FAQ:
Past & Future Climates

December 2019

During the *Summer Meeting In Lausanne Europe* (SMILE, 05.-09.08.2019), young activists from Fridays for Future asked questions about the climate crisis. These were collected and then answered by experts who attended the meeting and others who are engaged with Scientists for Future. At the end of the document, you find a list of the people who were involved.

The questions have been organized in different documents by topic. This document answers questions about the climate on the past and how it will develop in the future.

Feel free to read, reuse and share them with friends, parents, teachers, neighbours, colleagues.

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What will happen in a warmer world?

The answer depends on how warm it will get and this depends very much on how fast the world decarbonizes.

It will be really bad. The IPCC in its special report on a global warming of 1,5° from October 2018 outlines what could potentially happen in case of a business-as-usual-scenario in which global heating exceeds 2 degrees (full report, p. 280):

"… Global warming of 1.5°C is reached by 2030 … . Starting with an intense El Niño–La Niña phase in the 2030s, several catastrophic years occur while global warming starts to approach 2°C. There are major heatwaves on all continents, with deadly consequences in tropical regions and Asian megacities, especially for those ill-equipped for protecting themselves and their communities from the effects of extreme temperatures. Droughts occur in regions bordering the Mediterranean Sea, central North America, the Amazon region and southern Australia, some of which are due to natural variability and others to enhanced greenhouse gas forcing. Intense flooding occurs in high latitude and tropical regions, in particular in Asia, following increases in heavy precipitation events. Major ecosystems (coral reefs, wetlands, forests) are destroyed over that period, with massive disruption to local livelihoods. An unprecedented drought leads to large impacts on the Amazon rainforest, which is also affected by deforestation. A hurricane with intense rainfall and associated with high storm surges destroys a large part of Miami. A two-year drought in the Great Plains in the USA and a concomitant drought in eastern Europe and Russia decrease global crop production, resulting in major increases in food prices and eroding food security. Poverty levels increase to a very large scale, and the risk and incidence of starvation increase considerably as food stores dwindle in most countries; human health suffers.

There are high levels of public unrest and political destabilization due to the increasing climatic pressures, resulting in some countries becoming dysfunctional. The main countries responsible for the CO2 emissions design rapidly conceived mitigation plans and try to install plants for carbon capture and storage, in some cases without sufficient prior testing. Massive investments in renewable energy often happen too late and are uncoordinated; energy prices soar as a result of the high demand and lack of infrastructure. In some cases, demand cannot be met, leading to further delays. Some countries propose to consider sulphate-aerosol based Solar Radiation Modification (SRM); however, intensive international negotiations on the topic take substantial time and are inconclusive because of overwhelming concerns about potential impacts on monsoon rainfall and risks in case of termination. Global and regional temperatures continue to increase strongly while mitigation solutions are being developed and implemented.

Global mean warming reaches 3°C by 2100 but is not yet stabilized despite major decreases in yearly CO2 emissions, as a net zero CO2 emissions budget could not yet be achieved and because of the long lifetime of CO2 concentrations. The world as it was in 2020 is no longer recognizable, with decreasing life expectancy, reduced outdoor labour productivity, and lower quality of life in many regions because of too frequent heatwaves and other climate extremes. Droughts and stress on water resources renders agriculture economically unviable in some regions and contributes to increases in poverty. Progress on the sustainable development goals is largely undone and poverty rates reach new highs. Major conflicts take place. Almost all ecosystems experience irreversible impacts, species extinction rates are high in all regions, forest fires escalate, and biodiversity strongly decreases, resulting in extensive losses to ecosystem services. These losses exacerbate poverty and reduce quality of life. Life for many indigenous and rural groups becomes untenable in their ancestral lands. The retreat of the West Antarctic ice sheet accelerates, leading to more rapid sea level rise. Several small island states give up hope of survival in their locations and look to an increasingly fragmented *global community for refuge. Aggregate economic damages are substantial, owing to the combined effects of climate changes, political instability, and losses of ecosystem services. The general health and wellbeing of people is substantially reduced compared to the conditions in 2020 and continues to worsen over the following decades."*

