people become apathetic to the reality of what is happening. However, we believe that the industries contributing most to climate change want to achieve exactly this so that they can carry on with their activities.

Global warming was recognised as a problem in the late 1980s, and the following years of international climate change negotiations have shown that there is no straightforward solution to it. In 2015 countries agreed to fight global warming and try to keep the global temperature increase (since the beginning of industrialisation) well below 2°C. This was a big step forward towards a more sustainable and peaceful world. However, climate models predict that even if the countries keep all their promises of reducing greenhouse gas emissions, the average global temperature will likely exceed 2.5°C above preindustrial levels by the end of the century, with potentially dangerous consequences. Thus, despite increasing efforts, the problem of global warming cannot be solved by governments alone. It requires the participation of every one of us.

This booklet aims to make you ready to become part of the solution to the global warming problem. It contains all the necessary (and more) information about the causes and effects of climate change. Furthermore, at the end of the booklet, you will find a list of suggestions for what you can do personally to protect the environment and our society. The list is by no means complete. You are welcome to contribute in your very own way!

Our planet has survived many years without us and will go on, no matter what. Even if we burn all the fossil fuels still stored in the ground and use all our nuclear weapons, planet Earth will not be catapulted out of the solar system. Thus, addressing climate change is not about saving the Earth, but about saving its inhabitants (humans and other species endangered by global warming). Nature will evolve in one way or another. The question is whether it will be with us or without us.



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1. WHAT LEVEL OF CLIMATE EXPERT ARE YOU?

We don't know your background knowledge: therefore, we structured the booklet so that it ranges from basic facts to more complex topics of climate change. The following questionnaire will help you find out which part of the booklet you should start with.

1. Since the 1880s until today, Earth has warmed on average by about:

a) 0.3˚C.

b) 1˚C.

c) 3˚C.

2. Which of the following points can be related to climate change?

a) In the last year, we didn't have any snow in Berlin, although we normally have 10 days of snow cover a year.

b) In the last 20 years, there has rarely been snowfall in Berlin, although this often happened (more than 10 days a year) in the past.

c) On the 18th of March 2017, there was heavy snowfall in Berlin.

3. Which are greenhouse gases?

a) Ammonia (NH_3), carbon dioxide (CO_2), water vapour (H_2O).

b) Methane (CH_4), carbon dioxide (CO_2), iron (Fe).

c) Methane (CH_4), carbon dioxide (CO_2), water vapour (H_2O).

4. Climate change has no influence on…

a) Strength of tsunamis.

b) Acidity of oceans.

c) Rising sea level.

5. Which of the following factors does not affect the climate?

a) Emissions of nitrogen dioxide (NO_2) from wetlands.

b) Earth's orbit around the Sun.

c) Tides of the sea.

6. Who is currently the largest carbon dioxide (CO_2) emitter in the world?

a) European Union.

b) United States of America.

c) China.

7. The "Dust Bowl" caused human migrations due to changes in climate in

a) North America.

b) Eastern Europe.

c) India.

8. Carbon dioxide (CO_2) in the atmosphere does not:

a) Reflect solar radiation.

b) Trap terrestrial radiation.

c) Absorb solar radiation.

9. What share of changes in climate since the 1950s can be related to human activities?

a) 10 %.

b) 50 %.

c) 95 %.

10. Which of the following statements on ozone is wrong?

a) Ozone is a greenhouse gas.

b) Breathing ozone is harmful to health.

c) Ozone emits UV radiation.

11. Which of the following statements on the relation between Gross Domestic Product (GDP) and greenhouse gas (GHG) emissions is true?

a) GHG emissions per unit of GDP have increased since the 1950s.

b) GHG emissions per unit of GDP have decreased since the 1950s.

c) GHG emissions aren't related to GDP.

You can find the solutions at the bottom of this page. If you got 10 or more of the questions right – Congratulations, you are a climate expert. You may want to directly start at the 'Advanced' chapter of the publication. If you got 7 or more of the answers right, you may want to start at the 'Intermediate' chapter, while we would suggest everyone else start with the 'Beginner' chapter.

Solution:
1b, 2b, 3c, 4a, 5c, 6c, 7a, 8a, 9c, 10c, 11b.

2. LEVEL: BEGINNER

This chapter gives you just a brief insight into the climate change issue, since it is mostly written for beginners. However, you can get more information in the next chapters, where the difficulty level rises. :)

Global warming refers to the recent and ongoing rise in global average temperature near the Earth's surface. However, it is not all in the rising of the temperatures, as this is only one aspect of broader changes in the climate. Other possible changes in the climate include changes in winds, amounts of rain, sea level height, melting of glaciers, etc. Earth's climate has always been changing, with or without human influence, but the changes have never been as fast as nowadays.

Some quick facts about climate change:

• The Earth has warmed by about 1˚C since preindustrial times (1850-1880).

• Many of the observed changes since the 1950s have not occurred in millions of years.

• The sea ice covering the North Pole, the vast ice sheets of Greenland and Antarctica, and most glaciers worldwide are shrinking.

• Sea levels rose by about 20 cm in the 20th century.

• The concentration of greenhouse gases increased due to human activity and has reached the highest levels in the last 800.000 years.

• It is unequivocal that human activity has been the main driver of the observed warming since the 1950s.

• If we continue like this, heat waves will be more frequent and last longer, extreme rainfall events will become more frequent, sea level will rise further, glaciers will disappear.

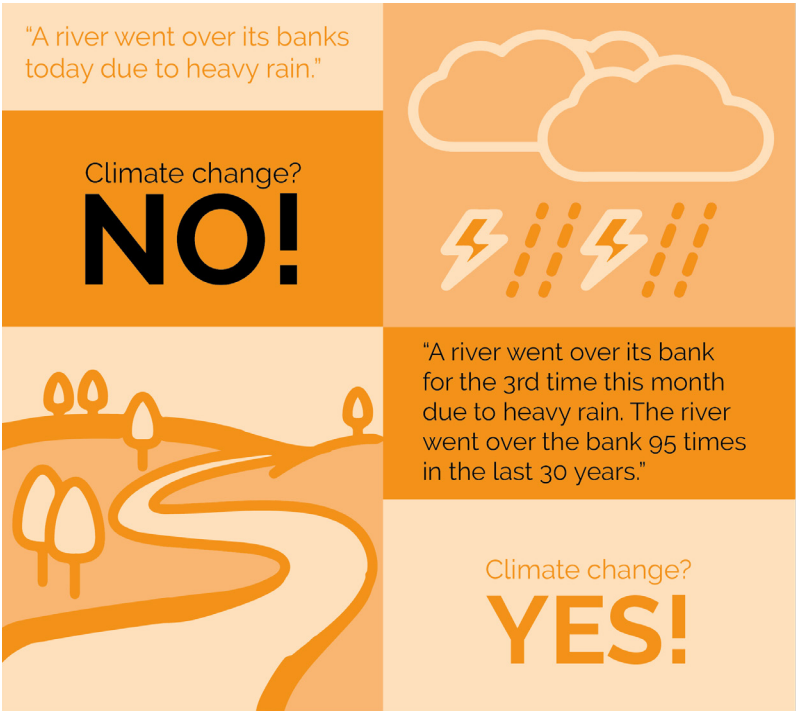
• Therefore, the climate-related damage for people and ecosystems will increase.

• Decreasing greenhouse gas emissions and adapting to changes in climate can substantially reduce these risks.*[1,2]*

2.1. Weather ≠ climate

Weather is the current situation in the atmosphere at a specific time and location. It can be described in terms of temperature, air pressure, cloudiness, rain intensity, etc.

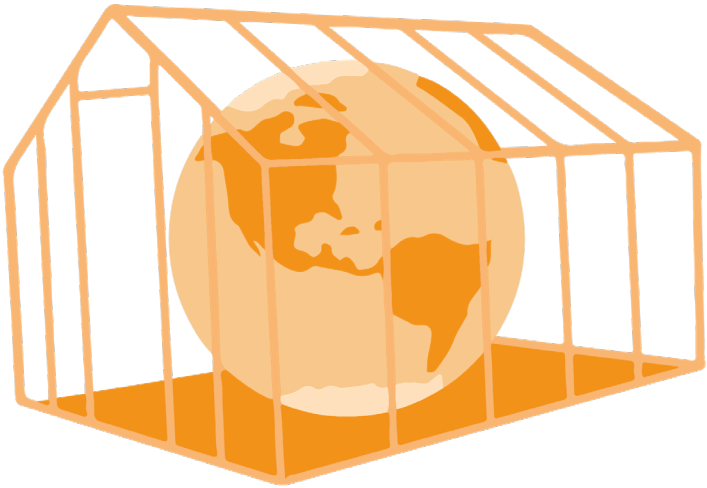
Climate is the range of weather at a certain location over a long period (usually 30 years). It can be described in terms of average weather, extreme weather, or the range of all possible weather situations.*[3,4]*



2.2. The greenhouse effect

What does the glass do to increase the temperature in a greenhouse? The glass is transparent to solar radiation (light). This radiation heats up the ground and is emitted back in the form of terrestrial radiation (warmth). However, for this radiation, the glass is non-transparent, and so the warmth is trapped inside the greenhouse.

Despite not presenting any physical barrier like glass covering a greenhouse, some gases in the atmosphere act similarly. The Sun's light can reach the Earth's surface, while the warmth is blocked by them and kept close to the surface. This mechanism is called the 'greenhouse effect'.



The most important greenhouse gases in the atmosphere are (ranked by their contribution to the greenhouse effect):

1. Water, both in the form of vapour (invisible) and in the form of clouds (which we can clearly see with our own eyes).

2. Carbon dioxide (CO_2).

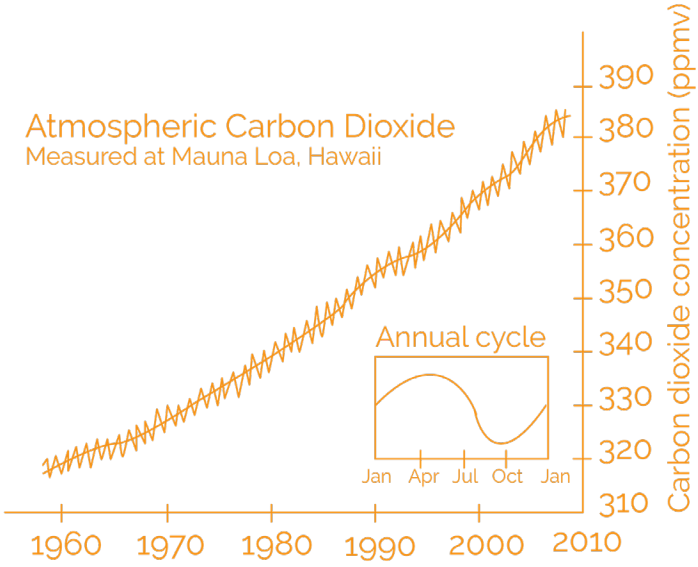
3. Methane (CH_4).*[2]*

The greenhouse effect is a fundamental mechanism for ensuring comfortable living conditions on Earth – without it, Earth would be about 33˚C colder, resulting in an average temperature of -18˚C!

