

WE ARE NOT ON TRACK: GREENHOUSE GAS EMISSIONS ARE HIGHER THAN EVER!

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YOUNG REVIEWERS:



JUDE

AGE: 15



THE
AMAZING SIX

AGES: 14–16

Even though we have known about climate change for more than 30 years, humans are releasing higher amounts of greenhouse gases, like carbon dioxide, than ever before. Scientists have shown that stopping carbon dioxide emissions could prevent global warming from getting worse. The single biggest source of greenhouse gas emissions is burning fossil fuels for electricity or transportation. Technologies like solar and wind power, electric vehicles, and advanced batteries can replace fossil fuels and help reduce emissions while also decreasing other problems like air pollution. Many countries have promised to stop their carbon dioxide emissions, and if their promises are backed up with laws, then global warming could be limited. Unfortunately, current laws are not good enough. We need to ensure that countries meet their promises, so that society can avoid the worst effects of global warming.

GREENHOUSE GASES

Gases that can trap the Sun's heat near the Earth, increasing the temperature of the planet.

EMISSIONS

Chemicals, like carbon dioxide, released into the atmosphere when burning coal, oil, or gas.

FOSSIL FUELS

Coal, oil, and gas that were formed underground from plant and animal remains millions of years ago.

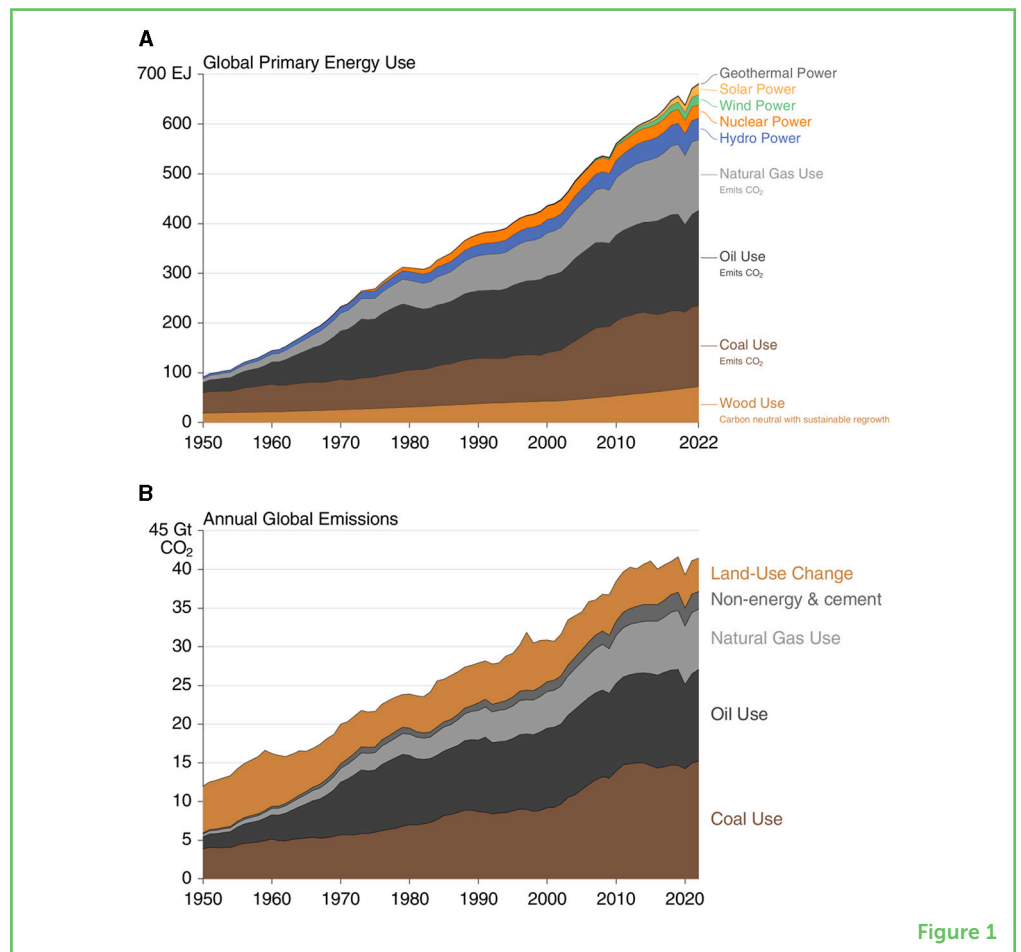
Figure 1

(A) The main types of energy used around the world since 1950, showing the dominance of coal, oil, and natural gas, with non-fossil sources (hydro, nuclear, solar, wind, geothermal) beginning to make a mark on the energy system. (B) Carbon dioxide emissions since 1950 come from burning coal, oil, and natural gas, as well as from cement production and the cutting down of forests to create farmland (land-use change), showing that only the fossil energy sources emit CO₂.

PAST ENERGY USE AND EMISSIONS

There have always been **greenhouse gases** (carbon dioxide, methane, and nitrous oxide) in the atmosphere due to natural emissions, such as decaying plants, wetlands, and soils. Thousands of years ago, our ancestors began to cut down forests, turning them into farmland. This started putting additional greenhouse gases into the atmosphere, but due to the small human population, the changes were minimal.

It was not until the start of the Industrial Revolution in the 18th century that greenhouse gas **emissions** really started to grow and build up in the atmosphere. Over time, the number of technologies hungry for **fossil fuels** increased. Today we burn record amounts of fossil fuels (Figure 1A) and cut down record levels of forests [1]. With the Industrial Revolution came widespread pollution. The water became toxic and the air became thick with smog. Society learned to reduce and manage much of this pollution, except for greenhouse gases. Greenhouse gases like carbon dioxide are invisible. While we cannot smell, feel, or see carbon dioxide, it still has serious effects on the atmosphere.



