

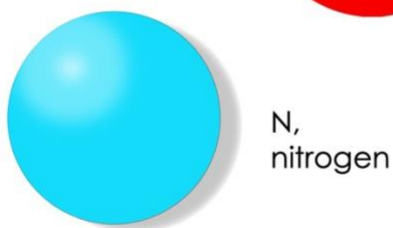


CLIMATE LITERACY & NUMERACY

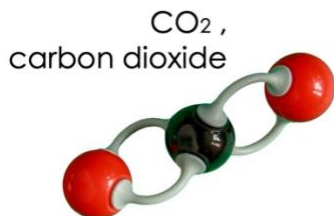
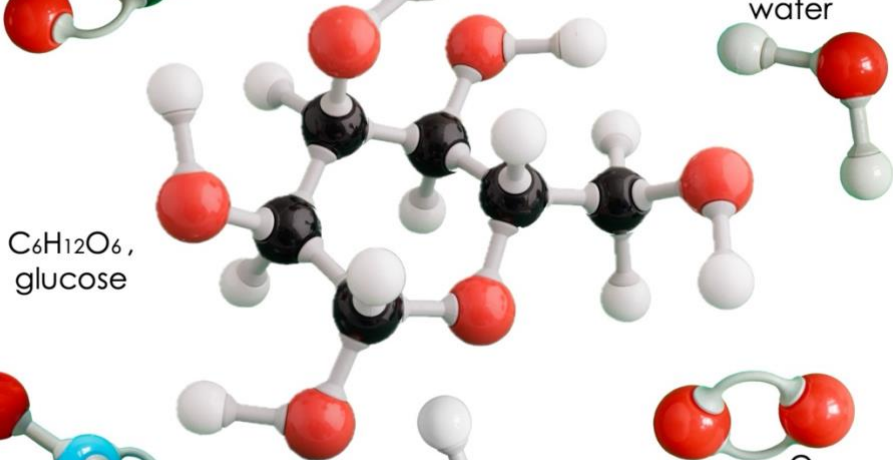
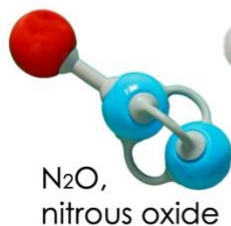
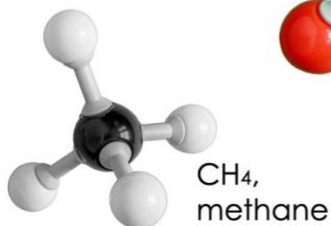
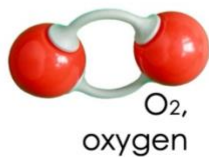
Understanding the emergency,
and what we can do about it

5th edition
August 2026

atoms



molecules



CLIMATE LITERACY & NUMERACY 5th edition i

ENERGY, CLIMATE, WEATHER, CARBON

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Introduction

Our climate systems are breaking down. Some changes are already inevitable, and we have to **adapt** to them. But that's futile unless we also **mitigate**. This means reducing the harm, by radically changing the systems we live by.

A healthier future depends on understanding what's been happening so far. Earth's heating up because we've changed the makeup of our atmosphere. Like a thickening blanket, it's getting too good at holding heat in.

Climate and weather

Energy from the Sun warms different parts of the Earth, as we spin from night to day and orbit from winter to summer. Land and sea warm up and cool down again, as currents in the ocean and winds in the atmosphere move heat and moisture around the seas and continents.

Climate describes the long-term patterns, as winds and currents cycle around the planet. Temperature, rain and snow used to be predictable, according to the time of year, and whereabouts you were. Species evolved, and civilisations developed, according to these seasons and climates.

Weather is what we experience in the short term, when currents and winds – warm or cold, wet or dry – are moving past us. It often changes, sometimes very quickly, but averages were predictable when climates were stable.

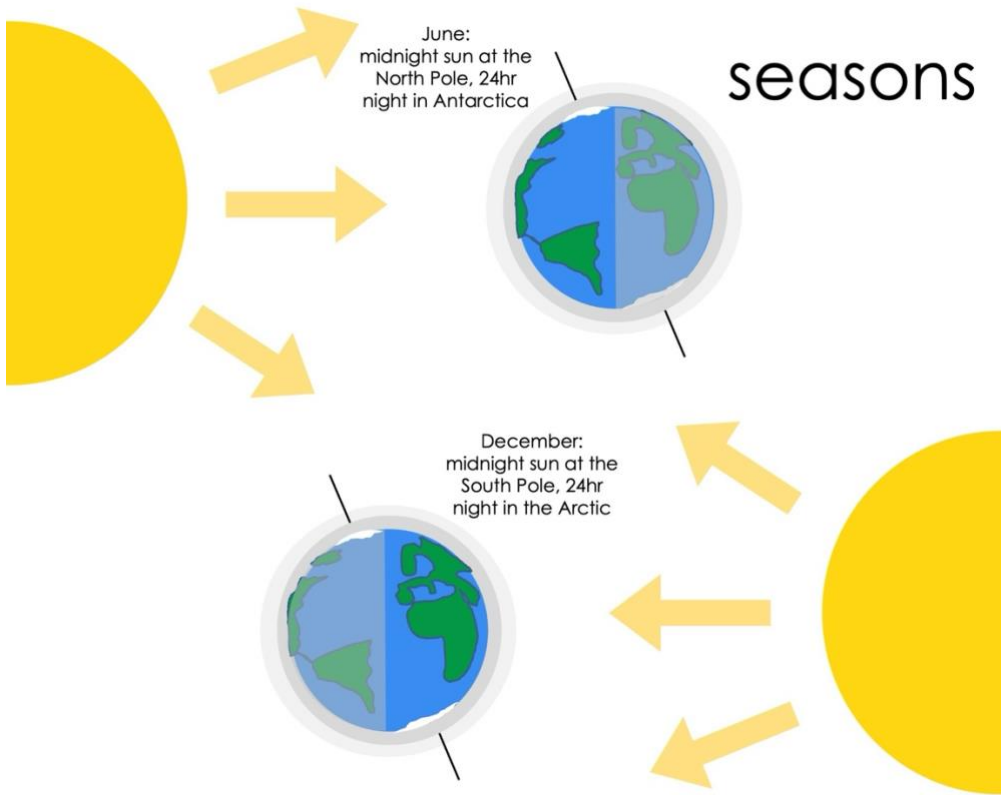
What's the 'Emergency'?

