FEEDBACK

BY MATT BOUCHER

There is no doubt. Our planet is warming, and our climate has begun to change. Since the 1800s, when people first burnt fossil fuels for power, Earth has become hotter by around one degree Celsius. Scientists warn if our planet's temperature rises by just another half a degree, the impact of climate change will become more extreme and harder to control. At the current rate of warming, 1.5 degrees could be reached by 2034.

The Unknown Future

Scientists agree that 1.5 degrees of warming is only the start. An increase of two degrees – even three or four – isn't out of the question. It's why people now talk of a climate crisis. Predicting exactly how much Earth's average temperature will rise, and by when, is a tricky business – and not because we don't understand the causes of climate change. We do. What we don't know is how people and their governments will respond to the huge challenges that lie ahead. If we want to keep the rate of warming as low as possible, we need to radically alter the way we live – now. But are enough of us prepared to make the necessary changes? And make them quickly?

There's another unknown factor when it comes to how intensely we'll experience climate change: feedback loops.

WHAT IS CLIMATE CHANGE?

Climate change describes a long-term shift in temperature and weather patterns. While the phrase can refer to change in one particular area, most people talk about climate change as something that affects the entire planet. Earth's climate has always varied, but we now know that the increases in temperature in recent decades have been caused by human activity, especially the burning of fossil fuels.

Fossil fuels provide energy. They allow us to make electricity, heat our homes, power factories, and drive cars. But burning fossil fuels also releases greenhouse gases into the atmosphere, the layer of air around Earth that prevents heat from escaping too quickly and keeps Earth's surface warm. Without the atmosphere, our planet would be too cold to support life. However, the atmosphere needs to be just the right temperature so we don't have the opposite problem: too much heat. More greenhouse gases help to trap more heat, making Earth warmer. This trend is called global warming.

Climate Feedback

Earth has supported at least some form of life for nearly 4 billion years. This has been possible because natural processes helped to keep the climate relatively stable. After long periods of volcanic eruptions, for example, when large amounts of carbon dioxide were released into the atmosphere, plants and the ocean absorbed some of that carbon dioxide. Without processes like these, known as **negative feedback loops**, Earth's climate would have been more erratic.

In recent decades, however, human activity has had a major impact on the planet. In less than a century, people have dug up and burnt huge amounts of fossil fuels, which took millions of years to form. Burning these fuels released a massive amount of carbon dioxide and other greenhouse gases into the atmosphere, raising their concentration to levels not seen for over 3 million years. Negative feedback loops are continuing to work, but not quickly enough. In the meantime, Earth's temperature is on the rise.

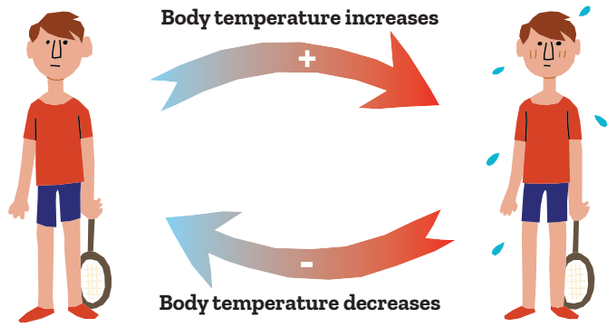
The news gets worse. Feedback loops come in two kinds. While negative feedback loops slow down the effects of climate change, **positive feedback loops** speed them up. Scientists fear this second kind will have a big role in the future, leading to an even worse outcome. So what are they?

negative feedback loop: a process that slows down the effects of an initial change
positive feedback loop: a process that speeds up the effects of an initial change