However, we do have a problem with the greenhouse of the Earth. The amount of greenhouse gases in the atmosphere is rapidly increasing. This is because we are emitting more and more carbon dioxide, methane, and other greenhouse gases into the atmosphere. We do that by burning fossil fuels for producing electricity, transportation, heating and cooling of buildings, and agriculture. This means that the greenhouse effect is getting stronger, and this leads to global warming.

Where is all this leading us? What will the world look like in 2100?

According to today's CO_2 emissions and the current state of climate policies, we can expect the world to heat up for 3˚C by 2100 *[see Section 4.2]*.



Did you know that...

The strongest greenhouse gas, water vapour, is not directly affected by human activities. However, warmer air can take up more water vapour. Therefore, in a warmer world, the additional water vapour in the air will lead to additional warming.

2.3. So what?

You may ask: 'Why is this bad?' Here are just a few examples:

- Glaciers melt

Glaciers are frozen water reservoirs. They accumulate water in the form of snow in winter and release it in the form of liquid water in summer when needed. They, therefore, supply millions of people with drinking water. However, most glaciers have retreated or completely disappeared in the last few decades due to global warming. This is evident from comparisons with historical photos of glaciers, such as the Pasterze glacier in Austria. This threatens the water supply in many countries and significantly contributes to rising sea levels.[4]

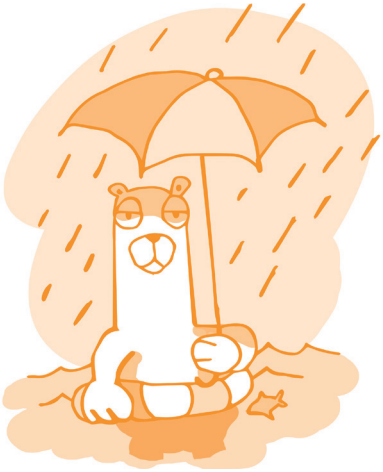
Pasterze glacier in 1994 and 2020.[5]

- Sea levels rise

Global warming leads to sea-level rise in two ways. Firstly, warmer water is less dense and therefore needs more space. Secondly, melting land ice from glaciers and ice sheets brings additional water to the oceans. Since 1880, the sea level has risen by about 20 cm, and it is expected to reach 1m by the end of the century if current trends continue.*[2]* This substantially increases the risk of flooding in coastal areas.*[6]* Some islands may even be completely submerged by the rising ocean.

- Extreme weather gets more extreme

It is difficult to say whether one specific weather event (for example, a hurricane) was directly caused by climate change, but there is evidence that global warming leads to more and stronger extreme weather events, such as heatwaves, heavy precipitation and droughts. *[2]* For example, the 2003 heatwave, which led to a death toll of about 20,000 people*[7,8]*, was the hottest summer in Western Europe since at least 1540. *[9,10]* Following the current climate trends, we can expect such extreme heatwaves to become more the norm and not exceptions anymore.



- Extinction of several species

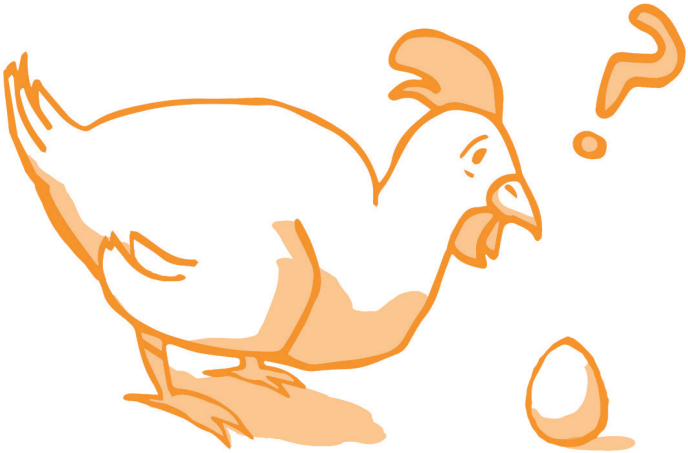
Every species on Earth has evolved to survive in specific environmental conditions. If these conditions change, they need to adapt or migrate. Current global warming occurs at a pace that is too fast for many species, and they are in danger of extinction (while some have already become extinct). Apart from global warming, the increasing carbon dioxide levels also make the oceans more acidic, damaging numerous marine species, like corals. For more details on how climate change can endanger plants and animals, look at chapter 3.6.

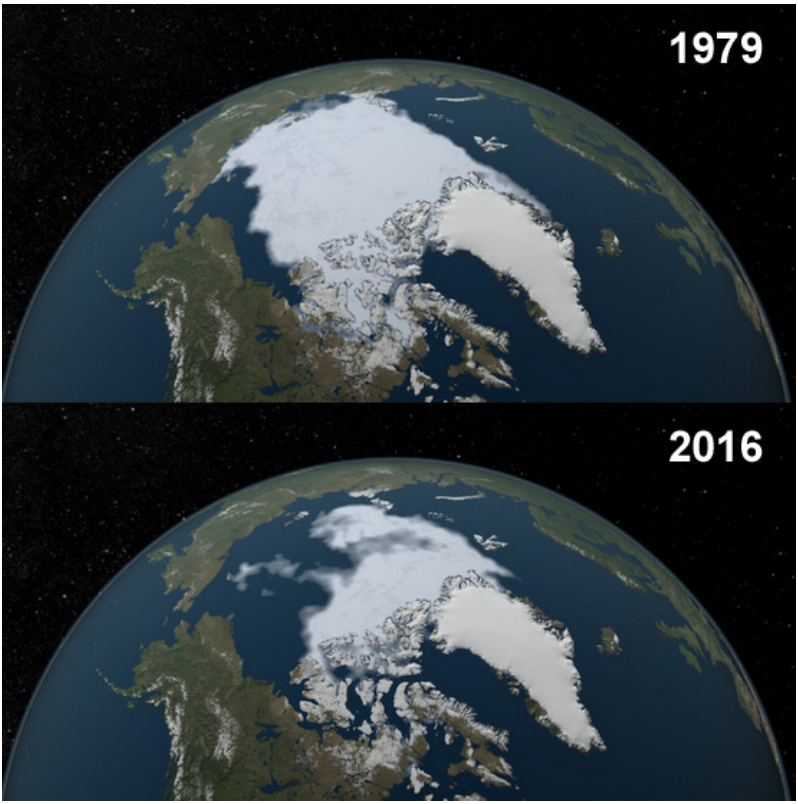
Bramble Cay melomys was a small rodent living on an Australian island. It has not been observed since 2009 and was recently declared extinct by the Australian government. The likely cause of its extinction was human-caused sea level rise flooding the island.

2.4. The melting of sea ice

Imagine the border of white, mirror-like ice surrounded by a dark ocean surface. The ice is white because it reflects most of the light coming from the Sun. On the other hand, the ocean is dark because it absorbs light and converts it into heat. This means that when sea ice melts and the sea ice cover becomes smaller, more surface area is covered by ocean and consequently more light is absorbed. This leads to stronger warming and thus even more melting of sea ice.

the vicious cycle





There is much less sea ice in the Arctic.[11]

The melting of sea ice and a rapid increase in temperature can already be observed in the Arctic. The sea ice cover has shrunk by more than 50% in the last 40 years, and temperatures have been increasing about twice as fast as the global average. If the current trends continue, Arctic summers might be nearly ice-free by 2050. This would be a dramatic change with a huge impact on the Arctic ecosystems (including polar bears).

Polar bears hunting for a seal in Svalbard, Norway.[12]

Did you know that...

A common misperception is that the melting of sea ice will cause sea levels to rise. If the floating ice melts, the sea level remains constant. The water only changed its state from solid to liquid. The story is very different when the melting ice lies on the top of a landmass, for example, Greenland or Antarctica. In this case, additional water is added to the oceans and, consequently, the sea level rises.

2.5. A few facts about carbon dioxide (CO_2)

• CO_2 has no colour, taste or smell.

• CO_2 is produced by the respiration of people and animals and by burning materials like oil, gas, coal, etc.

• CO_2 is not poisonous.

• CO_2 is long-lived. Once it is in the atmosphere, it will likely stay there for decades or even centuries.

• The current concentration of CO_2 is about 413 parts per million, or 0.0413%, of the total atmosphere.

Coal Power Plant.[13]

What you see on the picture is not carbon dioxide (CO_2), because CO_2 is invisible to the human eye. What you see is a cloud composed of small water drops and polluting particles.

3. LEVEL: INTERMEDIATE

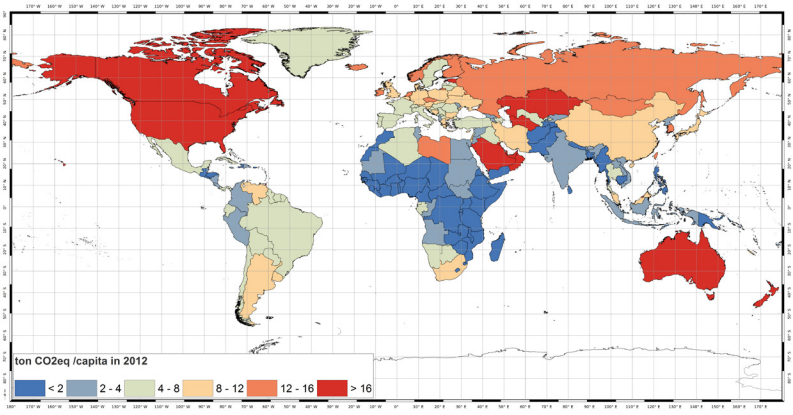
3.1. Who is most responsible for climate change?