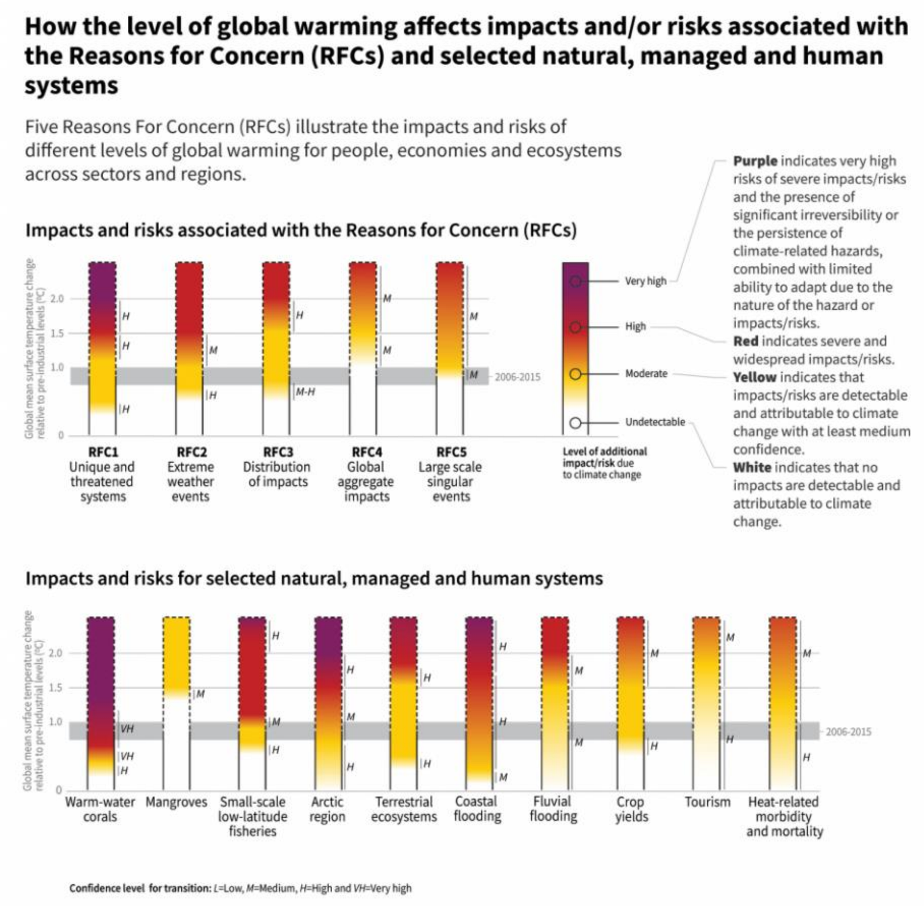
All of the claims made above are supported by science detailed in the aforementioned report. Evidently, some events may occur earlier or later, or with less or more severe impact. But it is firmly supported by science that failing to limit global heating means terminating human civilisation.

There is a similar question in the FAQ of IPCC special report on 1.5°:

" FAQ 3.1: What are the Impacts of 1.5°C and 2°C of Warming?

Summary: The impacts of climate change are being felt in every inhabited continent and in the oceans. However, they are not spread uniformly across the globe, and different parts of the world experience impacts differently. An average warming of 1.5°C across the whole globe raises the risk of heatwaves and heavy rainfall events, amongst many other potential impacts. Limiting warming to 1.5°C rather than 2°C can help reduce these risks, but the impacts the world experiences will depend on the specific greenhouse gas emissions 'pathway' taken. The consequences of temporarily overshooting 1.5°C of warming and returning to this level later in the century, for example, could be larger than if temperature stabilizes below 1.5°C. The size and duration of an overshoot will also affect future impacts."

The figure below shows what will happen in a warmer world depending on the amount of global mean-surface temperature change relative to the pre-industrial level.



More information in FAQ in the 1.5 degree Report:
https://www.ipcc.ch/site/assets/uploads/sites/2/2018/12/SR15_FAQ_Low_Res.pdf (page 13)

What are the consequences of climate change?

Note from reviewer (FM):
This question is too general to be answered in one page. While the answers below are accurate and follow the general consensus from the IPCC reports, they are a subjective choice of a subset of all possible consequences. It must be noted that there are some positive consequences as well, but they are far outweighed by the negatives.