Over the last two hundred years or so, and especially in recent decades, Earth has been collecting more and more heat energy. This has disturbed **climate** systems that were fairly settled for the last few thousand years. The result is more **extreme weather**, happening more often – from heatwaves and cold snaps to storms, floods and droughts.

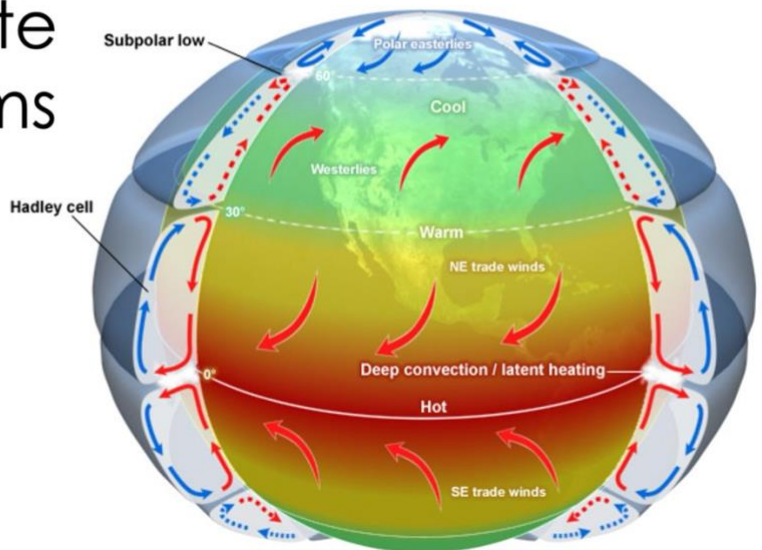
As ice-caps and glaciers melt, and the sea warms up and expands, sea-levels are rising. This changes coastlines and tidal riverbanks, directly affecting human settlements and economies. Indirectly, damaged harvests and food shortages, wildfires we can't control, opportunistic diseases and heat stress are all likely to fuel civil unrest and migration pressures.

Earth's energy balance has been knocked out of equilibrium by the activities of just one species - human beings.

What have we been doing with energy, and stuff, to make this happen?



climate systems



States of matter

Matter doesn't appear or disappear, but it can **change**. For example, when you heat solid ice it melts into liquid water: add more heat, and the water molecules evaporate into a gas ('water vapour').

Another example is the food we eat. It doesn't disappear when we digest it; we break it down into smaller molecules to make our bodies with, and release chemical energy to do work, to stay warm, and build/maintain those bodies.

The original food matter hasn't 'gone away'. Some molecules might be literally 'incorporated', becoming parts of our bodies, though many are offloaded as **waste** solids, liquids and gases. But they're all still **matter**, and still have **mass**.

Atmospheric gases

The air we breathe has **mass**, too. It's a mixture of gases; some are made of just one element, some are compounds of two elements or more. These pie-charts show their different shares of the whole as 'slices'.

Fresh air we breathe **in** is 78% nitrogen (N_2): 78 in every hundred molecules, more than $\frac{3}{4}$ of the pie. The atoms in N_2 (shown in blue) hold together firmly; they're unreactive, hard to break apart for any new sorts of molecules.

The next biggest proportion, 21%, is diatomic oxygen (O_2). Two oxygen atoms, shown in red. Bonded together like the nitrogen atoms in N_2 , but much more reactive: almost wanting to break apart and make new compounds.

A very small slice of the pie-chart, less than 0.9%, is a mix of mostly very un-reactive single atoms of elements like argon, neon, krypton and helium.

