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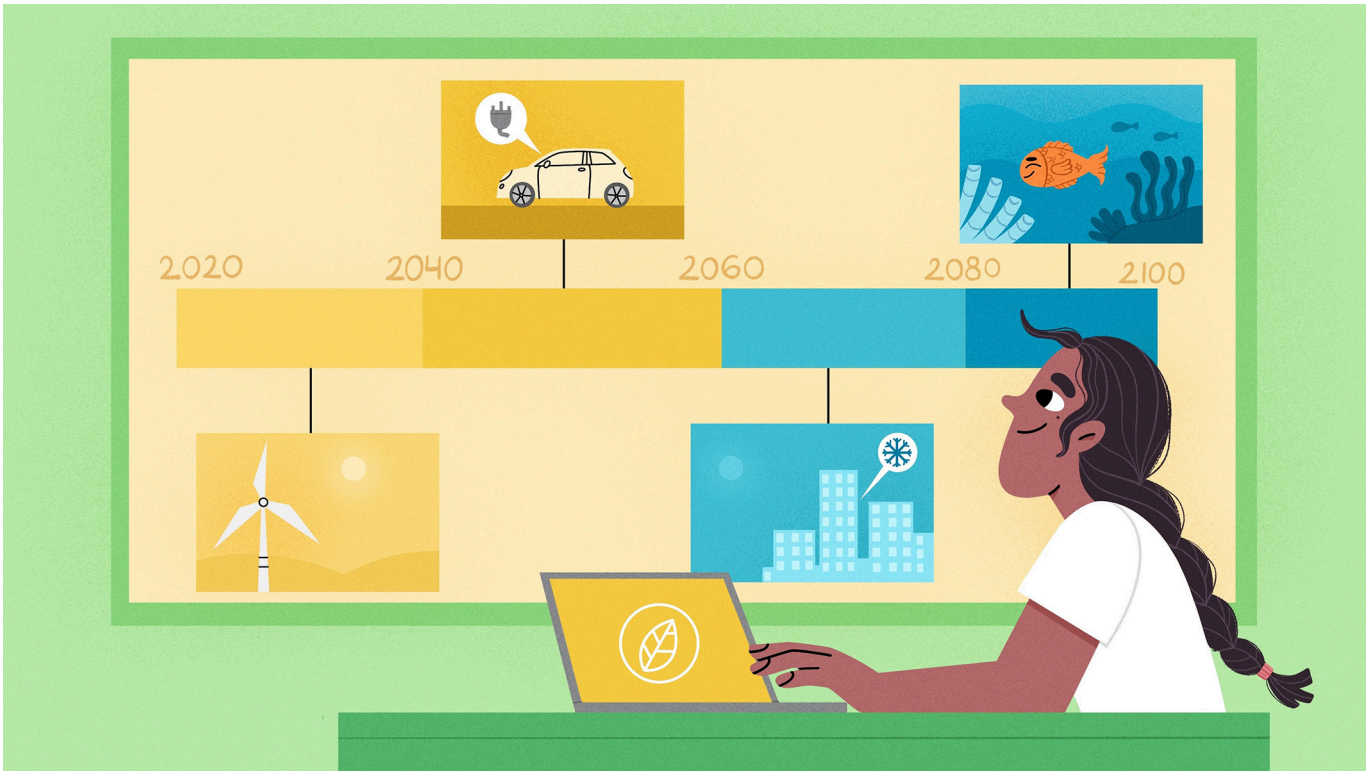

WHAT DO DIFFERENT LEVELS OF CLIMATE CHANGE MEAN FOR OUR FUTURE?

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Climate change, mostly caused by burning fossil fuels, is getting worse. Global warming is expected to reach 1.5°C by around 2030. Depending on the region and season, this would mean greater risk of heatwaves, heavy rainfall, droughts, or intense tropical storms. The strongest impacts would be on vulnerable regions or during extreme events. If global warming reaches 2°C or higher, it will affect even more people across the world. It would mean even worse impacts on our health, food and water supplies, wildfires, ecosystems, and the economy. Already now, people are dying due to hotter heatwaves fuelled by human-induced climate change. If we can understand the impacts better, we can motivate changes to reduce greenhouse gas emissions and protect vulnerable communities. It would also help us prepare for future climate-related events. Our actions today can