Climate Change means changes in average temperature, precipitation amounts, etc., but it also means that more extreme events become more frequent and more extreme. Droughts, storms, floods, hurricanes etc can have disastrous immediate consequences and they can be very costly in the short term. On a long term, changes in average conditions can for instance lead to the south of Europe (mediterranean region) not receiving enough rain to maintain its (water intensive) vegetable and fruit production, the Alps not having enough snow for skiing, etc. There are effects on natural systems (e.g. glaciers melting, plants, animals and pest spreading to new regions) and on managed systems (agriculture, forestry, tourism, hydropower, etc.) and there are indirect effects, e.g. the war in Syria, that is partly due to a 6-year drought. Migration is one form of indirect effect. One of the effects of average temperature rise is sea level rise - due to warming and expansion of the water and due to landbound ice melting. By the end of this century, sea level is expected to be about 90 cm higher (IPCC 2014) with a possibility of it being more than 2,5 m higher (Hanson et al. 2016)

While this is probably not the right place for longer explanations that you most will know, I like to sort some main effects of warming in three regional aspects:

a) Polar Regions

- sea ice made up of salt water melts, leading to even further heating due to lower albedo – water absorbs more of the insolation than reflective ice;
- land ice made up of fresh water melts, starting in Greenland and West Antarctica, leading to drowning of coastal areas under higher sea level; with the drawback that once the Greenland ice started to melt, the elevation of the surface will be lower, which corresponds to higher air temperatures, further increasing the meltdown.
- permafrost melts, with the potential release of large amount of methane buried within and beneath, which further increases heating.
- similar results for methane gas hydrates
- Jetstream (in higher atmosphere) and gulf stream (Atlantic water circulation) may be displaced, leading to modified local weather patterns

b) Oceans

- higher temperatures lead to higher evaporation leading to stronger rainfall, floods
- stronger hurricanes
- mass extinction of wildlife, including coral reefs destroyed by temperature rise and acidification
- acidification due to climate change impacts marine wildlife
- raise of sea-level

c) Land masses

- higher temperatures lead to higher evaporation leading to lower humidity of soil, more wildfires, deserts grow
- growth of arable plants will be adversely affected by higher temperatures;

- lack of topsoil will limit increase of agriculture in higher latitudes, where temperature became suitable for it;
- larger parts of the tropics and some of the subtropics can become uninhabitable for humans during daytime;
- starvation;
- stronger extreme weather events and more events passing certain thresholds;
- loss of low-lying coastal areas and coastal cities;
- more floods due to extreme rain and hurricane storm surge;
- mass migration and attempts of more mass migration to higher latitudes;
- wars;
- mass extinction of wildlife;

Contributions:

- *Helga Kromp-Kolb, Center for Global Change and Sustainability, Vienna, Austria*
- *Joachim Falkenhagen, Diplom-Ökonom (Infos: www.j-fa.de)*

Is the situation as bad as or worse than what scientists are telling us?

Scientists are telling us (with high confidence) that human activities have caused approximately 1.0°C of global warming (above pre-industrial levels) and that global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate.

Scientists have been worried about climate change for a long time, and that worry has been increasing due to both increased understanding of how the earth system works, and the lack of action in reducing greenhouse gas emissions. However, a scientist's beliefs about the future depend not only on science, but how one believes people will act in the future and that is quite uncertain. Science agrees that the impacts of climate change are here now, the difficulty of avoiding dangerous climate change is increasing, but we are not doomed. The sooner greenhouse gas emission go to zero, the less damage the planet and people will experience. We can build the resilience of societies, cities, and ecosystems to reduce the damage caused by climate change.

International scientific assessments processes, such as the IPCC and IPBES, gather hundreds of scientific experts from around the world to periodically assess what the distribution and confidence of the latest knowledge is. One can learn about the current state of the science by reading these reports or their summaries.

See for example: IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.

Answer provided by Alasdair Skelton, Professor of Geochemistry and Petrology , Stockholm University Stockholm, Sweden and members of the university's **Researcher's Desk**, Alasdair.Skelton@geo.su.se

How to limit global warming to 1.5°C?

We must stop emitting greenhouse gases as quickly as possible.

More specifically, global net anthropogenic CO2 emissions must decline by about 45% from 2010 levels by 2030, reaching net zero around 2050.