Since the 1800s, scientists have proposed that **burning fossil fuels could change Earth's climate**—a concept that is now proven beyond doubt [2]. Fossil fuels are the carbon-containing remains of dead

plants and animals that have been hidden underground for millions of years. When fossil fuels are dug up and burned, the carbon they locked deep underground for all those years is released into the atmosphere as carbon dioxide (Figure 1B). Carbon dioxide accumulates in the atmosphere and is the main cause of global warming.

THE CLIMATE IS CHANGING

Climate scientists have shown that it is the *total amount* of carbon dioxide emitted over time that matters, not the emissions in a single year [3]. Carbon dioxide does not simply disappear from the atmosphere when we stop burning fossil fuels. Some of it remains in the atmosphere, essentially forever. The carbon dioxide emitted by our ancestors during the Industrial Revolution still sits in Earth's atmosphere. The carbon dioxide we emit today will cause global warming for our kids and grandkids. We can stop global warming from getting worse by not putting carbon dioxide in the atmosphere, but we cannot stop the global warming that has already occurred. We have already put enough carbon dioxide and other greenhouse gases into the atmosphere to increase the global average temperature around 1.3°C since the Industrial Revolution (for more on why our climate is changing, see this [Frontiers for Young Minds article](#)).

THE WORLD IS ACTING, BUT FAR TOO SLOWLY

Global warming has already increased **climate impacts** across many parts of the world. The Intergovernmental Panel on Climate Change (IPCC), the body that looks at the science behind climate change, was established back in 1988. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was formed, which aimed to prevent human-generated effects on Earth's climate. The Kyoto Protocol was adopted in 2007 and the Paris Agreement in 2015, both of which built on the UNFCCC and aim to ensure its objective is met. So, you can see that the world clearly recognizes the severity of the climate challenge, and we have the science and international agreements in place to address climate change, but we have not yet curbed global emissions.

In response to global warming, society has developed technologies like wind and solar power, which in many cases are even cheaper than fossil fuels. We know that these environmentally friendly help reduce carbon dioxide emissions. In the US and Europe, fossil fuel use has declined [4], which means that solar and wind power are replacing fossil fuels. Electric cars are starting to replace cars that use petrol (gas) and diesel fuel.