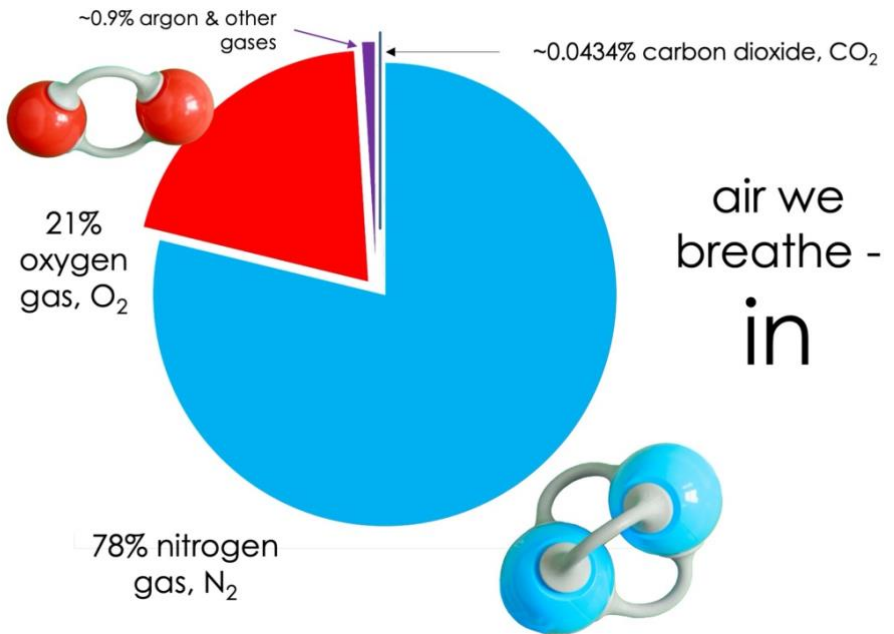
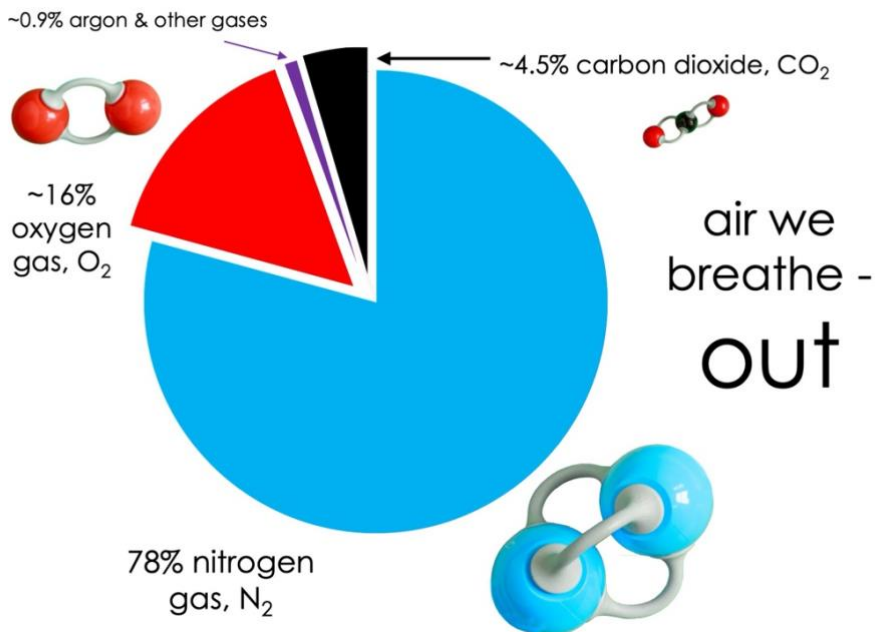
And a tiny sliver, a few hundred molecules per million, are carbon dioxide. Each molecule has 1 atom of carbon (shown in black) bound to 2 oxygen atoms: CO_2 , pronounced "C, O-two".

Air we breathe **out** has less O_2 , but a hundred times as much CO_2 . That's because when we 'burn' food to release energy, metabolising it in our bodies, we use up some of the oxygen we breathed in.

Then we breathe out CO_2 and water (H_2O) as waste products.

Very precise measurements began in 1958, when CO_2 was just 0.0315% of the atmosphere. By May 2026, this had increased by more than a third, to nearly 0.0434% of our atmosphere: that's 434 molecules, or 'parts', per million, or 'ppm' for short. Where's it all coming from?

This comes back to energy, and life on Earth.



Types of energy

Like matter, energy doesn't appear from nowhere, or disappear. But it can **change**, too.

The Sun bathes our Earth with **radiant** energy in a huge band of wavelengths, including the visible colours we call '**sunlight**'. About half reflects straight back out again (that's how we see Earth from space!). Some of the energy is absorbed and changed into **heat**, warming up the air and land, the oceans, fields, lakes and buildings around us. Then in turn, some of this energy radiates out again, as invisible, **infra-red** heat. (Concrete, and especially black tarmac, heats up and re-emits much more than grassland or forest. One of the reasons for the city 'heat-island' effect.)

Wind and waves, water and air moving around, are full of **kinetic** energy. Humans have long used this directly, to turn a mill and grind flour, or power a textile mill. Nowadays we use it indirectly, to turn a turbine and move electrons around, changing it into **electrical** energy. We can use this to do work right away, or store it for later as **chemical** energy, in batteries.

Our bodies use stored **chemical** energy, too, from our food. Whether we get it directly from plants themselves, or less directly by eating other animals, all of the energy in it was originally **sunlight**.

Except for a very few ecosystems on Earth (in the deep ocean, around 'black smokers'), Earth's whole food web is powered by the Sun.

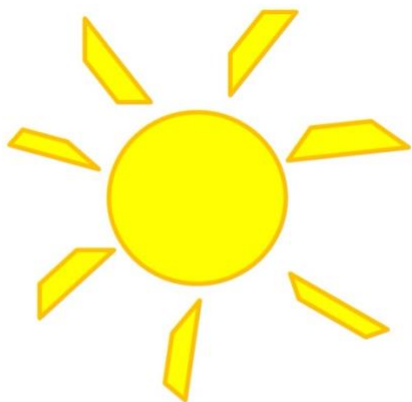
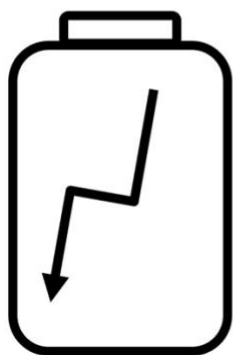
And the carbon or hydrocarbon molecules (hydrogen + carbon) in fossil fuels are chemical energy stores originally made by living things, using sunlight.