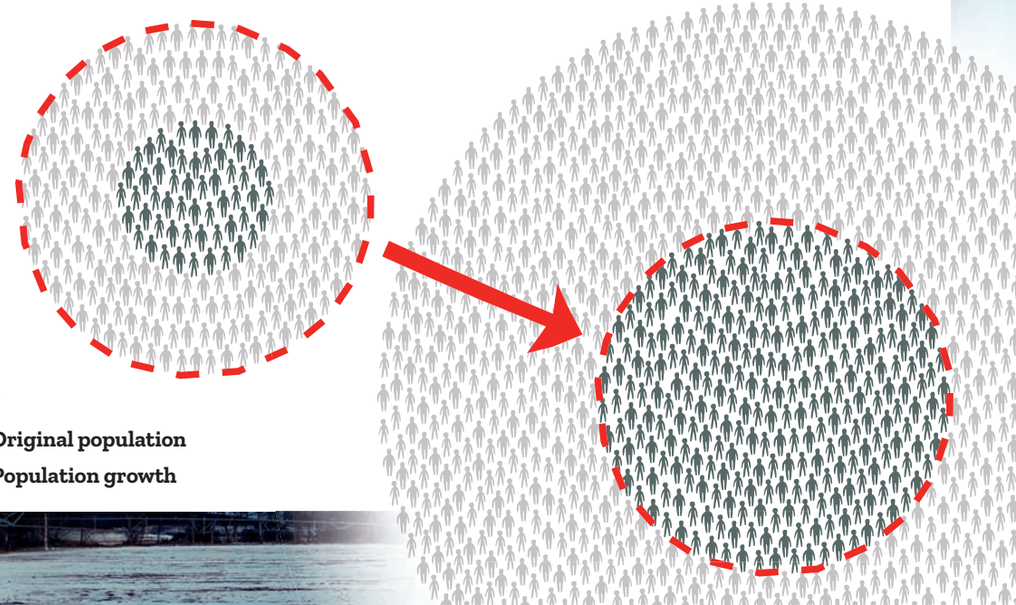
FEEDBACK LOOPS

A feedback loop is a circuit-like system in which one thing (an input) changes another thing (an output). These loops are found everywhere: in nature, computer software, heating systems, the economy, even the human body.

As we know, feedback loops come in two kinds: negative and positive. A negative feedback loop helps to keep things in balance because it reduces the effects of change. When you get hot, for example, you start to sweat (an input). The evaporating sweat cools you down, helping your temperature return to normal (an output).



A positive feedback loop increases the effects of change. This can be seen in the way population growth works. When a population gets bigger, there are more people to have babies (an input). These babies grow up and go on to have their own babies, and the population gets even bigger (an output). The bigger a population, the quicker it grows.