Currently, the country that emits the most carbon dioxide is China, with a 29% share of global emissions, followed by the USA (14%) and the EU (10%).*[14]* However, if we want to look at which country is most responsible for the current state of the climate, we have to consider all emissions since the beginning of industrial times in the late 18th century.

This perspective significantly changes the order of the top three emitters. China drops from first place to third place, accounting for 12% of the emissions, while the USA and the EU come to the first and second places, accounting for about 25% of total global emissions each.

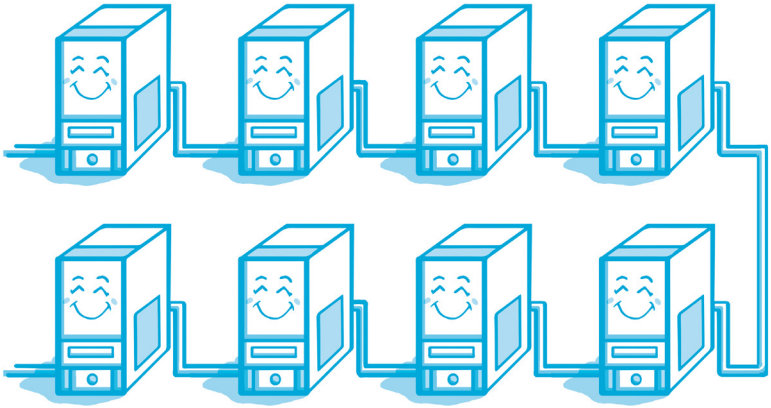
Of course, part of the reason they have such a big impact is their large number of inhabitants. If we look at the emissions not per country but per person, we see that the developed countries and oil-producing countries (for example the Gulf States) are amongst the biggest carbon dioxide emitters. Some of them exceed the sustainable limit of 2 tons of carbon dioxide emissions per person per year, which the oceans, soils, and plants can absorb, by a factor of 5 to 15.

The carbon dioxide emissions of all developed countries add up to about 75% of all human carbon dioxide emissions since 1750. We can therefore say the developed countries are most responsible for the current changes in climate.[15]



Countries by the amount of carbon dioxide per inhabitant for the year 2012.[16]

3.2. Future temperature projections



Climate scientists cannot perform real large-scale experiments in the atmosphere, as they would be impossible due to the large size of the Earth, could have many negative impacts on the environment and humans, and would often last longer than a human lifetime. However, luckily, they can perform experiments in the model world with powerful computers, which simulate all relevant processes affecting climate (radiation, winds, ocean currents, and cloud processes).*[17]*

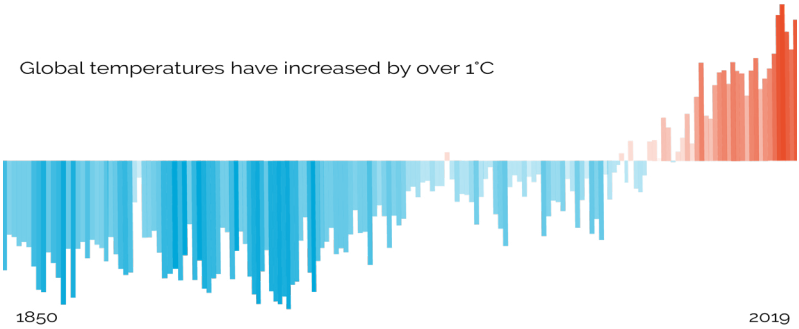
Climate models help scientists to better understand the current climate but also to understand possible future climatic conditions. Of course, this is inevitably done based on assumptions on future global development and, in particular, based on assumed future greenhouse gas emissions, expressed in the form of several emission scenarios. An example of one such scenario is the so-called 'business-as-usual' emission scenario, which assumes no change in the way the society, economy, and power production works and, therefore, leads to the highest greenhouse gas emissions and the highest increase in temperature.

3.3. Climate change: From the past to today

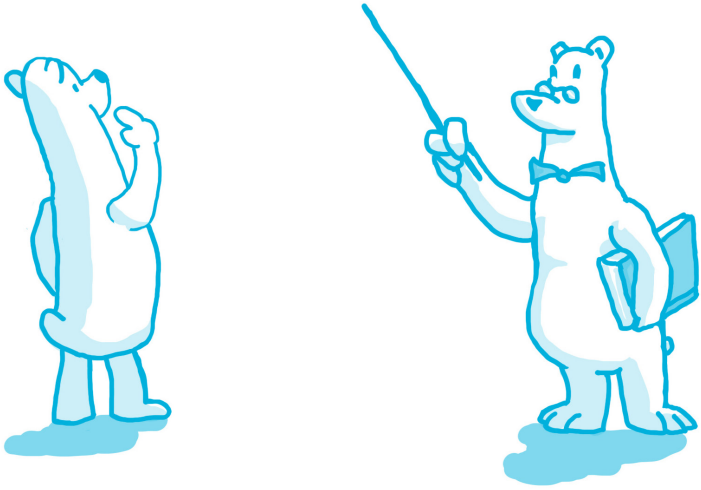
In the past, most changes in the environment were purely natural processes. In the last 2.5 million years, Earth's climate has often shifted from extremely low temperatures during ice ages (on average ~5˚C colder than today) to higher temperatures during warm periods (similar as today). These changes result from a combination of various factors: changes in the Sun's energy output, the varying distance between Earth and the Sun, volcanic eruptions, and changes in greenhouse gas concentrations. We cannot notice the majority of such natural changes in climate because they happen over periods of several hundreds to thousands of years, in comparison to which a human lifespan is like a blink of an eye. Today we are in one of the warm periods between two ice ages: the last one that finished about 12,000 years ago and the next one that should start about 50,000 to 70,000 years from now.*[18,19]*

However, the current rapid increase in temperature worldwide and the similar increase in greenhouse gas concentrations are not coincidental. The physical link between the two trends has been confirmed by both observational and computer-based climate modelling studies. According to the Intergovernmental Panel on Climate Change (IPCC) report, 'most of the observed increase in global average temperatures since the mid-twentieth century is very likely due to observed increase in anthropogenic [= human-made] greenhouse gas concentrations'.*[2]* This leaves very little space for doubt about human influences on climate. Human society has grown big enough to have significant impacts on any component of the environment. Earth has warmed by about 1 ˚C since the 1850–1880 period. This value seems small compared to temperature differences between ice ages and warm periods or between different times of the day, different days of the year, or different locations. However, in the last 50 years, the rate of warming has been extremely fast compared to Earth's climatic changes in the previous millions of years. This trend seems likely to accelerate in the future, and this is what is most worrying. Kids born in 2020 can expect a temperature increase of about 2˚C in

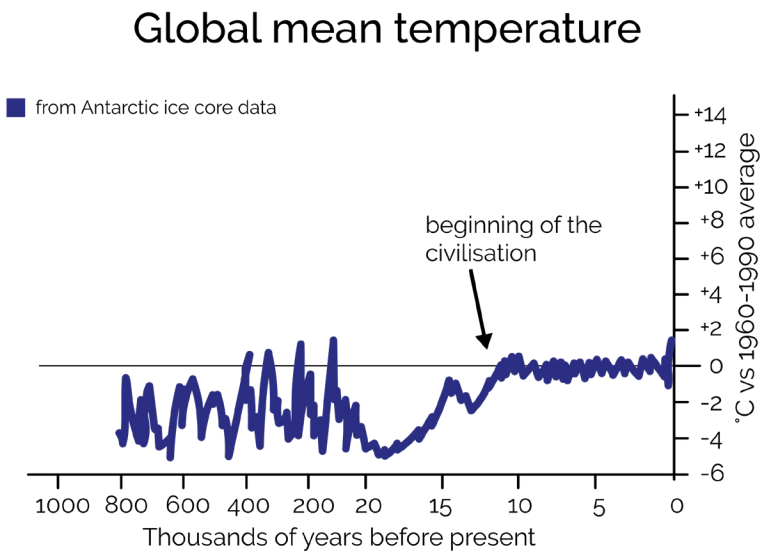
the course of their lifetime if the current trends continue. Such a rapid rise in temperature has never happened on Earth in the past 65 million years, since the extinction of the dinosaurs.



Global temperature changes since 1850.[20]



3.4. Climate change, human migrations, and human conflicts



Changes in global mean temperature in the past 1 million years.[21]

While people (homo sapiens) have existed for about 200,000 years, it is interesting to note that civilisation started to develop only about 12,000 years ago, with the first permanent settlements and the beginnings of agriculture. Thus, the start of human society corresponds to the beginning of the period of a relatively stable climate with temperature variations not exceeding ±1˚C in the global average. A reliable food supply, therefore, seems to be crucially dependent on a constant climate. We show below a few examples of how (regional) climate changes have disrupted the society, which should warn us of a potentially damaging temperature increase of 3˚C or more likely to occur by the end of the century.