This requires rapid and far-reaching transitions in energy, land, cities, buildings, transport and industrial systems. These transitions are unprecedented in terms of scale, but not necessarily in terms of speed.

In addition, we need to remove several hundred billion tons of CO2 from the atmosphere. To achieve this goal, the protection and restoration of forests on a global scale is very important.

Pathways to achieve 1.5° are nicely shown in the IPCC special report 1.5° (2018): *"Limiting warming to 1.5°C implies reaching net zero CO_2 emissions globally around 2050 and concurrent deep reductions in emissions of non-CO_2 forcers, particularly methane (high confidence). Such mitigation pathways are characterized by energy-demand reductions, decarbonization of electricity and other fuels, electrification of energy end use, deep reductions in agricultural emissions, and some form of CDR with carbon storage on land or sequestration in geological reservoirs. Low energy demand and low demand for land- and GHG-intensive consumption goods facilitate limiting warming to as close as possible to 1.5°C.*

Contributions:

- *Günther Beikert*
- *Deborah Detka and Lilian Schuster, master students in atmospheric sciences, Innsbruck, Austria*

References:

- Facts taken from Headline Statements from the Summary for Policymakers from the IPCC special report on a global warming of 1,5°
- "What do Energy Supply and Demand have to do with Limiting Warming to 1.5°C" https://www.ipcc.ch/site/assets/uploads/sites/2/2018/12/SR15_FAQ_Low_Res.pdf (p.11)
- See also: Is it too late?

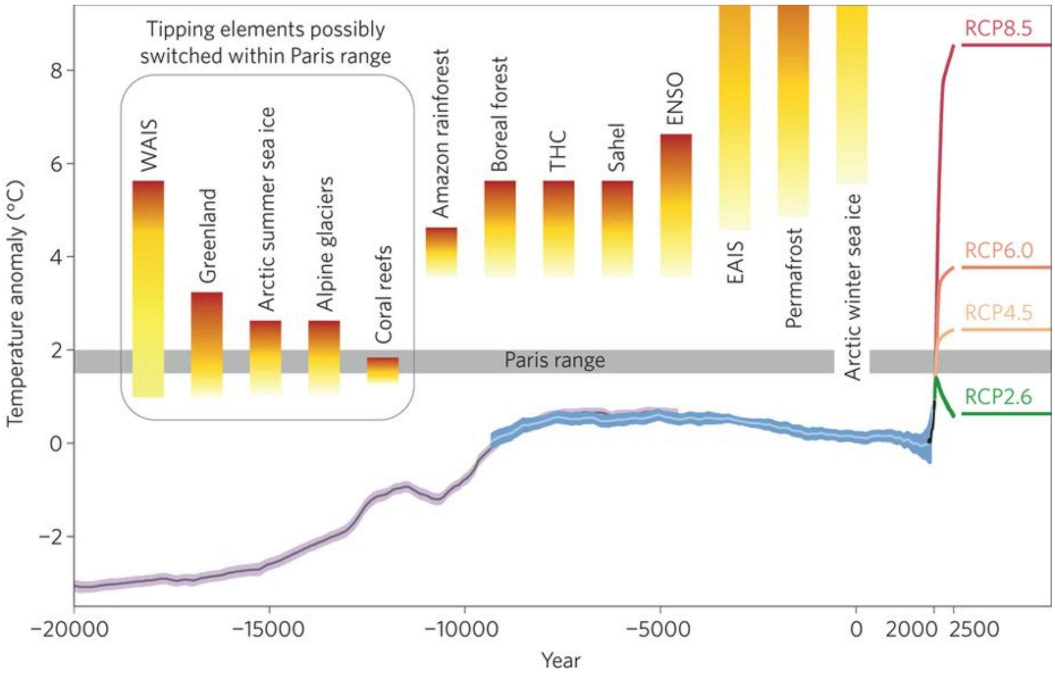
Is there a tipping point? When might / do we reach it?

There are many tipping points, and many are interleaved via feedback mechanisms. A good graphic illustrating the various tipping points can be found on the next page.

The bars for each tipping element essentially show the probability of exceeding a certain tipping point, according to current knowledge, for a given temperature rise. If you stay below the bar, the probability is zero, if you are above it is 100%. If you are in the middle, around 50%.

Figure 1 : Tipping elements in context of the global mean temperature evolution.