Carbon, and life on Earth

Plants and algae capture and store **radiant** energy from the Sun, solar energy, building their mass not from the soil, but the air. Much of their bodies, their **biomass**, acts as a store of **chemical** energy, for themselves and for the animals that eat them. And so on up the food chain, across the web of life on Earth. We are just one of the carbon-based life forms in this web.

Atoms of the element carbon are chemically just right for making big, complex molecules in almost infinite patterns and combinations, from individual sugars or proteins to muscles and bones, leaves and roots and whole bodies.

Photosynthesis stores energy and carbon into biomass; releasing that energy releases the carbon again, too.



Out of thin air: photosynthesis

This describes the way algae, then plants, evolved to make biomass using energy. Their energy stores and even their actual bodies are built from the matter, the 'stuff', of water (H_2O) and carbon dioxide (CO_2), using sunlight.

The initial carbon-based building block made by photosynthesis is glucose: the simplest energy source, easiest for cells to use. (That's why it's in energy drinks.) The diagram simplifies a lot, but in a way it's like toy bricks; all the pieces have to end up somewhere, whether or not you're using them.

A carbon atom can join up to 4 other atoms at the same time. Not many elements are this versatile. 'Organic molecules', in which carbon and hydrogen atoms join together, can make an almost infinite range of possible rings and chains. Carbon's been fixed out of the air and into biomass; and these big new molecules hold chemical energy. Some of it's used by living cells to do work, which includes knitting together bigger and more complex molecules. Enzymes, cells, tissues, whole complex creatures... the game of life has begun.

The carbon cycle; carbon sinks

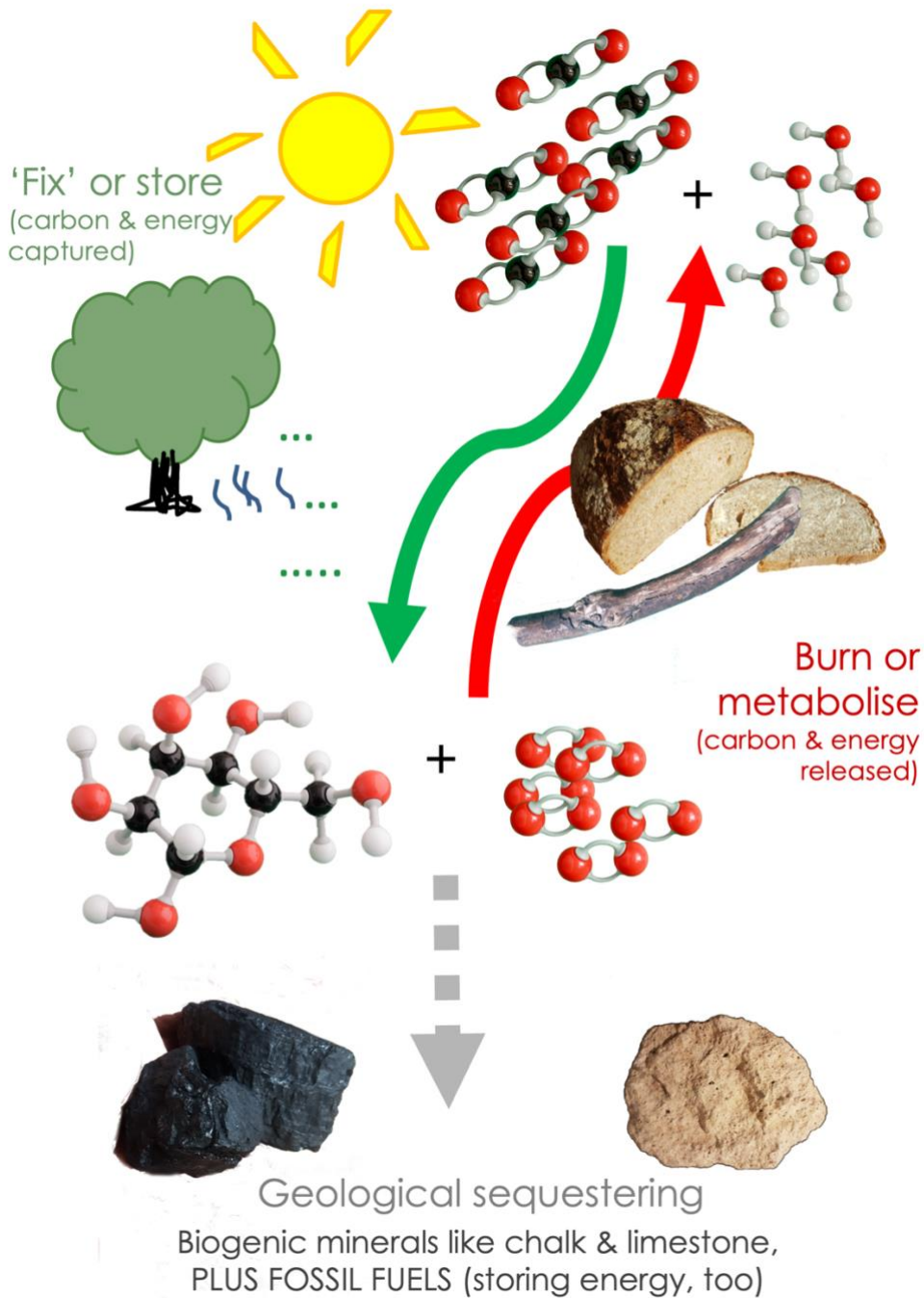
Some oxygen atoms are left over after fixing CO_2 into glucose; the waste product is O_2 oxygen gas. Reversing the process, O_2 is needed to release and use the stored energy – plants and algae use some of it themselves.