Roman empire, 300-500 AD

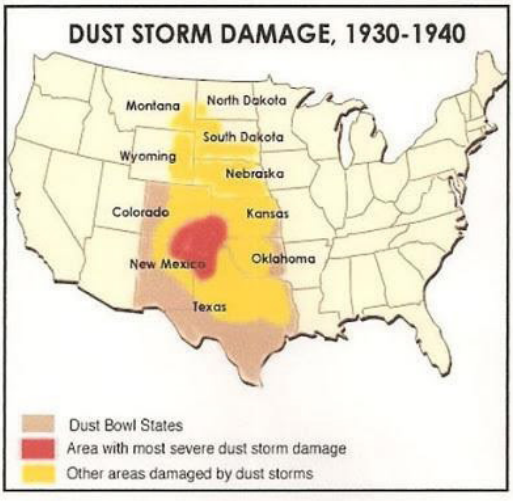
A hostile climatic change was likely the trigger for large migrations of nations in the beginning of the medieval period that led to the decline of the Roman Empire and later a reshaped ethnic picture of Europe, leading to a similar population mix as observed nowadays (despite totally different political borders).*[22,23]*

Central America, 800-900 AD

The Maya, a remarkably sophisticated civilisation that dominated the area of what is now Mexico and its neighbouring countries, suddenly collapsed during the 9th century. The most likely factors contributing to the collapse were repeated severe droughts following extensive deforestation.*[22-24]*

Central USA, 1930s

Good conditions for agriculture were also a reason for people to settle down in the North American Great Plains. However, in the 1930s, a persistent drought (lasting for about 10 years) hit the central area of the United States. This caused the soil to dry and turn into dust that was blown away by winds. At times, the clouds of dust blackened the sky, reaching all the way to East Coast cities such as New York and Washington. The immense dust storms reduced visibility to a metre or less. This phenomenon, called the 'Dust Bowl', affected an area of about 400,000 km^2 in the central USA. It caused an exodus of farmers from the affected states to neighbouring regions.*[25]*



left: Map of the areas the Dust Bowl affected in the 1930-1940s; right: South of Lamar, Colorado, a large dust cloud appears behind a truck travelling on Highway 59, May 1936.[26]

3.5. Climate change and environmental health

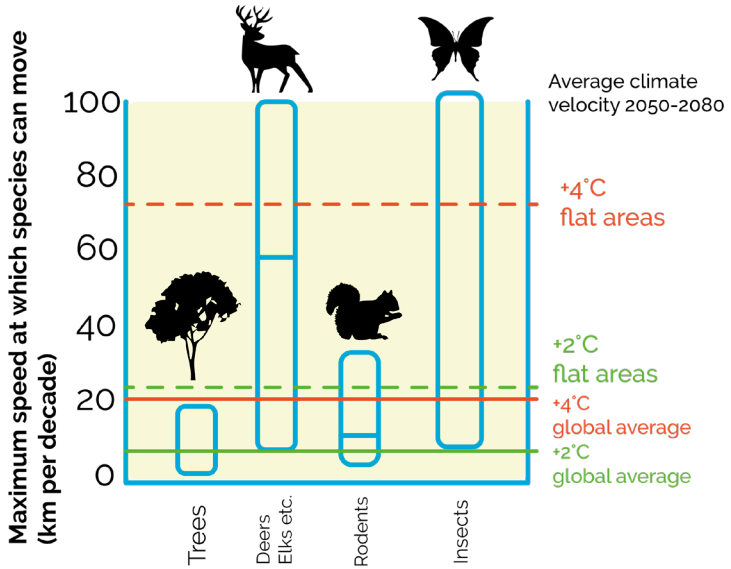
You may not have thought about human health when thinking about the phrase 'climate change'. And yet, our wellbeing and health are strongly related to the environment we live in, particularly its air, water, and soil quality.

Therefore, we can expect that a change in the environment will lead to a change in the human health condition. Climate changes can decrease wellbeing and health by increasing the occurrence of deadly weather events such as floods, hurricanes, or extreme drought events.

The most directly connected and deadly consequence of a warming planet is probably the increasing frequency and length of heatwaves. Extreme heat markedly increases the number of respiratory and cardiovascular diseases and related deaths, in particular, among elderly people and children. For example, the 2003 European heatwave was responsible for more than 20,000 deaths in Western European countries not adapted or used to

heat.[7] If we do not substantially and quickly reduce greenhouse gas emissions, we can expect about a 50% increase in heat waves in Europe and North America in the second half of the 21st century.[2]

3.6. Can species adapt?



The maximum speeds at which species can migrate across landscapes, compared to the velocity by which the climates (e.g. tropical climate, continental climate, etc.) are estimated to shift polewards.[6]

Indeed, a single tree is not moving anywhere. However, by spreading its seeds, a species of tree can slowly spread to new territories. With climate warming, for instance, we expect the treeline to rise to higher elevations.

When the climate changes in a specific region, species need to adapt or migrate to where the conditions are better. Some species can migrate towards more favourable conditions in an easier way

than others. Species that cannot adapt or migrate fast enough face a high risk of extinction.

By the middle of this century, the high rate of climate change could put a large stress on numerous ecosystems, particularly on those strictly related to specific trees or other plants. Trees cannot migrate fast enough to catch up with the climate changes if we continue with the current trend of greenhouse gas emissions (leading to a 3˚C temperature increase by the end of the century). In fact, trees would already become endangered in a 2˚C warmer world. This puts other species like rodents under enormous climate stress too, as they are tightly bound to specific types of tree or vegetation. Other species, like most insects or fast-moving mammals, in contrast, are better suited to migrate due to a changing climate.

Treeline rising to higher elevations

4. LEVEL: ADVANCED

4.1. Externalities and the Prisoner's Dilemma

In economic terms, climate change is one of the largest market failures ever seen.*[27]* Market failures are defined as situations in which the market does not optimise the wellbeing of society.

This means that at least someone could, in theory, be better off without making anyone else worse off. This is because the costs associated with greenhouse gas emissions are not included in the market price and thus not covered by those responsible for them. Instead, they have to be covered by others, for example, the developing countries and future generations. Such costs are termed 'external costs', and greenhouse gas emissions are a so-called 'negative externality'. Other examples of negative externalities are:

1) A factory polluting the environment with dangerous substances and damaging plants, animals, and people.

2) A smoker at a bus station making other people involuntarily breathe the smoke.

3) A loud party preventing the neighbours from sleeping.

Compared to these three examples, greenhouse gas emissions have a much more widespread (both spatially and temporally) impact. While the economic benefits of activities producing greenhouse gases are generally local and immediate, their costs are global and long-term. Inversely, the benefits of reducing greenhouse gas emissions are global and long-term, while the costs are local and immediate. For this reason, there is a strong incentive for countries to 'free ride' (meaning to profit from other countries' reduced greenhouse gas emissions without doing anything themselves).

The situation of the world's countries is similar to that of the two characters in the prisoner's dilemma analysed in game theory. In this example, two prisoners, who were accomplices in a crime, but are now not allowed to talk to each other, are offered a bargain: They can either admit that they were part of the crime or deny it. Depending on their decisions, they will be sentenced to the following punishments:

- If both prisoners admit the crime, each of them will spend one year in prison.
- If Prisoner A admits it, but Prisoner B denies it, A will spend three years in prison and B will be set free (and vice versa).
- If both prisoners deny it, each of them will spend two years in prison.

The punishments for the prisoners are illustrated in the following matrix (lower left corners for A, upper right corners for B):

B / A	B admits	B denies
A admits	1 / 1	0 / 3
A denies	3 / 0	2 / 2

The best outcome for both prisoners together would be reached if they both admitted the crime because, in this case, they would each only spend one year in prison.

However, for a single prisoner, denial would always be the better option, as it would imply fewer years in prison independently of what the other prisoner decides. Compare, for example, the left (admits) and right (denies) column for B: no matter what A does (admit or deny), denying would be the better option for B, and the same is true for A. Therefore, rational (and selfish) prisoners would always deny having been part of the crime and spend two years in prison, even though they would together be better off by admitting it.

Now imagine that the prisoners are countries and the years in prison are costs. Each country can decide whether it wants to invest in reducing greenhouse gas emissions or continue emitting as usual. For simplicity, let's assume that there are only two countries in the world, that the costs of reducing greenhouse gas emissions are three potatoes for each country (the units are not important), and that the costs of climate change are four potatoes (while each country can avoid half of that by reducing emissions). In this case, the cost matrix would look like this:

B / A	B reduces	B does nothing
A reduces	3 / 3	2 / 2+3=5
A does nothing	2+3=5 / 2	4 / 4

Like for the prisoners, the best outcome for both countries would be to cooperate, invest in reducing greenhouse gas emissions, and thus avoid the costs associated with climate change. This would mean that they would spend together six potatoes. However, independent of the other country's decision, each country on its own would profit most if it decided not to do anything (compare again the left (reduces) and right (does nothing) column for B).

This means that they will have to pay the costs associated with climate change and together spend eight potatoes.

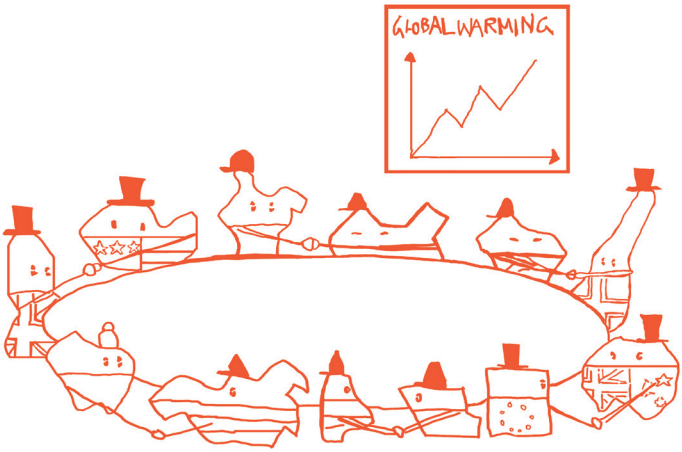
Although it is a simplified example, the prisoner's dilemma shows well why little has been done so far to reduce greenhouse gas emissions. To solve the problem of climate change and reach the best outcome for everyone, all countries have to cooperate. Luckily, in the real world, they are allowed to communicate with each other, unlike the prisoners in the prisoner's dilemma.

4.2. The very short history of climate negotiations

Since climate change is a global problem that does not respect political borders, solving the problem requires international cooperation. With countries primarily representing their own (economic) interests, this is not always easy.

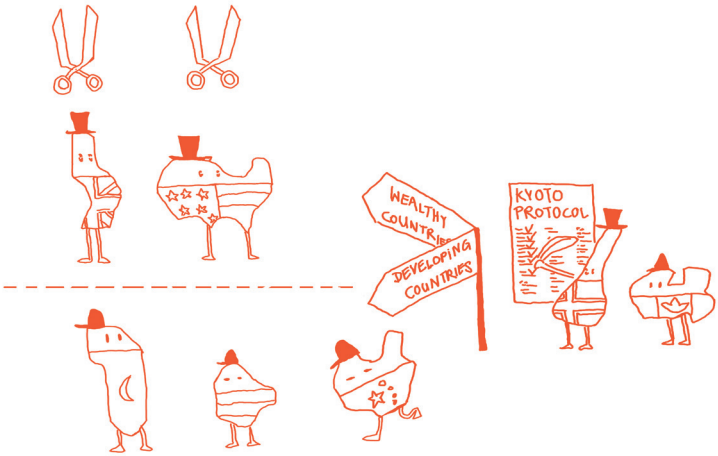
1.) 1992, United Nations

In 1990, the IPCC published its first climate report stating that greenhouse gas emissions are responsible for at least half of the observed warming in the 20th century. At the 1992 Earth Summit on Sustainable Development in Rio de Janeiro, this knowledge leads to establishing a political body: the United Nations Framework Convention on Climate Change (UNFCCC). Its role is to agree on stabilising greenhouse gas concentrations in the atmosphere at levels that would prevent dangerous consequences.