In some countries, like India and China, solar and wind power are also growing at a record pace. India is still considered a developing country,

CLIMATE IMPACTS

Changes in weather due to greenhouse gas emissions and climate change, such as more temperature extremes, heat waves, and intense rainfall.

with many people in poverty, and Indian society strives to have living standards like those experienced in the US and Europe. In these fast-growing economies, even the rapid growth of environmentally friendly technologies is not yet sufficient to stop increasing carbon dioxide emissions [4]. If we look at the world as a whole, energy use and carbon dioxide emissions continue to grow, although the growth rate has slowed down over the last 10 years (Figure 1).

DO NOT FORGET ABOUT CUTTING DOWN TREES AND FARMING

It is not only fossil fuels and their carbon dioxide emissions that drive climate change. We use more wood today than our ancestors did hundreds of years ago. If this wood is not sustainably harvested and efficiently used, then carbon dioxide emissions rise. We still cut down forests (a process called **deforestation**) and turn them into farmland for cows, sheep, and crops at record levels, releasing yet more carbon dioxide.

When we cut down forests to make places for food production, not only do we emit a lot of carbon dioxide when cutting down and burning the trees, but other greenhouse gases then follow. Methane comes from burping cows and sheep and from decomposing plant matter, like rice paddies and wetlands. Nitrous oxide (also known as laughing gas) is generated when fertilizers are used to help crops grow more efficiently. Fossil fuels also lead to emissions of other greenhouse gases like methane, either through leaks or through improper burning of those fuels. All these greenhouse gas emissions add up, but carbon dioxide is the most important.

AVOIDING THE WORST OF CLIMATE CHANGE

Today, many countries and companies around the world have **climate policies** to help slow the growth of greenhouse gas emissions [5]. Climate policies may include taxes that make it expensive to do things that harm Earth's climate. Climate policies can also include laws that forbid very inefficient cars to be sold. The climate policies followed today are expected to keep greenhouse gas emissions approximately the same until the end of the century. If this happens, then the global average temperature will increase about 2.2–3.0°C by the end of the century relative to the temperature at the start of the Industrial Revolution, approximately doubling the 1.3°C increase we are already experiencing today. Of course, we do not know exactly how much warmer it will be. It is not easy to predict greenhouse gas emissions for the next 80 years! Scientists understand the climate system well, but there are still many uncertainties. Instead of a 2.2–3.0°C increase by the end of the century, we could end up with only a 2°C increase, or an increase as high as 3.5°C. Governments have already agreed

DEFORESTATION

The cutting down of forests and conversion to another land use, such as cropland or pastures.

CLIMATE POLICY

An incentive by the government to help reduce emissions, such as making people pay extra for coal, oil, or gas, or making it cheaper to use solar, wind, or electric vehicles.

CLIMATE PLEDGE

A promise made by a country or company to do something that they have not done yet.

NET ZERO EMISSIONS

When the amount of emissions put into the atmosphere is balanced by the amount that is taken out in the same year.

that climate impacts at 2°C of global warming will cause unacceptable risks to society, such as more temperature extremes, heat waves, and intense rainfall.

Many governments and companies have made additional **climate pledges**, promising to reduce emissions, but they do not yet have policies in place to meet these pledges. This is like promising to clean up your room, but staying on the sofa instead of starting the job. For example, many countries have pledged **net zero emissions**, but they have no policies yet to get there. Net zero means that any emissions that go into the atmosphere must be taken out again. Given the difficulty in removing carbon dioxide from the atmosphere, this means we need to try to stop all emissions as much as we can. It is a bit like spilling hot chocolate in your room. It is much easier to be careful *not* to spill it in the first place than to clean it up afterwards.

Any long task starts with the promise to do it. It is good that we have those promises to reach net zero emissions, but now we need to see some action. If climate policies are put in place to make sure these pledges are met, then global emissions would soon begin to decrease, and the global average temperature increase may be kept below 2°C by the end of the century [5].