From: Why the right climate target was agreed in Paris



Shown is the global-mean surface temperature evolution from the Last Glacial Maximum through the Holocene, based on palaeoclimatic proxy data[35,36] (grey and light blue lines, with the purple and blue shading showing one standard deviation), instrumental measurements since 1750 AD (HadCRUT data, black line) and different global warming scenarios for the future (see ref. 37 for the latter). Threshold ranges for crossing various tipping points where major subsystems of the climate system are destabilized have been added from ref. 8, 14 and 37,38,39,40. (Note that we follow the tipping point definition of Lenton *et al.*[8] which does not require irreversibility, so that sea ice cover is included here.) The range for the West Antarctic Ice Sheet (WAIS) has been adapted to account for the observation that part of it has probably tipped already[10,11]. THC, thermohaline circulation; ENSO, El Niño–Southern Oscillation; EAIS, East Antarctic Ice Sheet.

The most important tipping point that we are certain to exist relates to the loss of the Greenland and the Antarctic ice sheets.

Greenland: If ice melts, the top of the ice sheet is in warmer air (it gets colder higher up as one knows from climbing a mountain). As it is in warmer air, it melts further and gets into even warmer air.

Antarctic: Most of Antarctic ice sheet ice is lost by sliding into the ocean. The amount of sliding depends on the thickness of the ice where it hits the ocean. Because of the way the land underneath the ice sheet slopes downward towards the South Pole in some regions, less ice sheet ice means that the ice is thicker where it hits the ocean, more ice is lost, etc. There is some uncertainty as to when these tipping points are reached, but most studies suggest this limits to be somewhere around 2 °C global warming. For most other tipping points, there is much less certainty that they exist, including the one related to hot-house Earth.

Knowledge about tipping points is less precise than for smaller changes in global temperatures, as experienced today. Researchers believe that if temperature increase to above 2° C global temperature, there is an increased risk of reaching such tipping points. This could mean that the increase cannot be stopped at, for example 2.5 or 3 degrees, even if anthropogenic carbon emissions were totally stopped, but would quickly rush to even higher temperatures "without return" for centuries or longer. There is, however, no safe limit. Even at 1.5° C warming, it could be possible that some tipping point was already trespassed and that mankind would not be able to stop warming there.

The question probably refers to the "point of no return" after which we will not be able to undo our mistakes.

According to the IPCC special report on a global warming of 1,5°, we will not be able to limit global warming to 1,5° if our emissions continue to rise until 2030.

According to Steffen et al. (Trajectories of the earth system in the Anthropocene), failing to limit global warming to 1,5° implies increasing the likelihood for "tipping cascades". At some (tipping) point, some parts of the earth system like arctic ice or boreal forests (called tipping elements) degrade and by their degradation fuel a further CO2 emission and/or earth heating (so called "positive" feedback). The interaction between the various tipping elements is then called the "tipping cascade". For example, permafrost thawing emits methane, which increases earth heating, which makes Amazon forest dieback more likely, which emits CO2 and reduces CO2 capture, which in turn might trigger the loss of the Antarctic ice sheet.

Contributions:

- *Stefan Rahmstorf, University of Potsdam, Head of Earth System Analysis, PIK*
- *Bernhard Steinberger, Geophysicist, GFZ Potsdam*
- *Dirk Notz, Max-Planck-Institute for Meteorology, Lead Author IPCC AR6*
- *Joachim Falkenhagen, Diplom-Ökonom*
- *Günther Beikert*

References:

Why the right climate target was agreed in Paris ***https://www.nature.com/articles/nclimate3013*** *good explanation about this paper and figure also in: http://www.realclimate.org/index.php/archives/2017/06/why-global-emissions-must-peak-by-2020/)*

Paper about tipping points: "Trajectories of the Earth System in the Anthropocene", https://www.pnas.org/content/115/33/8252 , summarized and explained in https://skepticalscience.com/pliocene-2018.html

How do we know how the climate looked like in the past? Like e.g. 3 million years ago.