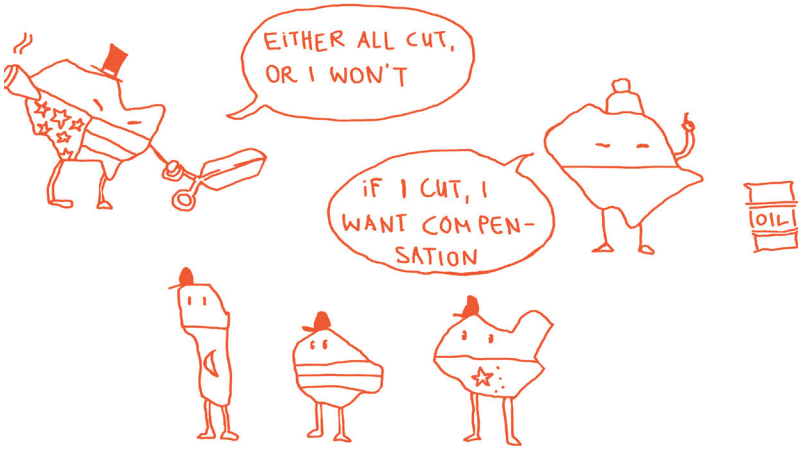


2.) 1997, Kyoto

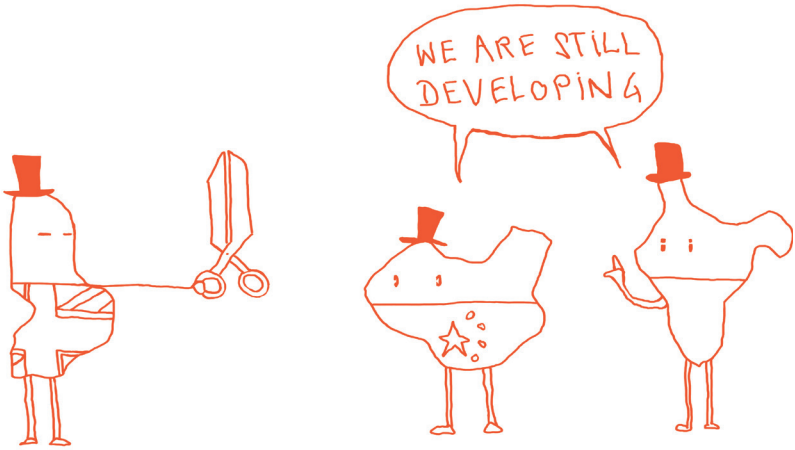
After that, the government representatives are meeting at the so-called Conference of the Parties (COP). In 1997, they signed the Kyoto Protocol, an international treaty that commits the wealthy, industrialised countries to reduce greenhouse gas emissions.



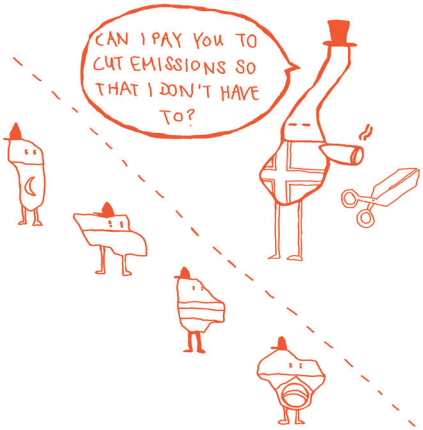
3.) However, the following years bring many troubles in implementing the Kyoto protocol. Some wealthy countries, most notably the USA, do not agree any more on emission cuts unless all countries, also the developing ones, are bound to cut.



4.) Most notably, this argument is used by China and India, developing countries that over time have become larger greenhouse gas emitters than the USA or the EU.



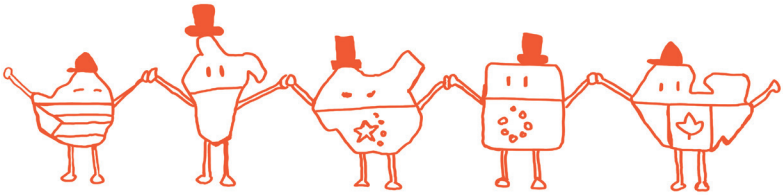
5.) The Kyoto protocol allows countries to reduce part of their emissions outside of their borders by cheaper investments in developing countries (the so-called Clean Development Mechanism). However, the developing countries don't want to cut emissions either.



6.) Thus, unfortunately, the Kyoto protocol doesn't prove itself as very effective. Despite the greenhouse gas reduction targets, greenhouse gas emissions continue to increase exponentially. All countries admit that more has to be done to protect the climate, but nobody wants to take concrete action.

7.) 2015, Paris

Eighteen years after the Kyoto protocol, the countries, at last, come to an agreement at the 21st COP in Paris. They commit themselves to keep the global average temperature increase well below 2°C compared with preindustrial temperatures and to pursue efforts to limit it to 1.5°C, which would significantly reduce the risks of climate change. The agreement is signed by all member states of the UN Framework Convention on Climate Change.*[28]*



8.) World until 2020

In the meantime, there are mixed developments on climate action. The European Green Deal is adopted in the European Union, aiming to achieve a sustainable European economy and turning environmental and climate challenges into opportunities. The US resigns from the Paris agreement under the administration of Donald Trump, who actively fights against climate and environmental regulations. In 2020, the newly elected president of the US, Joe Biden, promises a more active role of the US in pursuing ambitious climate targets. At the same time, China announces a bold strategy for reaching carbon neutrality by 2060.

Moreover, in 2018, Swedish teenager Greta Thunberg starts with a school strike for climate. This grows into a powerful movement called Fridays For Future, and helps put climate on the forefront of the public and media attention.

Despite being overshadowed by the COVID-19 pandemic in 2020, the new climate movement, together with recent ambitious political climate pledges, gives hope that the world can avoid the worst consequences of climate change through collective action.

Tweet

Tonald J. Drump

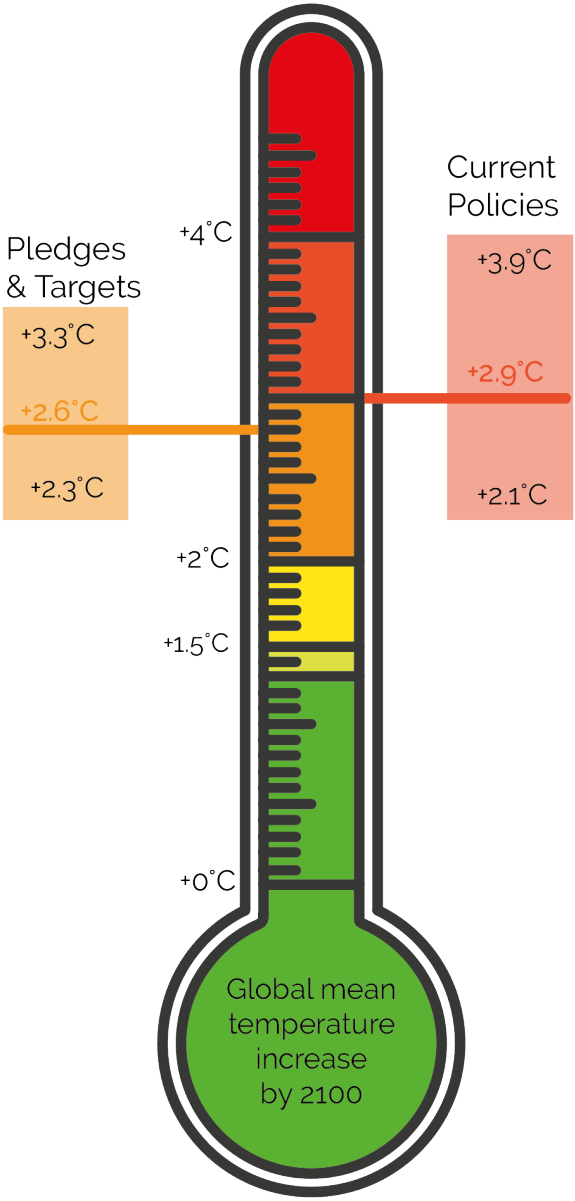
It's freezing outside, where the hell is "global warming"??

7:00 PM · 25 May 2013 · Twitter for Android

25 k Retweets **25,8 k** Likes

9.) Where are we going?

Can we estimate what the temperature will be in 2100, considering the current greenhouse gas emission trends and the political commitments made by now? Yes, we can. With the help of current climate models, we come to a value of 2.9°C of warming (with an uncertainty range between 2.1°C and 3.9°C). This value is much higher than the 1.5-2°C range aimed for by the Paris agreement.



Global mean temperature increase by 2100.[29]

4.3. Renewables

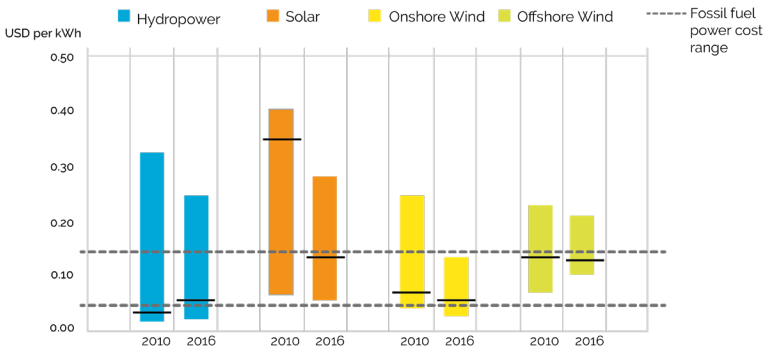
Humankind would never have made such a development and the jump from an agriculture-based society towards the industrialised and finally the current digitalised world without the help of fossil fuels. Yet, the large demand for fossil fuels is responsible for the biggest portion of both the current climate change and broader environmental and health problems. As an example, the companies with the highest global historical CO_2 emissions are oil corporations.