Figure 1

Climate change affects all regions of the world, and as global warming increases, its impacts become larger. For some regions, the consequences are severe even at 1.5°C of global warming. This figure shows the impacts of climate change on heat and rain extremes across the world. Here, climate change is measured by degrees of global warming, which is the increase in average global temperature compared to the average during 1850–1900. Figure adapted and modified from Figure SPM.2a,c from the IPCC 6th Assessment Synthesis Report, Summary for Policymakers [3]. Adapted and modified from Figure SPM.2a,c from IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 1-34, https://doi.org/10.59327/IPCC/AR6-9789291691647.001. Original figure caption: Projected changes of annual maximum daily maximum temperature and annual maximum 1-day precipitation at global warming levels of 1.5°C, 2°C, 3°C, and 4°C relative to 1850–1900. Projected (a) annual maximum daily temperature change (°C), and (c) annual maximum 1-day precipitation change (%). The panels show CMIP6 multi-model median changes.

make a big difference in creating a safer and more sustainable future for everyone.

THE CLIMATE IS CHANGING

The Earth climate is a complex system, and people are an important part of it. For example, human activities that burn fossil fuels such as petrol, gas, and coal release carbon dioxide into the atmosphere. Carbon dioxide is a greenhouse gas which keeps the Earth warm by trapping heat in the system. Too much of it, however, would make the Earth too warm and lead to other changes in the climate. This is the main driver of human-induced climate change and affects people and society in many ways. For instance, it leads to stronger and more frequent extremely hot days and heavy rainfall across the world [1, 2] (Figure 1). It also leads to more extreme droughts in several countries. How bad global warming gets mainly depends on how much more greenhouse gases we emit. The more we reduce the emissions, the more we reduce the negative impacts.

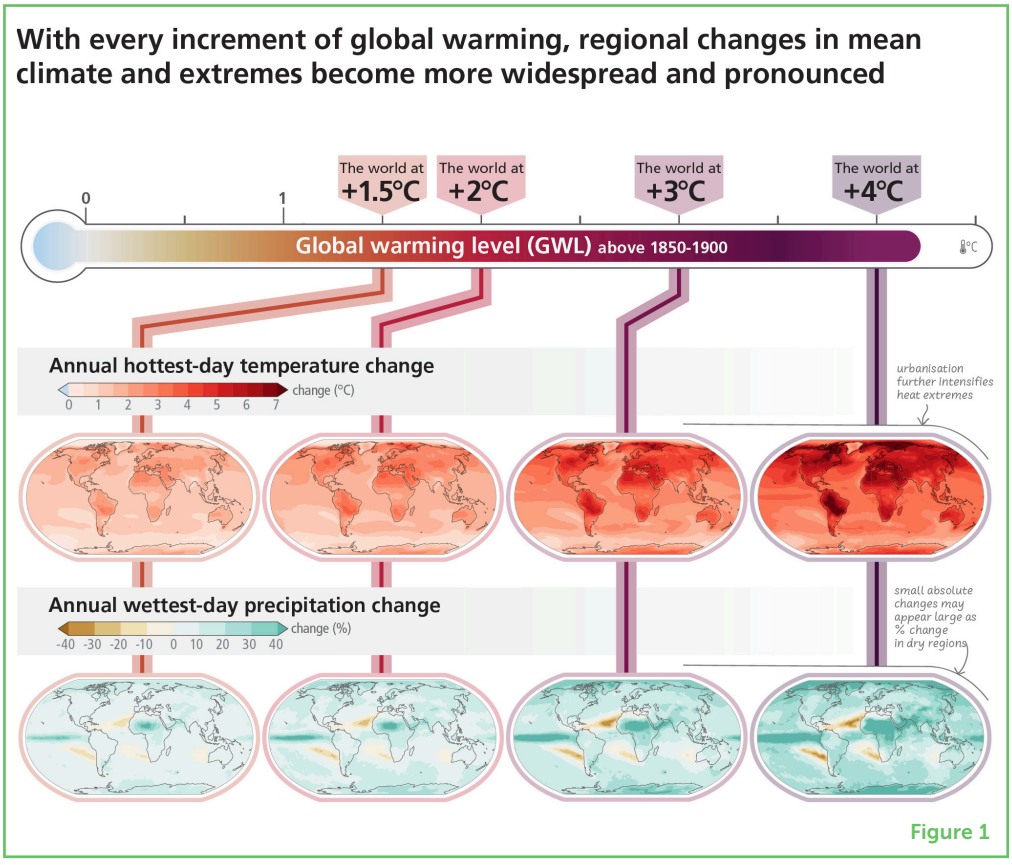

Figure 1

Understanding the impacts we can expect under different climate change conditions is important, because it shows us the possible effects of our actions. This can then motivate us to limit further greenhouse gas emissions. It can also help us plan for a future where some of these impacts may become inevitable. In this article,