Governments still have time to create climate policies to keep temperatures from rising to dangerous levels. This would require cutting greenhouse gas emissions in half by 2030, with carbon dioxide emissions reaching net zero around 2050 and all greenhouse gas emissions reaching net zero around 2080. That is a bit more than what all the governments have promised to do together so far. Now we need the countries to “clean up their rooms”. Imagine not only having to convince your friend to clean up their room, but your whole school class! Since most countries have already pledged to clean up, the task now is to get them started.

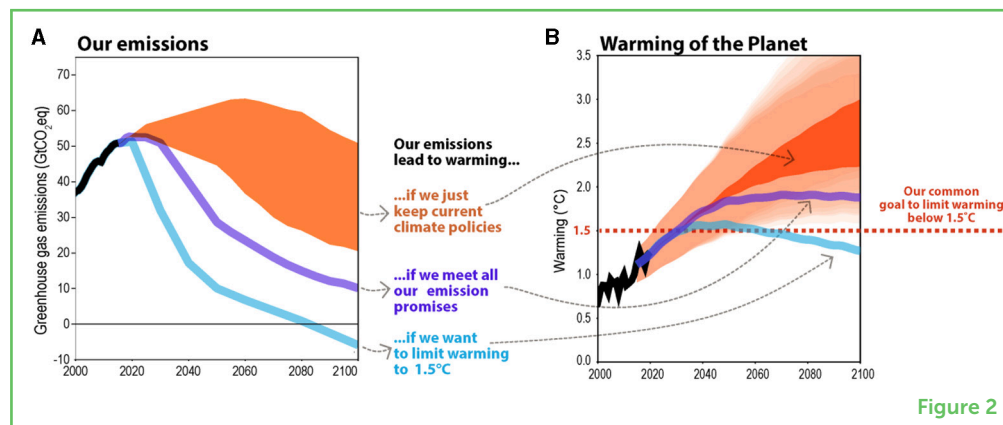
LIGHT AT THE END OF THE TUNNEL

The good news is that studies show that **we have what it takes to reach net zero emissions** and keep global warming to around 1.5°C. We may exceed 1.5°C temporarily, but will likely return below 1.5°C again [5] (Figure 2B). The world has been great at developing solar and wind power, electric vehicles, and batteries. But the world has not been as good at stopping the burning of coal, oil, and gas. Instead, the world continues to look for more and more fossil fuels, making the problem even worse. Energy use and emissions continue to rise, although at a slightly lower rate than they would without any climate policies.

The less the world does today to reduce emissions, the worse the future climate impacts will be and the harder it will be to reduce emissions. The easiest path forward is to embrace renewable energy

Figure 2

(A) Estimates of future greenhouse gas emissions and (B) the amount of warming they can cause. If we want to limit warming to around 1.5°C, we must achieve net zero emissions in the second half of the century (blue line). According to all the climate pledges, scientists' best estimate of warming would be around 2°C (purple line). Pledging countries must create climate policies to reduce emissions further. If we estimate only based on current policies, the world will not reduce emissions fast enough (orange area) and global warming will go well over 2°C, leading to worse climate impacts.



and not make a further mess by burning fossil fuels that we must clean up later. Just as our parents and ancestors made the decisions that caused the global warming we see today, the decisions society makes today will have profound impacts for our children and grandchildren. Future climate impacts will build on top of the impacts we are already experiencing. Since carbon dioxide accumulates in the atmosphere, it is necessary to act quickly. This is something the world is failing to do. We should try to work together—to do a bit more every day. We can all start by reducing our own emissions and asking others to do so, too.

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YOUNG REVIEWERS

JUDE, AGE: 15

I enjoy playing guitar in my spare time, when I am not walking my cat. I often spend time with my two loving brothers. In the summer, I enjoy doing water sports in the lake district along with hiking and paddle boarding. I have lived in the UK all my life and love the weather for about two weeks per year, so I look forward to doing more traveling.



THE AMAZING SIX, AGES: 14–16

Our study group brings together six teenagers interested in science and analytical research. The group was born in December 2023, when our Maths teacher asked us to join this interesting project. We decided to call our team: The Amazing Six. The study group is made up of cooperative and outgoing students between the ages of 14 and 16, coming from different small towns nearby Rome (Italy).



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