Entity	Percent of global emissions 1751-2010
1. Chevron, USA	3.52 %
2. Exxon Mobil, USA	3.22 %
3. Saudi Aramco, Saudi Arabia	3.17 %
4. BP, UK	2.47 %
5. Gazprom, Russian Federation	2.22 %
6. Royal Dutch/Shell, Netherlands	2.12 %
7. National Iranian Oil Company	2.01 %
8. Pemex, Mexico	1.38 %
9. Conoco Phillips, USA	1.16 %
10. Petroleos de Venezuela	1.11 %

Top ten investor- & state-owned entities and their attributed CO_2 & CH_4 emissions.[30]

While the fossil fuel share to energy production remained constant at about 80% in the last decades, we currently find ourselves at the beginning of a major shift in energy production worldwide. Will renewables be able to power the future world?

The cost of renewable energy technologies



The total costs of renewable energy technologies have become competitive with fossil fuels.[31]

Once a renewable power plant is installed, it produces energy for free (except for necessary maintenance). The sun, wind, and rivers don't bill us.

4.3.1. Hydropower

Hydropower is the only 'traditional' renewable energy source, exploited for electricity generation since the early beginnings of power supply in the 19th century. Its share in electricity production has been steady at about 15-20% of the total, and it is one of the cheapest energy sources.[32] However, it is a viable energy source only in regions rich with flowing water: the plant is in general connected to an artificial lake, which covers a large surface area. Therefore, conventional hydropower's potential cannot grow indefinitely and has already reached values close to its maximum in some of the developed countries. Moreover, the accumulation lakes are a significant source of methane, a strong greenhouse gas, which increases hydropower's climate impact.[33,34]

In summary, while there is still lots of potential for new hydro plants, this is probably not the resource that can lead to the energy transformation of the power supply.

4.3.2. Wind

Wind energy is rapidly increasing its electricity production share in parts of the world with strong enough and constant winds. We find these regions most commonly along the shores, or even over the oceans (offshore) with more favourable wind conditions.

In particular, the Northern Atlantic, its coasts, and adjacent seas proved to be able to generate a large share of wind power production. New technologies and investments significantly reduced the price of wind power production. For example, the price of offshore wind power in the UK has been halved in only two years, making it a cheaper energy source than most non-renewables.*[35]*

A recent study pointed out that North Atlantic wind farms could supply all of Europe's electricity even in situations of weak winds, while on an annual mean basis, 'the wind power in the North Atlantic could be sufficient to power the world'.*[36]*

4.3.3. Solar energy

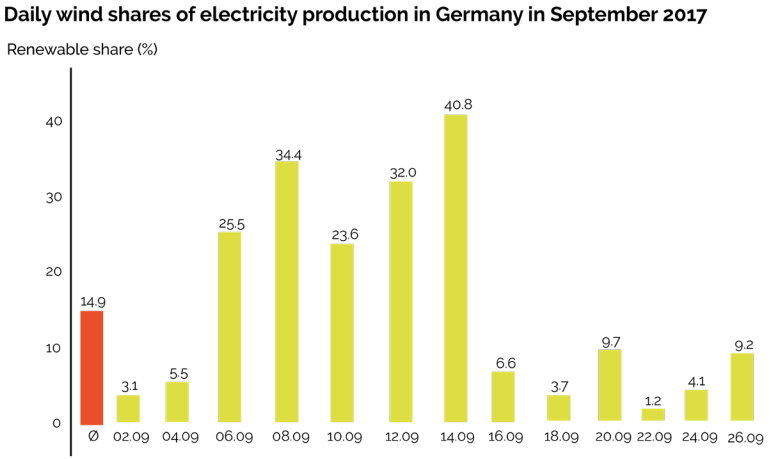
'Solar PV is on track to be the cheapest source of new electricity in many countries'.*[37]* The Sun is the source of life and the driver of our climate. Can it become the driver of our civilisation too? The stakes are high. The cost of solar photovoltaic (PV) energy decreased by a factor of three in only six years, becoming competitive in terms of energy production costs to fossil fuels.

Both solar and wind power are fully carbon neutral after they are installed, while even taking their whole production cycle into account, they have a 10 to 100 times smaller carbon footprint than fossil fuels.*[38]*

Interestingly, an area of the size of 500 × 500 km (similar to the size of the United Kingdom) with a 20% efficiency could generate

enough power to meet the whole world's power demand. While this indeed is not (yet) a technically viable idea, it illustrates the fascinating potential of solar energy production.
Moreover, solar photovoltaics can decentralise the power market, making each house owner largely energy independent. A nice prospect, isn't it?

4.3.4. Caveat – power grid



Daily wind share in electricity production in Germany. The share can reach levels of up to 50% and drop to 5% within hours.[39]

Renewable energy production, in particular, wind and solar energy are, as distinct from fossil fuels, quite unstable sources of energy. Imagine a sunny day with lots of wind in Germany, where the share of both wind and solar energy is one of the highest in Europe. The energy supply peaks at high levels, beyond the German energy demand. The German power grid, therefore, has to, at least for a couple of hours, deal with an oversupply of energy, driving the prices towards zero or even below it – people would be paid for consuming electricity!

In contrast, the opposite situations, for example, a very calm winter day, imply a large energy supply deficit.

A high share of renewables, therefore brings new challenges to grid operators. The power grid must be made more flexible to sustain large fluctuations in power supply and transport electricity to where it is needed. However, there are immediate solutions in sight too: in large energy supply situations, one could consume energy by pumping water to higher laying reservoirs. Conversely, in situations of poor wind and solar power production, the pumped water could be discharged, providing hydropower to fill the energy gap.

However, we are also experiencing the rapid electrification of the transportation sector, which might further increase the power demand and decrease air pollution levels. While change is possible, we urgently need to act on all levels to achieve it fast enough!

And, do not forget that … The cheapest energy is the energy we don't use!

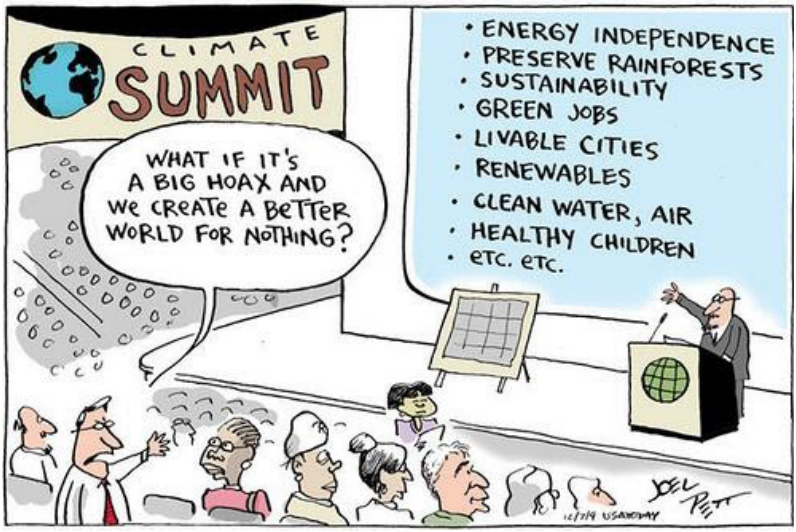
The developed world has some low hanging fruit to pick: there are still large potentials to cut our energy consumption! For instance, better insulation of houses and the implementation of smarter cooling systems can be achieved without undertaking large investments into renewables.

4.4. And what if climate change turns out not to be as bad as projected?

What if many of our climate projections turn out to overstate the damaging impacts of human-made changes to the climate? What implications would that have for us? Would we need to draw dramatically different conclusions on the actions we need to take? Nope – not true, the main conclusions about the directions the society needs to take would remain the same, because:

1. In today's fossil fuels addicted world, the countries that possess large oil and natural gas reserves have a major influence on global politics. It is just a matter of their interests about how much of their resources they export and at what price. In this kind of world, individual countries cannot just rely on their own resources but are often totally dependent on the lucky petrol owners, and this would continue to be so with the unlimited continuation of fossil fuel consumption. This means an increase of local renewable energy sources would promote a country's independence from pressures from big oil and gas producers and not depend on shaky oil prices but rather have a more independent power market.

2. Burning of fossil fuels, particularly coal, represents a danger for climate and the health of inhabitants and ecosystems close to the power plants. In countries with less strict environmental regulations we unfortunately still have problems similar to the ones Europe or North America have been facing in the mid-20th century (like, for example, smog).



Cartoon by Joel Pett for USA Today. 2009.[40]

5. CONCLUSIONS

5.1. Wind of change

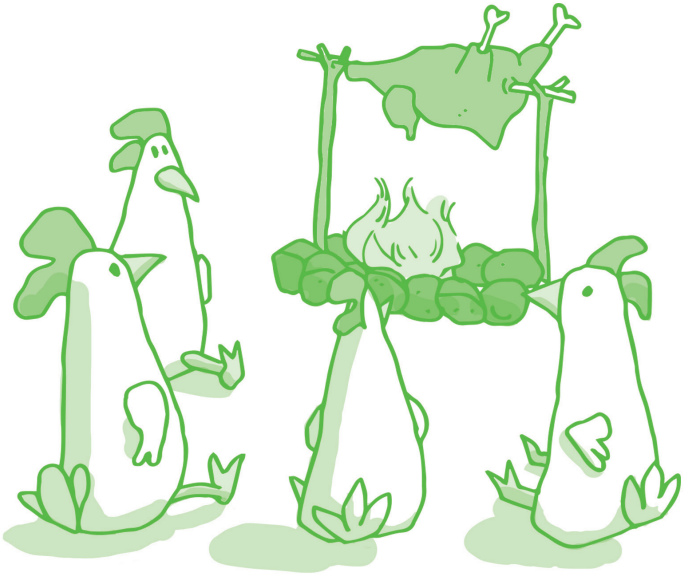
Within a century, our society made giant steps from carriages to aeroplanes, from the first motorised vehicles to the International Space Station. We defeated numerous previously perilous diseases, doubled life expectancy and quadrupled the population. At the same time, we also increased our energy consumption by more than a factor of 10. Likewise, carbon emissions increased, closely bound to global economic growth. Economic crises occasionally slowed the rise in emissions, but never stopped it.