But so do animals. They breathe in the 'waste' gas from photosynthesis to digest the plants (or other animals) they eat. They use plants' building-block molecules and stored solar energy for their own benefit.

Burning food calories to stay alive and do things, or burning wood on a fire to release heat energy: they're almost the same, chemically. Photosynthesis is being reversed, to release energy: it's the other side of the 'carbon cycle'.

Some carbon is 'fixed' for longer. Chalk and limestone are the skeletal remains of marine organisms or plants, mostly carbonates (no hydrogen atoms). But fossil fuels like coal, oil and gas are rich in 'hydrocarbons'; literally, molecules containing hydrogen and carbon, stored in the Earth over millions of years.

When the amount of carbon being fixed out of the air is the same as the amount being emitted, the level of CO_2 in the atmosphere stays the same. There have been times in the past when more carbon was stored away or 'sunk' (sequestered), than released into the atmosphere. Then levels reduced. But when more's released than sequestered, the level goes up.



Carbon dioxide in the air

The 'Keeling Curve' precisely tracks CO₂ concentration (the vertical amount) over time (along the bottom). It goes up and down a little during the course of the year, every year. That's because the Northern hemisphere has twice as much land and vegetation as the Southern; significantly less photosynthesis happens between October and March, than in the Southern 'winter'.

But the annual average has risen steadily, by over a third since measurements began in 1958. This is only explained by emissions from burning fossil fuels.

The second graph has time along the bottom, too; the last few **hundreds of thousands** of years. By analysing air bubbles trapped in ice cores, scientists can see bigger, longer-term cycles in CO₂. These match 'Milankovitch' cycles in how the Earth tilts and orbits around the sun, and the ice-ages those cycles brought about. Now we can see climate history in a bigger context.

Human history, energy and carbon

Humans in control of fire could use it to move into new ecosystems and eat differently, begin farming and build towns and cities.

But this was almost all fuelled by current or recent photosynthesis: **biomass** in food for ourselves, to feed working animals, or burn as firewood. And we used kinetic **energy** in wind and water to travel, process food and weave cloth.

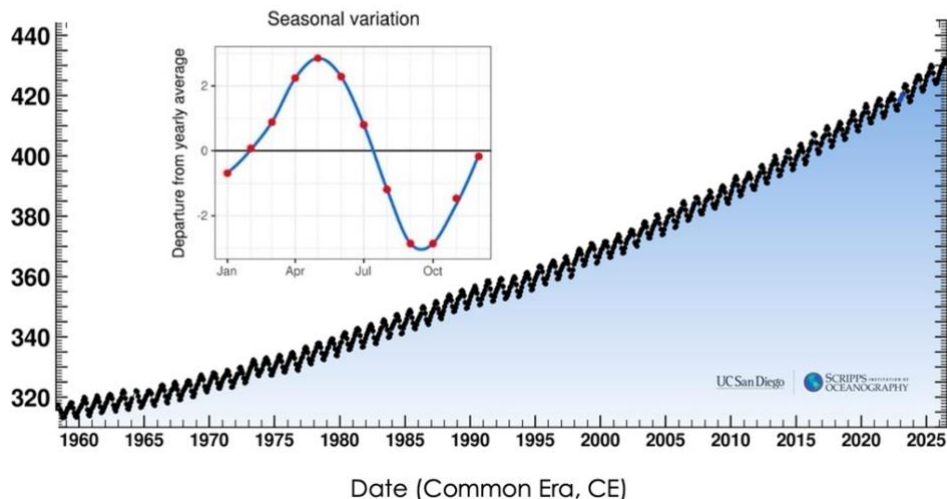
The industrial revolution of the late 18th century didn't come from nowhere. Burning coal to convert its stored **chemical** energy into **heat** wasn't a new discovery, either. But using it to make steam, as a way of changing that heat into **kinetic** energy to power machinery: this is what changed the world. Soon energy stores saved up over millions of years of photosynthesis were being spent incredibly quickly. The carbon cycle was knocked off balance by coal use, then overwhelmed when we started burning oil and gas as well.

In 2008, NASA scientist James Hansen proposed 350 ppm as a 'critical level' for a planet '*similar to that on which civilization developed*'. The Keeling curve shows that we went past this level around the year 1990. Burning fossil fuels has taken CO₂ concentrations higher than they've been for millions of years.