In panel (c), large positive relative changes in dry regions may correspond to small absolute changes. The WGI Interactive Atlas (https://interactive-atlas.ipcc.ch/) can be used to explore additional changes in the climate system across the range of global warming levels presented in this figure.

we present the latest findings on this topic as according to the 6th assessment report from the United Nations Intergovernmental Panel on Climate Change (IPCC) [1, 4]. IPCC reports are authoritative overviews of everything we know about climate change based on scientific publications from around the world. The 6th assessment report is the latest version, published between 2021 and 2023.

HOW DO WE PREDICT FUTURE CLIMATE CHANGE IMPACTS

Predicting how climate change will impact the future involves three main steps (Figure 2).

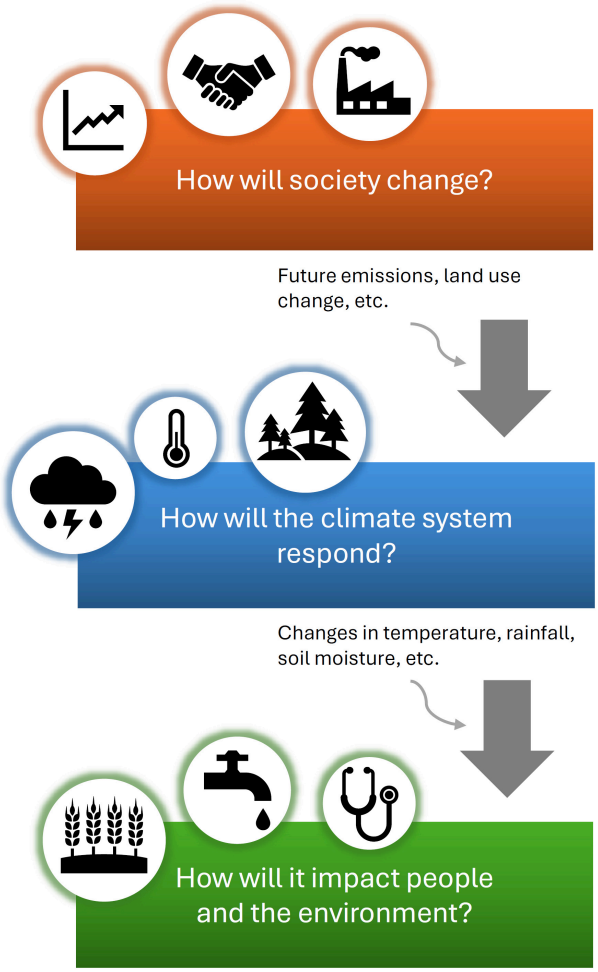

Figure 2

To understand what future climate change might mean for people and the environment, we need to consider three main questions: how will society change, how will climate respond to these changes, and how will these climate responses affect society. The answer to each of these questions is complicated and it is impossible to make a single perfect prediction. Instead, we consider many scenarios, models, and analysis methods. This helps us get an idea of a range of possible futures based on different assumptions.

The first question to think about is how the future society might look like. A range of possible scenarios are considered. For example, one scenario might imagine a world where countries work together to reduce climate pollution. Another scenario might imagine a world where countries continue to rely heavily on fossil fuels. There are many

factors at play: how much the economy grows, how much countries work together, what climate policies are in place, etc.

Climate models are then used to study how the natural environment might respond to these different societal changes. Climate models are huge collections of computer code and equations that describe the physics and chemistry of our environment. They are continually being improved. However, no model is perfect, so the results of multiple climate models need to be considered.

Lastly, climate model outputs are analyzed to understand how changes in the environment can lead to impacts on people. Tools used may include statistics or impact models. Compared to climate models, impact models generally include more details but are focused on a specific sector. For example, a crop model may simulate how a specific crop deals with different conditions throughout its life cycle.

IMPACTS AT DIFFERENT DEGREES OF GLOBAL WARMING

Climate change can be measured by degrees of global warming. This is how much the global average temperature has gone up compared to the late 1800s (1850–1900), before people burned fossil fuels widely for energy. It generally refers to the average temperature over a period of 20–30 years. This way, a complete shift in the climate condition is captured instead of a single extreme year. Earth's average temperature is expected to reach 1.5°C warmer than the late 1800s by around 2030. By the end of this century (2081–2100), the global average temperature could be between 1.4°C and 4.4°C warmer than the late 1800s. Exactly how much it warms will depend on how much greenhouse gas is emitted between now and then.