The Water Vapour Feedback Loop

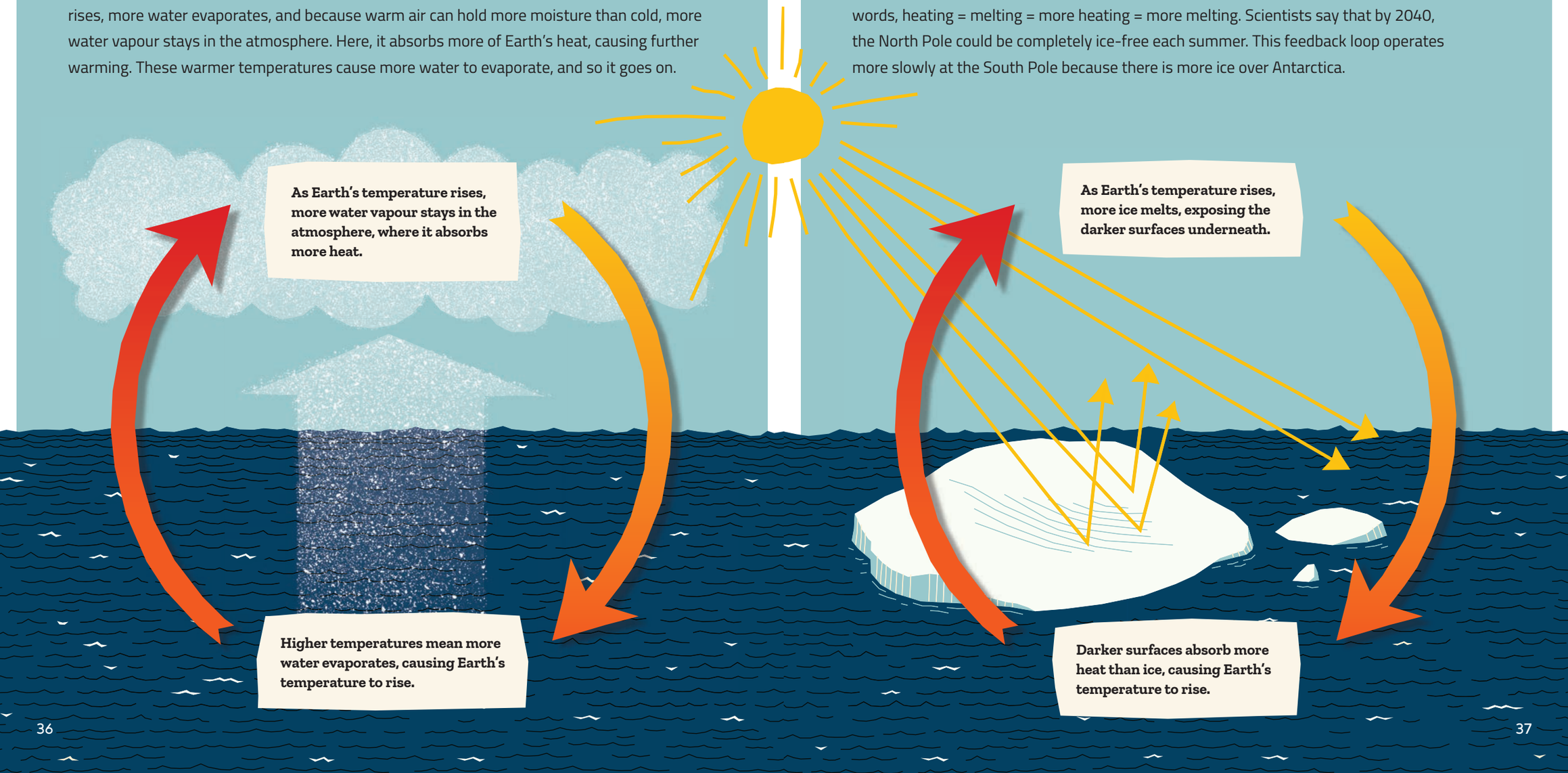
When the temperature is warm enough, water evaporates and becomes water vapour. The hotter the temperature, the faster this happens. You'll know that clothes dry quicker on a hot day than on a cold day. You'll also know that we sometimes have hot, sticky days in summer. These happen because warm air can hold lots of moisture (cooler air can't hold as much, which is why dew collects on the grass on cold winter nights). Water vapour – along with carbon dioxide, methane, and nitrous oxide – is one of Earth's most powerful greenhouse gases.

Most of the water vapour in our atmosphere comes from the ocean. As the temperature rises, more water evaporates, and because warm air can hold more moisture than cold, more water vapour stays in the atmosphere. Here, it absorbs more of Earth's heat, causing further warming. These warmer temperatures cause more water to evaporate, and so it goes on.

The Ice Albedo Feedback Loop

The coldest parts of our planet are covered in ice all year. Because ice is a light colour, it reflects the sun's heat back into space, which helps keep Earth cooler. But as the temperature rises, the ice in these places is melting, exposing water or land underneath. These surfaces are darker than ice, so they absorb heat, making Earth hotter instead of cooler. The amount of light a surface reflects is called its albedo.