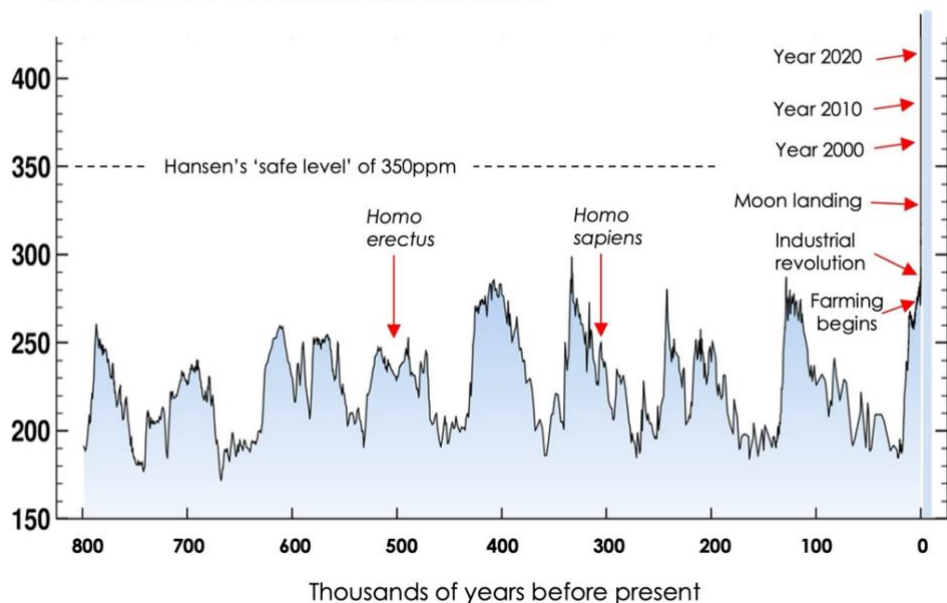
Such high CO₂ levels are changing the face of our planet. 'Anthropogenic' literally means 'caused by humans'; some say we're now in a new geological epoch, the 'Anthropocene'.

Why do CO₂ levels matter?

The 'Keeling Curve'; atmospheric CO₂ since 1958
 Monthly averages to July 2026, parts per million (ppm)
 (433.95 in May 2026)



Atmospheric CO₂ over the last 800,000 years
 From 'Holocene' (in which humans evolved) to 'Anthropocene'
 (pre-1958, ice-core data; then Keeling measurements)



Greenhouse Earth

Atmospheric CO₂ traps long-wave infra-red heat energy. This is why Earth has been warm enough for life to evolve and flourish.

Apart from clouds, our atmosphere is 'see-through': transparent to visible **light** from the sun. And much of the heat that radiates back out again, can pass through, too – but not all of it. CO₂ molecules absorb some of this energy and stop it shining back out into space.

Like in a greenhouse, light shines in and bounces out again, but some of the warming-up it causes is trapped inside. It's been called the 'greenhouse effect', though some think of it as an insulating blanket or duvet.

Without it, Earth's average surface temperature would be **minus** 18°C, or less.

Global heating and climate systems

With more CO₂ in the atmosphere, less and less heat radiates back out.

Ocean, land and air all warm up more than they used to, changing the climate systems that move heat and moisture around.

Over the last 200 years, rising CO₂ levels have increased the strength and frequency of extreme weather events like droughts, floods and cyclones, not least because warmer air holds more water vapour. Ice-caps and glaciers are melting, sea-levels are rising, ocean currents and even the jet stream are changing. And just like CO₂, water vapour molecules trap infra-red heat energy from radiating out again, in a feedback loop.

Whole ecosystems – and the human activities depending on them – took millennia to evolve, around predictable seasons and weather patterns.

Now these are changing within decades, even years.

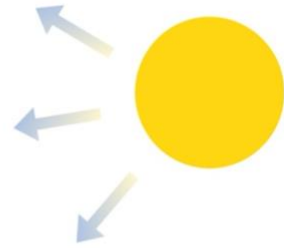
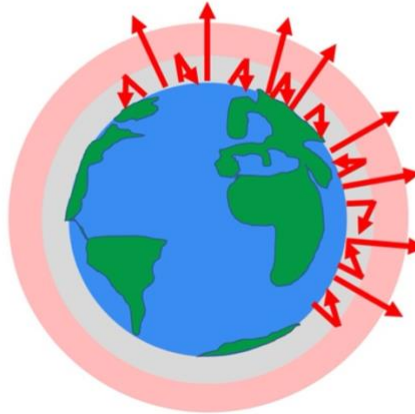
Complex living things can't evolve quickly enough to cope.

Gradual changes are bad enough, but there's a risk some climate systems will make big switches. For example, the ocean currents that warm Northern Europe are weakening. Food production, housing needs and day-to-day survival will be devastated if they grind to a halt (see p34).

The emergency is speeding up; wildfires of the 2020s are changing whole biospheres. Talk of 'saving the planet' misses the point: Earth will keep spinning round the sun. What's at risk is life as we know it.



If no CO₂ in the atmosphere
minus 18°C or less

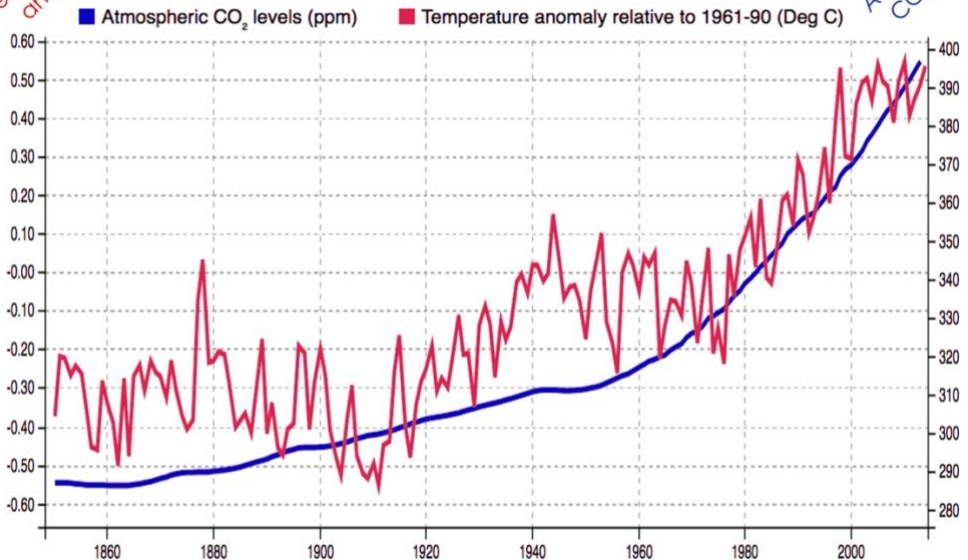


Average
surface temp, 1980;
+14°C (CO₂ that
year, ~340ppm)

Surface
temperature
anomaly

CO₂ levels and temperatures

Atmospheric
CO₂ ppm



CO₂ ice core data (pre-1959): [NOAA](#), and post-1959: [Mauna Loa](#)
Temperature data: [MET Office](#)

Extreme weather

More heat energy and water vapour in climate systems leads to more extreme weather events, happening more frequently. Even the wealthy 'global North', responsible for most greenhouse gas emissions, is seriously suffering now.