However, this trend seems to have been reversing for more than a decade, when the global economic growth rose about twice as fast as carbon dioxide emissions. From 2014 to 2016, carbon dioxide emissions even stayed constant despite continued economic growth. For the first time, economic growth and carbon dioxide emissions seem to be decoupled.*[41,42]* Something interesting happened in spring 2020 after the global COVID-19 pandemic and lockdown measures taken by many governments. Global CO_2 emissions decreased by 7% in 2020 compared with the mean 2019 levels.*[43]* Consequently, the world may have already surpassed the peak in greenhouse gas emission, particularly if the economic recovery from the pandemic will be focused on sustainability. This might avoid a global warming of over 2˚C, in accordance with the climate targets agreed on the Paris climate conference in 2015.*[44]*

Moreover, while about a decade ago the price of electricity from renewables seemed to be prohibitively expensive compared to traditional sources like coal or oil, human ingenuity found a way to make renewables today economically competitive to the carbon-intensive sources of energy, and this was done with only a little political help.

The future is here. Soon society will no longer be powered by non-renewable fossil fuels but will be running on renewable power! But how soon is soon? Will this be soon enough to prevent damaging changes to humans and ecosystems? Probably not. Well, at least not without your help. Don't just wait for changes to come by themselves or from the side of the policy. We cannot deny that the problem is imminent and complex. We need to transform the way our society is powered, but not only that. We need to redistribute part of the huge influence and power from the fossil fuel companies to the people. We need to convince the policymakers about the urgency of the problem. And we need you to help here – only criticising or even suggesting changes will not be enough. We need you to act!

5.2. What can I do?



Looking at the problem is not enough.

5.2.1. Save

Even though climate change is a global problem, we can all contribute to solving it (or make it less bad, at least) by reducing our own greenhouse gas emissions. This doesn't mean that we have to live in caves and eat raw potatoes every day. Even small changes in the way we live, without big sacrifices, can have a large impact. At the same time, we can even save some money.

1. Recycle! Recycling aluminium consumes 20 times less energy than making aluminium from raw materials. Recycling paper is estimated to decrease the energy consumption for about 60% compared with the production of new paper.*[45]*

2. Dress warmer and decrease the heating or cooling level in

your flat by 1˚C.

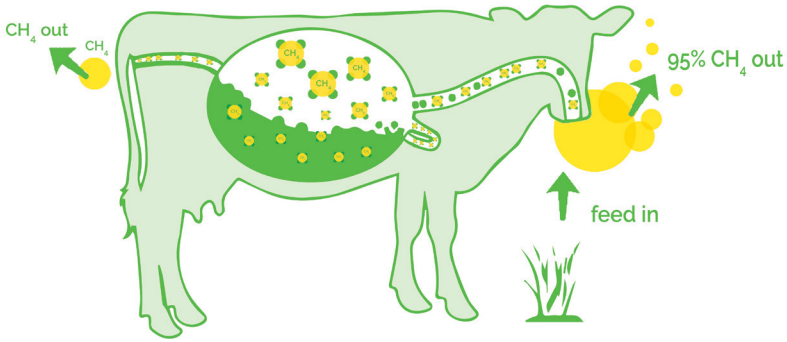
3. About 20% of the CO_2 emitted in the EU comes from road transport. By using public transport, cycling, or walking, you can save CO_2, money, and nerves.

4. Try to avoid flying with an aeroplane when possible. Consider other public transport options (trains, busses, car-sharing, active mobility) for travelling less than 1000 km. Keep in mind that only one tropical vacation a year can even double your annual CO_2 footprint.

5. Turn the lights off when you don't need them. Households represent 30% of the electricity consumption in the EU, thus saving part of it can have quite a big impact on the overall electricity consumption.

6. Buy local and seasonal food and reduce emissions related to long-distance transport and refrigeration of food that has grown far away. In this way, you will also directly support the farmers of your region.

7. Eat less meat and other animal products, especially red meat. Animal products require several times as many resources (water, land) as plant products do, and they have a significantly larger carbon footprint.*[46]* Besides, cows also emit significant amounts of methane, which is a strong greenhouse gas. Starting by reducing only your red meat (beef, lamb) consumption can already lead to a significant reduction in your personal ecological footprint.*[47]*



Our demand for beef results in an increased number of cows, which results in more methane (CH_4) because of their farting.[48,49]

8. When buying a new device or appliance, decide for an energy-efficient one. You can easily find them – they are labelled 'A+' or even 'A++'. This is a well-accepted energy certificate proving the energy efficiency of a device.

9. Heating and boiling of water consume a lot of energy. For example, heating water from 20°C to 100°C consumes the same amount of energy as lifting this water from sea level to 34 km (almost four times the height of Mount Everest!). Heat only the amount of water you really intend to consume! Also, put a lid on the pan when you heat water or, even better, use an electric kettle.

10. Showering (if not for too long ;)) uses much less hot water compared to bathing.

11. Second-hand first. Instead of buying new furniture, electrical devices, clothes, etc. (all of which need energy for their production), you can get high-quality products on the second-hand market. Also, if you don't need a certain product anymore, don't throw it away. Someone else might like to have it.

12. Before buying something new, think about whether you really need it. If the answer is no, just don't buy it. If the answer is yes, be aware that there is a wide variety of products that look/work almost the same. Try to get the product, which is most environmentally friendly, for instance, those with the European environmental logo or Forest Stewardship Council (FSC) label.

13. Do not leave your windows open for too long when you are getting some fresh air in winter, and the heating system is on. Instead, open the windows completely for a short time instead of keeping the windows slightly opened for longer.

14. Buy energy-efficient light bulbs that last longer and consume about five times less electricity compared with standard ones.

15. Do not leave your electrical devices on stand-by mode – turn them completely off. If all of the EU inhabitants decided not to have any device on stand-by, this would save about 10% of the total residential electricity consumption*[50]*, equivalent to the amount consumed by the whole of Belgium.

16. Plant a tree in your garden, your neighbourhood, at school. A tree can store more than 1 ton of CO_2 in its lifetime (about 1/8 of the annual CO_2 emissions of an average inhabitant of the European Union).

17. When buying a new car, think about its energy efficiency. This will save you a large amount of money and considerably decrease your personal CO_2 emissions.

18. If you can, install solar panels or thermal collectors on your roof. In this way, you can directly contribute to a renewable energy system.

5.2.2. Inform

Education is the engine of progress. If people are better informed about global warming, they are more likely to act against it, by reducing their own CO_2 emissions, speaking up for stricter environmental standards, working out low-emission strategies, and so on. The support of people is essential for a turn towards a CO_2-neutral economy.

Education doesn't only happen in classrooms, but it can happen everywhere. You as a friend, schoolmate, sister or brother, daughter or son can inform the people around you. Here are some examples of what you can do:

1. Be informed yourself, so you can disprove false arguments and answer questions on the currently very important and much-discussed topic of climate change (see also Section 6 on climate change myths).

2. Inform yourself and others about where your spending goes. Find out if your bank, pension fund, products, and services you are paying for are investing in dirty fossil fuels. You and your spending are part of a big puzzle, and even your small financial decisions can make a difference in the global effort of divesting money from fossil fuels.*[51]*

3. Inform yourself and others about the climate action plans of your elected local and national politicians. Electing responsible political parties and candidates is very important for climate action and environmental sustainability.

4. Inform yourself and others about where your electricity comes from and what percentage is coming from renewable energy sources. Find out the potential of your country and area to balance a stable energy supply with the most renewable energy possible.

5. Advocate for more effective climate change and energy policies with a positive effect on the environment and society.

6. Organise campaigns and round tables and invite experts to discuss the climate change phenomenon.

7. Raise awareness among people (especially the young generation) about the negative effects of climate change and what can be done about them.

Finally, one educational tool is also the booklet you have in your hands, believe it or not! Once you have skimmed through and finished using it, please share it with a friend rather than throwing it away. Or leave it at a public place where someone else will be able to check it when waiting for the bus/dentist/a friend.

5.3. CLIMATE CHANGE MYTHS

It is healthy to be sceptical in life, at least as long as the scepticism is based on established facts and well-founded arguments and not following an ulterior motive (for example, not wanting to feel bad about flying to London for a weekend). Unfortunately, the opposite is often the case in the context of climate change, where people cling to false arguments convincing them that they are not responsible and everything is fine. Here are some popular examples of such climate change myths and balanced responses (following skepticalscience.com).

- Climate has changed before.

This is true, and we know that most of the rapid climate changes were linked to changes in greenhouse gas emissions – like today – and were often highly destructive to life on Earth. The human emissions today increase at a rate much faster than natural emissions increased during any of the past rapid climate changes, and will likely have unprecedented consequences.

- It's the Sun.

The Sun is indeed an important driver of Earth's climate. However, over the last ~35 years, the Sun's energy has been decreasing, while the Earth has been warming. This means that the Sun cannot be the main cause of the current warming on Earth.

- Global warming is not bad.

Negative impacts (rising sea levels, melting glaciers putting water supply of millions in danger, collapsing ecosystems, more extreme weather, worse air pollution, etc.) by far outweigh any positive impacts global warming may have.

- There is no consensus.

Ninety-seven per cent of all climate experts agree that humans are the cause of the current global warming. Imagine you consult five different doctors, and four of them (so 80%) say you are ill and urgently need to have an operation, while one says all is fine and you don't need to do anything. Would you go for the operation or not?

- It's cooling.

While it is true that global warming slowed down between 1998 and 2012, multiple studies attributed this unusual period to natural oscillations/natural variability.*[52]* However, the warming resumed its pace in recent years. The year 2016 was the warmest year since the beginning of temperature measurements around 1880, with 1.02˚C above the 1951–1980 average.*[53]* It was the third year in a row setting a new record for global average temperatures, following 2014 and 2015. The year 2020 will likely tie with 2016 as the warmest year on record.*[54]*

- Climate models are unreliable.