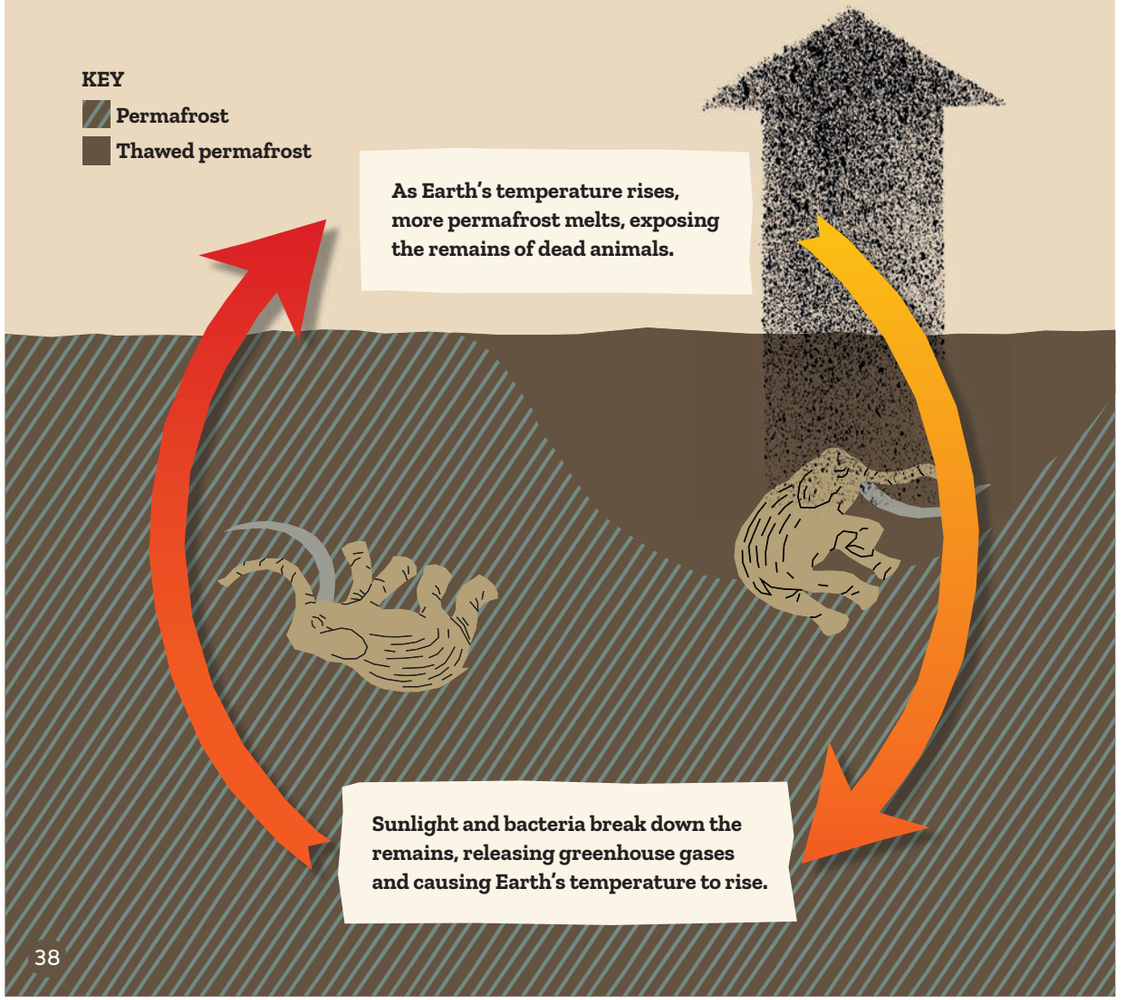
As Earth continues to warm, more ice melts. With less ice to reflect the sun's heat and more exposed water and land to absorb it, Earth's temperature climbs further. In other words, heating = melting = more heating = more melting. Scientists say that by 2040, the North Pole could be completely ice-free each summer. This feedback loop operates more slowly at the South Pole because there is more ice over Antarctica.



The Permafrost Feedback Loop

Very cold parts of Earth, such as the Arctic, aren't always covered in snow and ice, but they are cold enough to have frozen ground all year. This is called permafrost (permanent frost). Permafrost contains all of the usual things that soil contains, including the remains of dead animals. Some of these animals are very large, including frozen mammoths found in Russia. These ancient creatures have been preserved in permafrost for over four thousand years.