We've gone well beyond 'normal' variation: the 2020s are piling up 'hottest year on record' for year after year, and rivers vital to economies are drying up.

The global South have suffered stronger cyclones for several decades. But more recently, wetter winters and drier summers have fed horrifying wildfires and droughts across wealthier Europe and North America.

Oceans, acidification and heating

Oceans absorb about 90% of the increased heat, but also much of the excess CO₂. It dissolves in water to make carbonic acid, which weakens shells of animals like sea urchins, corals, crustaceans and shellfish – even some plankton. Rising CO₂ is endangering marine creatures, whole species and entire ecosystems, which is in turn damaging fisheries & human communities.

And heat destroys whole ecosystems. For example, coral reefs are built by animals called 'polyps', that co-habit with photosynthetic algae. Polyps eject their algae if the sea gets too warm. They lose their food source as well as their colours, in what's called 'coral bleaching'. When it's too severe, they die.

Feedback loops – and the natural world

Other feedback loops could tip Earth into chaotic change.

'**Albedo**' describes how reflective a surface is (*albus* means white, in Latin): snow, glaciers and ice-fields reflect solar radiation back out into space. But open oceans, land and bare rock are darker, with a much lower albedo. They soak up light, converting more of it to heat energy – leading to even more melting. And damaged ecosystems become feedback loops, too.

Forests of seaweed, coral or trees; meadows, peatbogs; they're all '**carbon sinks**': full of carbon fixed into biomass. Ploughing, trawling, uprooting or allowing them to burn switches them into carbon **sources**, releasing CO₂.

Climate and Nature are bound together, and are both in crisis.

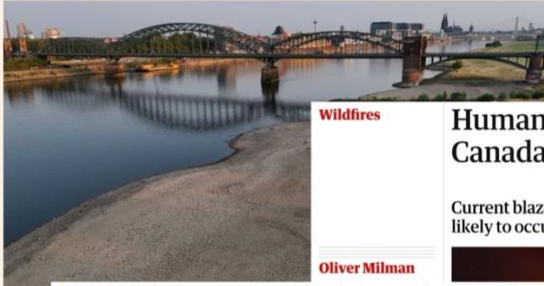
The International Panel on Biodiversity and Ecosystem Services (IPBES) define climate change as one of the 5 main 'drivers' of biodiversity loss.

Because of the way they interlink, it amplifies all the other 4 and is possibly the single biggest priority.

Germany + Add to myFT

Rhine drought strands ships and forces German production cuts

Water level of crucial trade river has fallen to match 2018 record low after extreme heatwaves



The drought transport

Environment

Pippa Neill
Environment
reporter

Mon 20 Jul 2026 20:00
BST

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Wildfires

Oliver Milman

Human-driven climate crisis fuels Canada's deadly wildfires, study finds

Current blazes roaring across country more than twice as likely to occur because of fossil fuel-driven global heating



Typhoon Dolphin: more than a million people evacuated in China as record rainfall dumped on Shanghai

Authorities warn that days of intense rain could trigger widespread flooding and landslides as storm moves north and further inland



Slowdown in Arctic ice melt ends after largest winter decline on record

Scientists recorded slower reduction over past 20 years, but study finds this was 'temporary rather than sustained'



Researchers found between 2024 and 2025 Arctic sea ice declined by 5.6% in year-to-year wintertime, the lowest ever recorded. Photograph: Anadolu/Getty Images

How heatwaves are hammering the economy

It's too hot to sleep in the high across productivity to down in north and prices are rising, reports Tim Wallace



Who's vulnerable?

High-income countries are still mainly concerned with extreme weather and wildfires within their own borders. But even the most selfish and wealthy rely on a healthy global climate system for food and water.

And elsewhere, villages in Greenland are subsiding into melting permafrost. Pacific Island states are being eaten away by rising sea-levels. Heat deaths in Asia and Africa aren't so well tracked, but are likely to already be in the millions.

'Wet bulb temperature' and limits to survival

In high temperatures, sweating can keep us cool enough to stay alive – as long as that sweat can evaporate. If the air around our bodies is already too full of water vapour, sweating doesn't help. A thermometer wrapped in a wet cloth mimics a sweating body, and takes this into account. It usually shows a lower temperature than dry. But if 'wet bulb' temperature goes over 35°, even fit and healthy people will die. Other animals die, too, and crops fail.

Human life is hitting absolute limits. Some places on the planet will stay cooler for longer – and inequalities will escalate quickly, with wealthy people managing to hold out for longer. But sooner or later 'business as usual' will be impossible for anyone, and nowhere will be safe for anybody.

Speed of change – urgency and agency

Global heating is speeding up. Neither **mitigation** (reducing the harm) or **adaptation** (tweaking systems to cope with harm) will stop it without radical change to the systems we live by.