Climate models are different from weather models – they predict long-term trends, not single events. For specific days, the models may considerably overestimate or underestimate temperature, but this internal variability averages out in the long-term. The models successfully reproduce the temperature trends observed

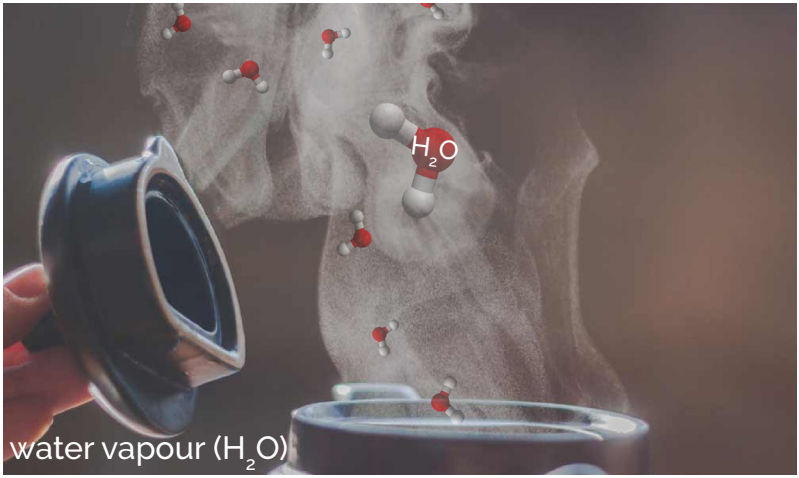
in the 20th century. This means that they capture the physical mechanisms relevant for long-term trends and are a reliable tool to project climatic conditions into the future.

- The temperature record is unreliable.

There are about 30,000 stations measuring surface temperature all around the world. 7,000 of these stations have long records, and they all show a clear warming trend.

- Water vapour is the strongest greenhouse gas.

This is true, but it doesn't affect the role of other greenhouse gases but vice versa: with global warming (due to the other greenhouse gases), the air can take up more and more water vapour, which further enhances the warming. Thus, the other greenhouse gases turn water vapour into an even stronger greenhouse gas.



water vapour (H_2O)

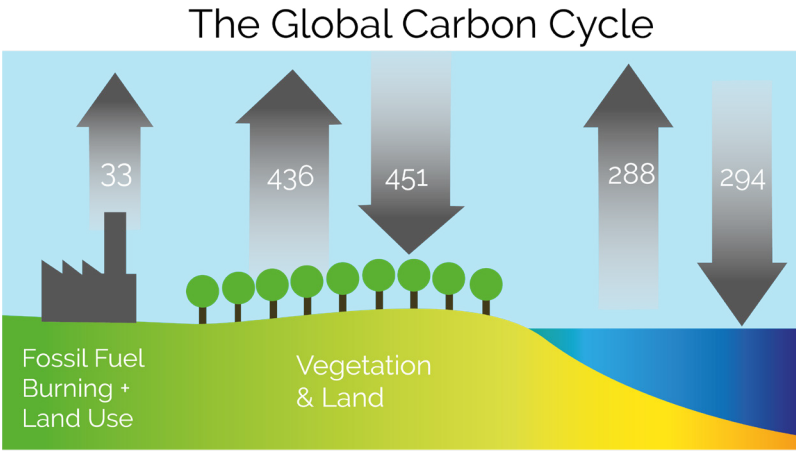
- There is no correlation between CO_2 and temperature.

Short-term climate variability can lead to cooling periods despite increasing CO_2 emissions (as observed, for example, in 2002-2008). However, there is a clear long-term correlation between the CO_2 concentration and global average temperature.

- Glaciers are growing.

Some may be, but most (~90%) of glaciers are retreating. This poses serious problems to many countries that rely on glaciers for water supply, and contributes to rising sea levels.

- Human CO_2 emissions are only a tiny part of all CO_2 emissions.



Sources and sinks of carbon dioxide in units of Gt of CO_2/year.[2]

The natural CO_2 sources are balanced by natural CO_2 sinks. Despite accounting for only about 4% of the total, human CO_2 emissions bring this equilibrium out of balance, like the straw that breaks the camel's back. They are the source of the additional 35% of CO_2 that accumulated in the atmosphere since preindustrial times (that is, for the increase in its concentration from 270 to 400 ppm).

- It was very cold today, where is climate change?

Weather events must not be confused with long-term climate trends. Cold days, months or even years are part of natural variability. They have nothing to do with the long-term trend showing increasing global temperatures. It is like trying to guess whether the tide is rising or falling by looking at the height of individual waves. The waves mask the slow change of the tide, as weather can mask the slow change of climate.

- CO_2 is not at record level.

True, CO_2 concentrations were often higher than today until ~3 million years ago, and global temperatures were still sometimes lower (for example, ~450 million years ago when there was a short ice age even though CO_2 levels were high, likely above 2000 ppm). How is this possible? It is important to consider all factors determining the global temperature. That is, apart from the level of greenhouse gases, also the energy of the Sun. At that time, the Sun was 4% dimmer than today. This raises the CO_2 threshold for glaciation to 3000 ppm, meaning that if CO_2 falls below 3000 ppm, an ice age is possible.

- It's a natural cycle.

Climate changes are the result of changes in Earth's energy balance. This doesn't happen by itself but requires an external force, such as changes in solar activity, volcanic eruptions or atmospheric greenhouse gases. There is no known forcing that fits the fingerprints of global warming, except human greenhouse gas emissions.

- Scientists can't even predict the weather.

Weather and climate are different. Weather is chaotic and thus difficult to predict more than 10 days ahead. Climate is the statistics of weather over time. This removes the chaotic element and thus enables predictions over many years. It is like tossing coins. Predicting whether one specific coin will land on its heads or tails is difficult, but it is possible to estimate the average number of heads and tails over a very large number of tossed coins.

- CO_2 is good for plants.

It is true that plants need CO_2 for photosynthesis and thus for their growth. In this sense, its increase would be beneficial. But they also need other elements to grow, for example, water. Due to global warming, the frequency of severe drought is increasing, which reduces the water supply for plants.*[1,2]* Thus, the overall effect of increasing CO_2 emissions on plants might not be positive at all.

- Polar bear numbers are increasing.

After a restriction on the hunt of polar bears in 1973, polar bear numbers increased temporarily. However, today, polar bear numbers are on average declining, and the species is in danger of extinction. This is because polar bears depend on sea ice for easier hunting for food (e.g. seals) and also other aspects of their life. The retreat of Arctic sea ice decreases their opportunities to hunt and build up fat reserves. Furthermore, due to the reduction and fragmentation of the sea ice, they have to swim longer distances, and there are fewer seals, which are the polar bears' main source of food.

How many climate skeptics does it take to change a light bulb?*[55]*

Glossary

CO_2 = carbon dioxide
CH_4 = methane
IPCC = Intergovernmental Panel on Climate Change; a United Nations body, aiming at the selection and publishment of most updated reports on climate
UNFCCC = United Nation Framework Convention on Climate Change
COP = Conference of the Parties
ppm = parts per million, the measure of the share of a certain gas out of the total atmospheric gas content

6.
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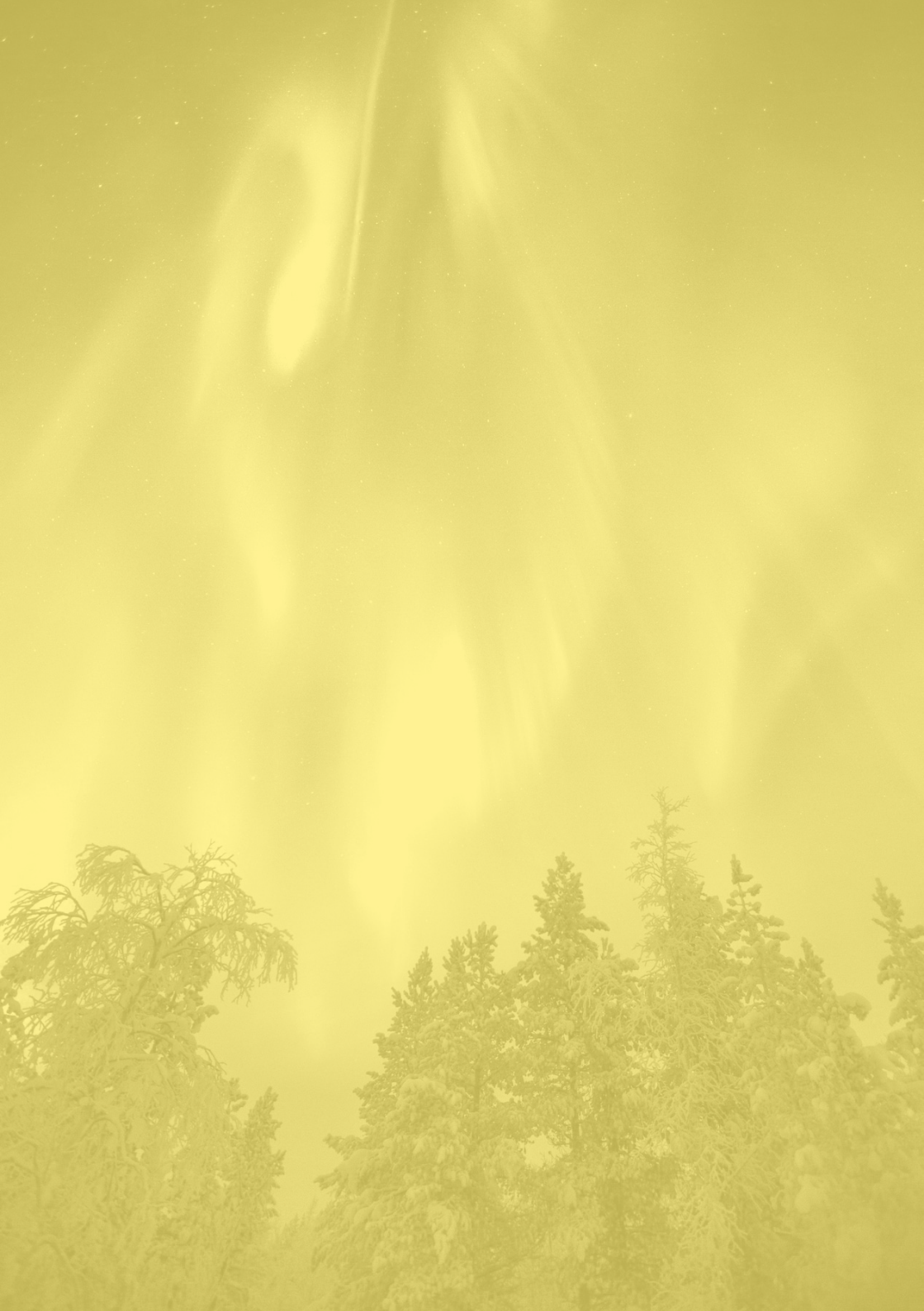

Notes


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Mahatm


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