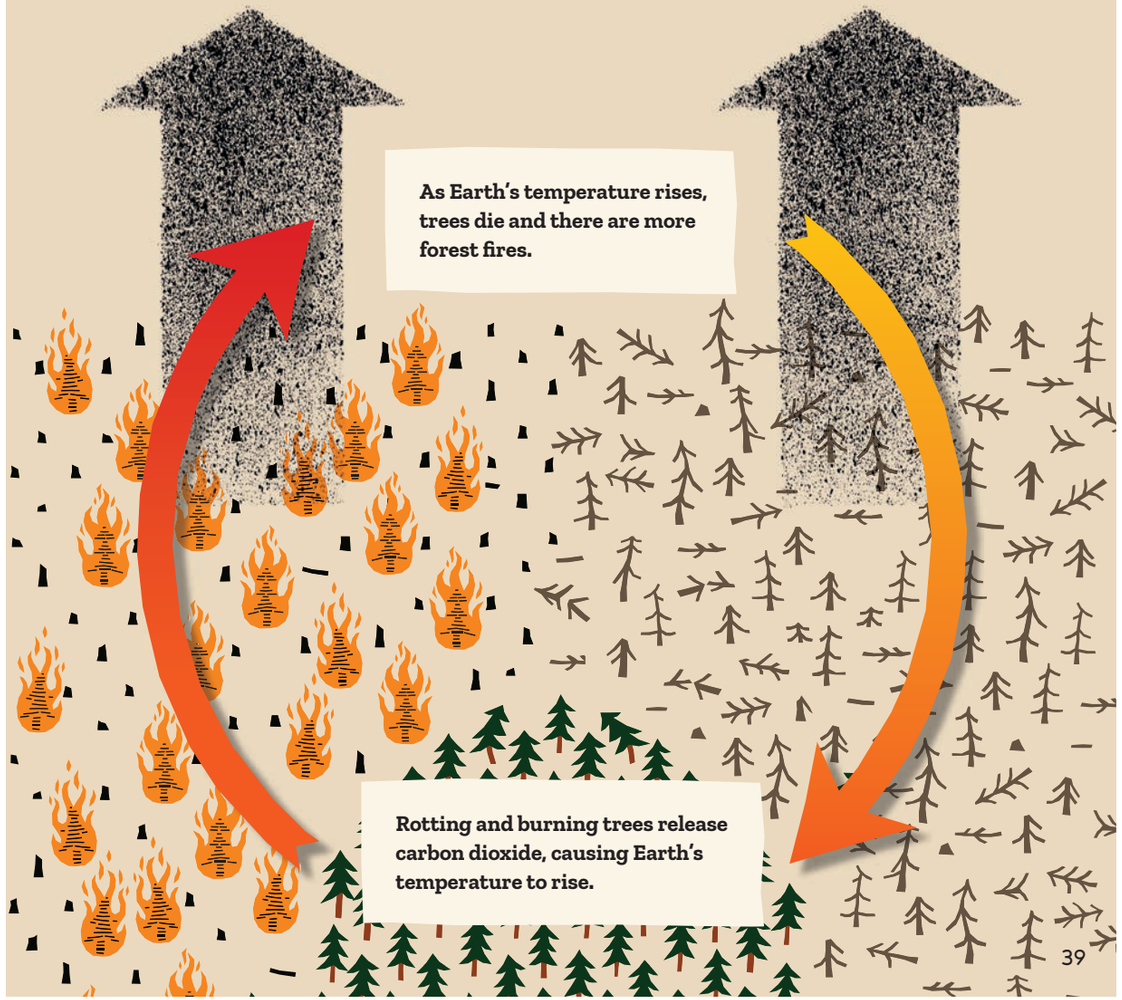
Because Earth is warming, its permafrost is starting to thaw. As this happens, the frozen animals thaw, too. Their remains are broken down by sunlight and bacteria, a process that produces carbon dioxide and methane. This increase in greenhouse gases warms Earth further, causing more permafrost to thaw. More thawing permafrost leads to more thawing remains and more carbon dioxide and methane being released.