Short summary of the answers below by the reviewer (FM):

The method and its accuracy depend on the time frame considered. But there are a few common themes in paleoclimatology (the study of past climates):

- the use of indirect climate indicators called "proxies": an example of a proxy is tree rings (thicker when the climate is such that trees can grow fast, thinner when not

- the need to date the proxies: when was this indicator recorded? Carbon 14 is a famous method but works only for certain age ranges. Other methods exist but may be less accurate.
- as a general rule of thumb: the further back we go, the less information we have and the less precise the indicators are. Our knowledge of how the climate was 3 million years ago is less good than the knowledge we have of how the climate was 2000 years ago.

Also see the answers of the following question on isotope measurements.

This is the task of Paleoclimatology. Basically, we can *measure* the climate only since the second half of the 19th century. For the time before, we are dependent on so called proxy data. Proxy data refer to physical and chemical properties of material in ancient deposits that, in one way or another, are related to or dependent on climate variables (mostly temperature or humidity). These deposits are either sediments, geological formations, ice (mostly on ice sheets or glaciers) or remains of organic material. So, when paleo scientists drill an ice core (for example), they will analyze the physical properties of the ice and the air bubbles between the ice) at a certain depth. Essentially, two types of information are required: age and the climate relation to the measured property (proxy).

Dating:

for example, information based on ^{14}C is used, which is the isotope of Carbon having 14 neutrons rather than the 12, Carbon usually has. *'The atmosphere and living terrestrial organisms (..) contain* ^{14}C *in minute concentrations (…). Upon the death of the organism, the* ^{14}C *decays as a function of time with a half-life of 5730 years. Thus, by measuring the remaining amount of* ^{14}C *in fossil remains, the time of death can be established'*. Van der Plicht (2013) There are many complications associated with paleoclimate dating. But it is based on measurable physical properties in principle.

Relation to climate variables:

One of the most prominent methods is again based on an isotope, this time ^{18}O (Oxygen usually has 16 neutrons) where both, the ^{18}O and the ^{16}O are stable – and their ratio is temperature dependent. Thus, the ratio at a certain depth (for the corresponding age) gives a clue about the temperature at the time when the archive was formed, i.e. the snow fell. Again, the application of the method includes all sorts of difficulties, but in principle, is based on sound physical principles.

Paleoclimate information is therefore indirect, but physically based. Its largest challenge is that we have very limited data due to the huge costs of the 'measurement' (imagine to drill a 3000 m ice core in the middle of Greenland, get it uninfluenced by today's air to the lab where you can make all the isotope analyses. And then you have only 'one location'…). So, paleoclimate science needs to answer the questions for the (spatial) representativeness of its data. Therefore, paleoclimate modeling also plays an important role, where – essentially – the same climate models are used as for present-day or future climate, but for the conditions (Earth orbital parameters, atmospheric compositions, etc.) back to (many) thousands of years ago.

Ice cores:

The CO2 concentration is known from analysing ice cores from Greenland and the Antarctic. Also the temperature can be estimated from these ice cores. This is based on isotope analysis, specifically Oxygen isotopes. The ratio between 16O and 18O can be measured e.g. in fossils. Since the reaction rates of both differ slightly in their temperature dependence, the ratio you find in a fossil tells something about the temperature at which that fossil lived. In the ice cores isotope ratios are used as so-called temperature proxy. The ice cores reach back around 800,000 years in Antarctica and 150,000 years in Greenland.

Ocean Sediments:

Beyond that, CO2 levels in the more distant past can also be estimated by proxies. For example, it is known that the content of carbon-13 in some oceanic sediments is a function of CO2 content in seawater. However there is added uncertainty further back in time. Nevertheless, I think within some uncertainty range, there is an overall agreement in the scientific community on how CO2 levels (and temperatures) changed through geologic time.

Contributions:

- *Andreas Pfennig, University of Liège,*
- *Bernhard Steinberger, Geophysicist, GFZ Potsdam*
- *Mathias Rotach, prof. of Dynamic Meteorology, University of Innsbruck*

References:

- The climate question a book by Eelco Rohling Oxford university press, 2019.
  He is paleo-climatologist and explains all details quite well.
- The IPCC AR-5 has a detailed chapter (Chapter 5) on the present state of knowledge. *https://archive.ipcc.ch/report/ar5/mindex.shtml*
- *van der Plicht 2013: https://doi.org/10.1016/B978-0-12-409548-9.09564-6*

How reliable is the analysis of isotopes? Can we really know how the climate was a few thousand years ago by this method? Which other methods are available and applied?