In 2015, countries around the world signed the Paris Agreement. It is a commitment to keep global warming to well below 2°C and to try to keep it to 1.5°C. However, even at 1.5°C of warming, there will be important impacts on people and the environment [5]. Heatwaves will get hotter and last longer, which can lead to more people dying from heat. Depending on the region and season, other disasters such as heavy rain, drought, or intense hurricanes and typhoons, will also get worse. Many animals and plants will be at risk of extinction, and coral reefs will be severely damaged. Much more of the Arctic sea ice will be melted each year during summer melt season. It changes the Arctic environment greatly and affects polar bears, seals, and communities living in the region. More glaciers will also melt away and disappear. This is particularly bad for places that depend on water supply from glaciers and snow melt during warmer and drier seasons. Sea levels will rise by around 44 cm by the end of the century at 1.5°C [6]. Because oceans respond to warming very slowly, it will continue to rise even further for a long time even if warming is kept to 1.5°C.

If global warming reaches 2°C, these effects would get worse. Meeting people's food and nutrition needs would be harder, especially in poorer countries. More and worse droughts, floods, and heatwaves would affect crops and animals. Not having enough water to water farms will also become a bigger problem. It would become more likely that all the world's biggest grain-growing areas experience climate disasters at the same time [2]. The grain could then get very expensive or even run out because there is not enough on the market for everyone. Cities and buildings would also face more damage from natural disasters, costing more money to repair. Human health would be greatly affected too, with more intense heatwaves and diseases spread by mosquitoes, like Dengue and Malaria. At 2°C, there's a higher risk of reaching climate "**tipping points**", which are big, sudden changes in the climate. They are particularly bad because people are less prepared for them and their effects cannot be easily reversed.

TIPPING POINTS

When a small change leads to big, sudden changes that cannot be undone by reversing the process. Imagine nudging a glass across a table, eventually tipping it over the edge.

ADAPT

To adjust or take action to deal with change.

By 3°C global warming, climate change would impact most of the world. The problems would get worse everywhere. Some damage would be irreversible, meaning it could not be fixed even if global warming is later reduced. Some of these changes will also become so big that it would be impossible to **adapt** to. Arctic sea ice would completely melt away almost every September. Sea levels could rise by about 60 cm by the end of the century. It could reach 4–10 m in two millennia if global warming stays at 3°C [6]. Damages to the economy would also increase faster as temperatures climb. At this level of warming, some climate tipping points could be reached that would cause very serious problems.

At 4°C or warmer, the Earth would be drastically changed. About half of the plants and animals in tropical oceans would not be able to survive where they live now, and around a third of the land areas would change significantly. Wildfires would get a lot worse, with 50–70% more areas burnt. Problems with water supply and food production would be widespread, with around 4 billion people facing water shortages [4].

BEYOND NATURAL HAZARDS

The impact of climate change on people in the future will depend on more than just changes in the climate. It will also depend on how societies grow and change over time. The same event can lead to different results depending on how well people are protected against it. For example, if healthcare improves, fewer people who catch Malaria might die from the disease. However, there will also likely be more elderly people in the future. This means heatwaves would become even more problematic because older people have a harder time with them. On another hand, as cities near coasts get bigger,

more people and buildings would be exposed to rising sea levels and coastal flooding.

To help reduce the risks from climate change, we need to plan ahead and think about these changing conditions. However, the best way to prevent the worst effects of climate change is to limit greenhouse gas emissions now, so we do not push the climate toward these extreme conditions.

TODAY'S ACTIONS WILL SHAPE THE FUTURE

Global warming is expected to reach 1.5°C soon. The more it warms, the worse the impacts and the more parts of the world are affected. If human-induced climate change is not stopped, it would cause big changes in society and nature over time. The changes may also happen suddenly if tipping points are reached. Some of these changes may be too extreme for people and nature to adapt to, leading to lasting damage and losses.

However, the future is not hopeless. By using less fossil fuel and planning for a changing future, we can reduce future warming and its harmful impacts. Important steps to take include cutting down on greenhouse gas emissions to reach **net zero** CO_2 emissions as soon as possible, switching to renewable energy sources, protecting **vulnerable** ecosystems and communities, and building stronger infrastructure to handle extreme weather. It is essential that countries work together globally and commit to climate action. How society prepares for the future can affect how well we cope, but it will get harder for people to adapt as human-induced climate change worsens. By understanding possible future outcomes and acting now, we can build a safer and more sustainable future for everyone (Figure 3).