The Deforestation Feedback Loop

Trees and other plants help clean Earth's atmosphere. They "breathe" in carbon dioxide and "breathe out" oxygen. As parts of the world become hotter and drier, trees and plants get less of the water they need to survive. Our forests, especially our tropical rainforests, are shrinking and even dying. A hotter planet also means more trees are burning in forest fires. The loss of forests on a large scale is called deforestation.

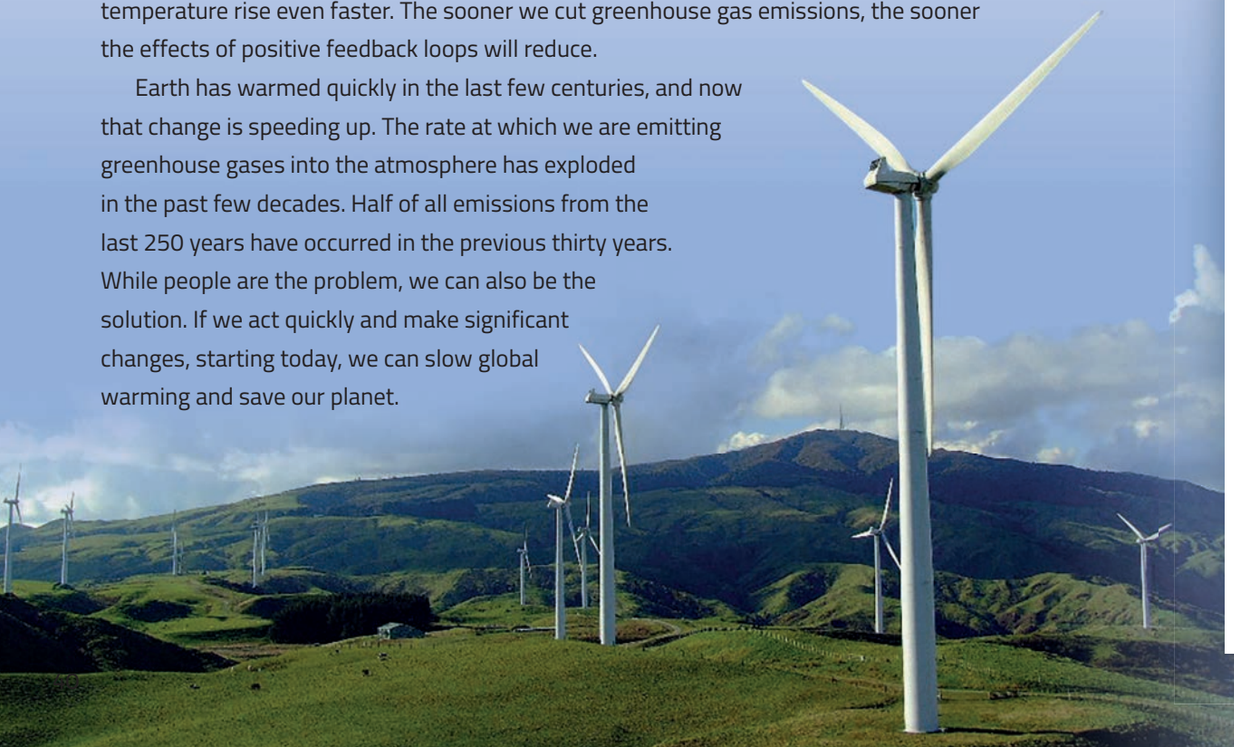
Fewer trees on the planet means less carbon dioxide is absorbed from the atmosphere, and rotting and burning trees also release carbon dioxide. This results in a lot more carbon dioxide in the atmosphere, which means more warming. More warming leads to more deforestation.



Time to Act

Many more positive feedback loops are already at work; others haven't kicked in. And new feedback loops – both positive and negative – will be discovered, but the ones we do know about make climate change hard to predict. Positive feedback loops also make Earth's temperature rise even faster. The sooner we cut greenhouse gas emissions, the sooner the effects of positive feedback loops will reduce.