To get a feeling of the accuracy of the science that is based on analysing ice bores and other sources you can compare the results of different studies. The following studies examined the temperature difference between the last ice age a little more than 20 000 years ago and present day temperatures. The one from 2007 estimated the temperature difference to be around 10°C, the one from 2012 estimated it at around 3.5°C (this study is relatively broad meta-study focussing on the time since last ice-age and trying to reconstruct the global mean temperature) and the one published in 2016 around 6 to 7°C.

When multiple studies using multiple lines of evidence lead to similar conclusions, i.e. if different proxies (all with their own but different uncertainties) say similar things, then the likelihood that the results are correct increases. For example, we are confident that the climate was very warm in the Cretaceous because we found plant and animal fossils much further north than we would find them today. Another method available is climate modelling: the same climate models that are used to simulate the future are also tested in past climate conditions, and compared to proxies.

Contributers:

- *Andreas Pfennig, University of Liège, www.chemeng.uliege.be/Pfennig, andreas.pfennig@uliege.be, www.vision3000.eu*
- *Fabien Maussion (University of Innsbruck)*

How would the earth look like at the end of the century if we go on with business as usual? How do we know? Is it like 3 million years ago?

Under a business-as-usual scenario, the CO2 content in the atmosphere in 2100 would well exceed the levels that were reached during the past 3 million years (see the figure added below), and average temperatures might as well exceed everything reached in the past 3 million years, the Earth would not look the same as 3 million years ago or before, because of the much faster changes in CO2 content: Because it takes much longer than a century for the Greenland Ice Shield to melt, only a fraction of it would have been melted by then. However, we might well have exceeded a tipping point by then, such that melting of the remaining ice sheet over the centuries following could no longer be stopped. Another difference is that, because of the rapid temperature change, many species could probably not adjust, and would go extinct over the next century. In contrast, during the gradual temperature changes 3 million years ago, many species could adjust through evolution or migration, and thus avoid extinction.

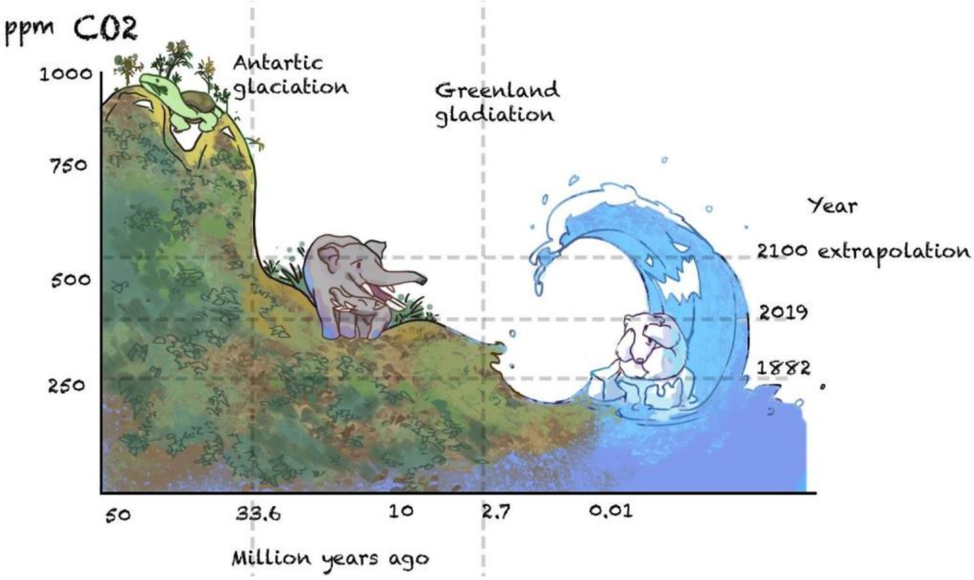


Figure: CO2 levels and onsets of glaciations in the geologic past compiled from a variety of papers, in particular Foster et al. (Nature Communications, 2017). Figure by Alisha Steinberger and Catelyne Ma.