NET ZERO

A balance where the amount of greenhouse gases emitted into the atmosphere is the same as the amount removed, so there is no extra impact on the climate.

VULNERABLE

At risk, easy to get hurt. This may be because it is sensitive to something and/or because it cannot easily respond or adapt to change.

Figure 3

How the future climate will look like will depend on decisions now and in the near future. The impacts of these decisions will be felt most strongly by younger generations. A very low emission future would mean a stable climate even as young people reach old age. In contrast, a very high emission future would mean climate change continues to get worse for years to come. Figure adapted and modified from Figure SPM.1c from the IPCC 6th Assessment Synthesis Report, Summary for Policymakers [3]. Adapted and modified from Figure SPM.1c from IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland,

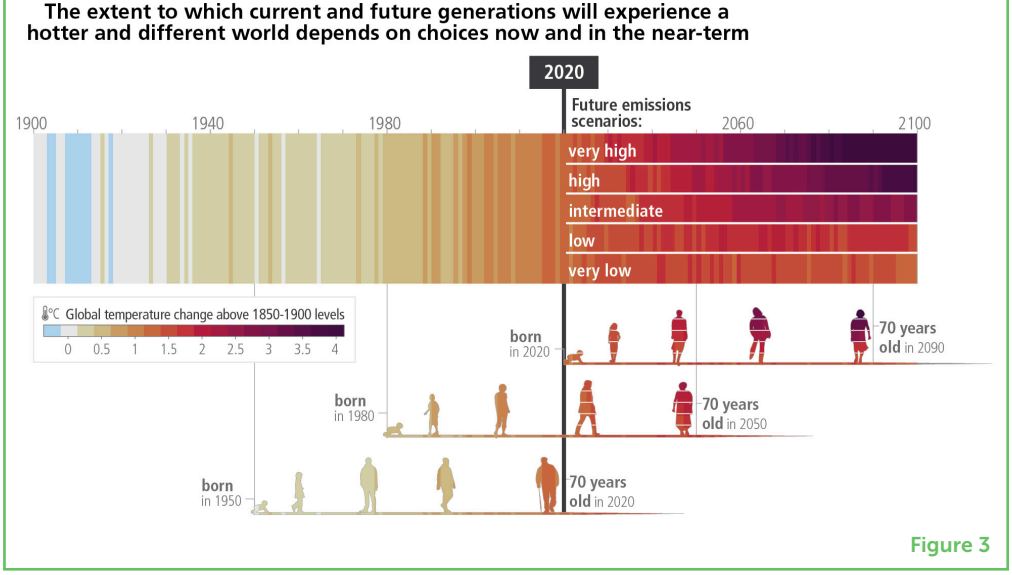

Figure 3

ACKNOWLEDGMENTS

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pp. 1–34, https://doi.org/10.59327/IPCC/AR6-9789291691647.001. Original figure caption: Observed (1900–2020) and projected (2021–2100) changes in global surface temperature (relative to 1850–1900), which are linked to changes in climate conditions and impacts, illustrate how the climate has already changed and will change along the lifespan of three representative generations (born in 1950, 1980 and 2020). Future projections (2021–2100) of changes in global surface temperature are shown for very low (SSP1-1.9), low (SSP1-2.6), intermediate (SSP2-4.5), high (SSP3-7.0) and very high (SSP5-8.5) GHG emissions scenarios. Changes in annual global surface temperatures are presented as 'climate stripes', with future projections showing the human-caused long-term trends and continuing modulation by natural variability (represented here using observed levels of past natural variability). Colours on the generational icons correspond to the global surface temperature stripes for each year, with segments on future icons differentiating possible future experiences.

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The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

YOUNG REVIEWERS

AYAT, AGE: 12
I am a 12-year-old with a big passion for sketching and painting, especially when nature sparks my creativity. My favorite books, like "Amari" and "The Magicians of Paris", along with other fantasy stories, fuel my imagination. I love cycling, playing chess and badminton, and hiking to uncover nature's hidden treasures. Along the way, I enjoy taking notes and drawing detailed sketches of the plants and animals I encounter!

SEA CREST SCHOOL, AGES: 11–12
We are a fun and diverse crew with a singular goal: to leave toe world better than we found it! We share the gift of living and learning in coastal California, and we are always ready to dive into big ideas like sustainability, climate action, and, of course, science!

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