Earth has warmed quickly in the last few centuries, and now that change is speeding up. The rate at which we are emitting greenhouse gases into the atmosphere has exploded in the past few decades. Half of all emissions from the last 250 years have occurred in the previous thirty years. While people are the problem, we can also be the solution. If we act quickly and make significant changes, starting today, we can slow global warming and save our planet.



SOPHIE HANDFORD: FEEDBACK FOR CHANGE

Sophie Handford wants to make the world a better place. For her, this means fighting climate change – something she's been committed to since the age of twelve. So how does Sophie fight? "By helping people understand we're facing a crisis and encouraging them to take action." Sophie says that getting results is partly about the numbers. "When people learn about climate change, they talk. They influence others, and then those people talk. As the word spreads, we can make positive change on a large scale – exactly what the planet needs." You could call it a positive feedback loop.

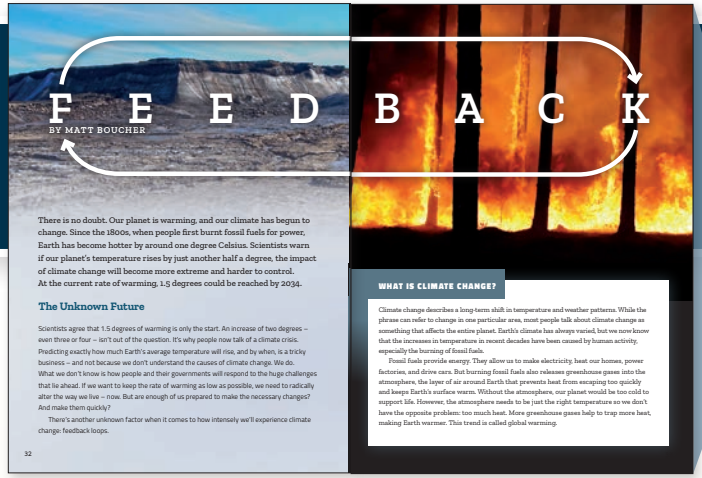
Sophie had always followed the work of climate activists overseas. She was deeply affected by the student strikes in other countries. Could the same thing happen here, she wondered? She began to make contacts and co-ordinate people. The first strike she helped organise, in March 2019, drew 20,000 people. A second strike came six months later, when over 170,000 people took part. New Zealand had more protesters per capita than any other country in the world (3.5 percent of the population).

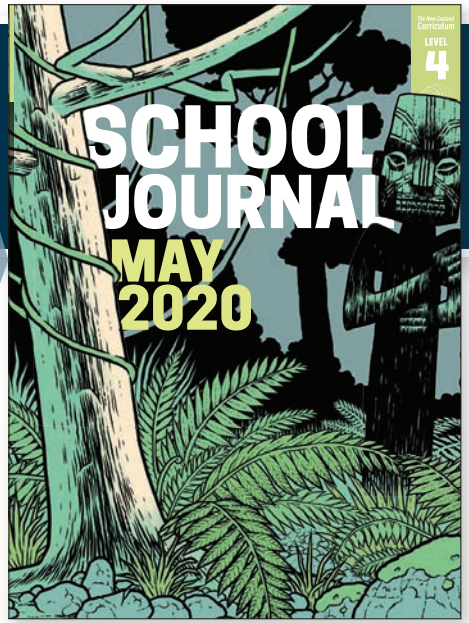
It was a busy year. Sophie also ran for council in the local body elections and won a seat on the Kāpiti Coast District Council. She's now – at eighteen – New Zealand's youngest councillor. She wants to ensure young people have a voice. She also speaks for the environment because that, she says, isn't often represented, either.

Sophie has a message for students. "Climate change is the biggest challenge we've ever faced, and it can feel like the news is all bad. But there's still time, if we act now. Find your tribe and feel empowered. Trust your voice, then use it for change."

Feedback

by Matt Boucher





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