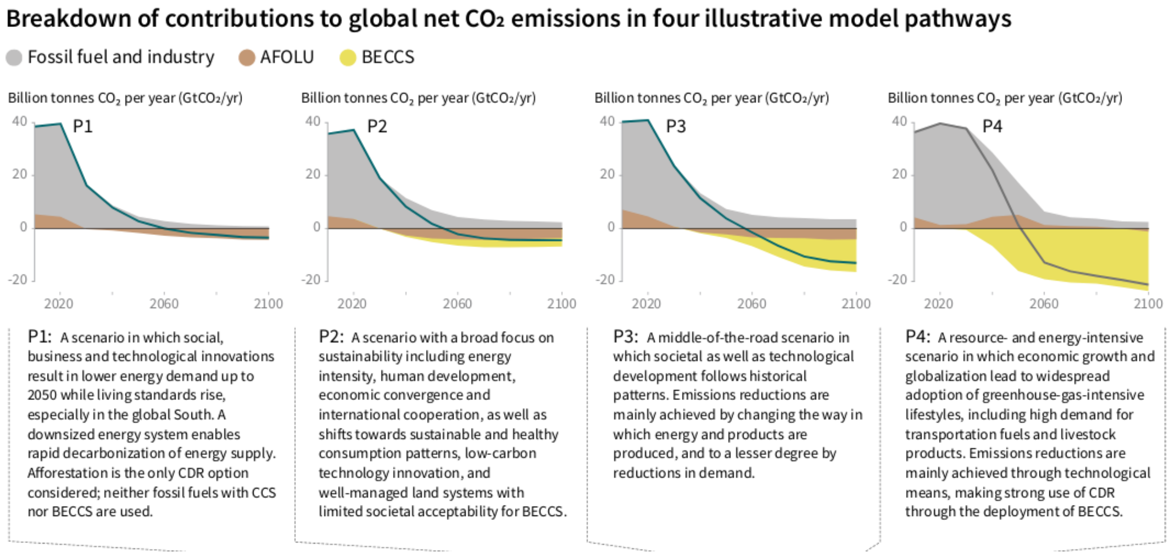
Contributions:

Bernhard Steinberger, Geophysicist, GFZ Potsdam: Regarding the question on how we know past CO2 levels, see my comment on the question "How do we know how the climate looked like in the past?"

Is it too late?

Note from reviewer (AK):
This question is very general and the answers depend on subjective assumptions (e.g. the definition of what or whom exactly it would be too late) Therefor the answers, although citing on scientific facts, are subjective in nature.

No !!! We still have time to act. But the time is running. Special IPCC report on the difference between 1.5° and 2° showed this clearly. For meeting the +1.5° target, CO2 emissions must decline by 45% from 2010 and reach zero net emissions worldwide by 2050. This means for (the richer parts of) Europe - if one counts the aspects of equity/social justice which are mentioned in the Paris Agreement - to get to near zero within the next twelve to fifteen years (CEMUS Uppsala, Niclas Hällström). The IPCC special report illustrates 4 possible ways / scenarios on how to reach 1.5° limit. All of them demand deep structural changes and immediate action but it is possible to get there!



Source: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

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No it is not too late but for all technological measures with long lifetime we have to start NOW. This is especially true in the building sector with lifetimes of HVAC (heating ventilation air conditioning) components of up to 30 years and building measures (insulation, shading etc) with lifetimes of over 40 years. Otherwise we have lock-in effects. So every item that is replaced by renovation or built new NOW must be already “2050 ready”. so NO NEW GAS or OIL Burners, all new Buildings as lowest energy buildings, passive houses or energy generating houses.

<u>Contributions:</u>

Deborah Detka and Lilian Schuster, master students, atmospheric sciences, Innsbruck, and David Fopp, Dr., PhD in education and philosophy, Stockholm University
Wolfgang Streicher, Professor of Energy Efficient Buildings and Renewable Energies at Innsbruck University in Austria and currently ISES Europe president

<u>References</u>

- *FAQ from climate-NASA: “[Is it too late to prevent climate change?](#)”*

- Reaching energy autonomy in a medium-sized city– three scenarios to model possible future energy developments in the residential building sector. https://onlinelibrary.wiley.com/doi/pdf/10.1002/sd.1855

Contributing experts and scientists

Please note that the responsibility for the content of the answers lies solely with the listed authors and not with the whole scientists for future community. However, all answers have been reviewed and edited by experts in the field.

Reviewer

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Contributors to the answers

Contributors are listed at the beginning of each answer