The UK's Committee on Climate Change made recommendations in May 2026's Report, 'A Well-Adapted UK'. Predictions about future decades are already coming to pass; deaths from heat, water shortages, farms becoming unviable and buckling of infrastructure are harder and harder to ignore.

The greenhouse effect will continue to accelerate unless mankind stops emitting greenhouse gases, and stops destroying natural carbon sinks.

This will take commitment from individuals, governments, corporations and civil society. We can all sound the alarm. And together we can respond, with an understanding of how human activities are causing the damage.



The Guardian picture essay

Waiting for the tide to turn: Kiribati's fight for survival

Guardian, 2019-05-04

▲ Salt water from sea incursions and storm surges has isolated some houses in Kiribati's main island of South Tarawa. Photograph: Mike Bowers/The Guardian

The 33 islands of Kiribati, a remote and low-lying nation in the Pacific Ocean, are under threat from climate change. But the islanders have not given up hope

by [Mike Bowers](#)

UK risks:

Floods/droughts

Ecosystem viability (farmed, managed & 'wild' all at risk)

Collapsing supply chains, power failures

**Human health issues
– extreme heat**

Knock-on effects from impacts overseas

Where's all the CO₂ coming from?

Concentration isn't the same as **amount**. Tracking where **actual amounts** of CO₂ have come from, can be framed in different ways.

In 2024 China had the biggest 'territorial emissions' of any single country. This counts CO₂ emitted within it's borders. In China, that's still mainly from burning coal – the dirtiest fossil fuel, emitting most CO₂ per unit of energy. But China has a huge population, and exports much of what they make. So the middle graph shows emissions assigned to the same 'Top Ten' countries - but as consumers, not producers; and per person, not per country. (The top-ten chart for this criterion would begin 'Singapore, Qatar, Malta(!)...'). Meanwhile less industrialised countries where most have simpler lifestyles contribute very little to the warming blanket, but take the impacts full-on.

These emissions data are all about how quickly we're adding more each year. But it's the cumulative **total** up there that's heating things up.

Data can also show the different places it came from, over historical time. The bottom graph shows these 'cumulative' emissions.

Who started it?

Until the early 1900s, most of this cumulative total came from burning coal in the home of the industrial revolution – the UK.

As the United States industrialised, and oil grew more significant, they began to take over as top emitters. Their agricultural **and** industrial production rates both soon outstripped Europe's.

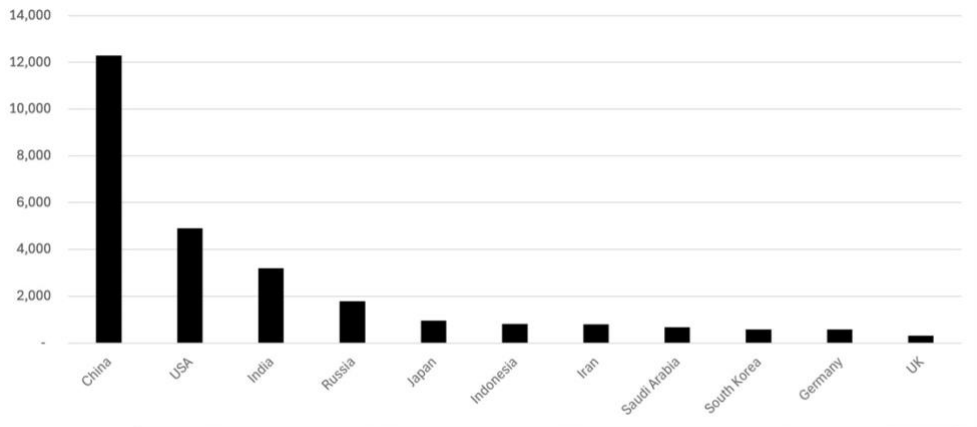
By the end of World War II, the USA accounted for 40% of cumulative total emissions. Only after the 1950s did emissions from China begin to surge – not least because of outsourced manufacturing, for consumers elsewhere.

Capital is globally mobile, just like fossil fuels and greenhouse gases. It finds compliant workforces in countries with surplus, cheap or even imprisoned labour. Low pay & conditions often co-exist with lower environmental standards. For example, fast-fashion for the UK is often made in coal-powered Bangladeshi factories.

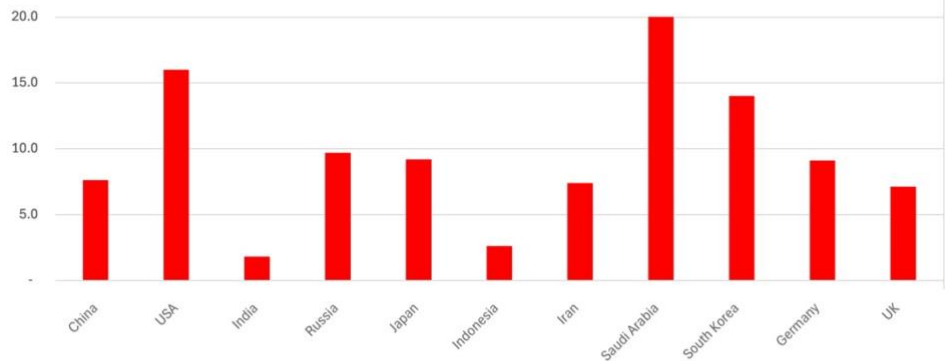
Do these emissions 'belong' to Bangladesh, or to UK consumers?

(See more on 'Scopes', pp.28-29.)

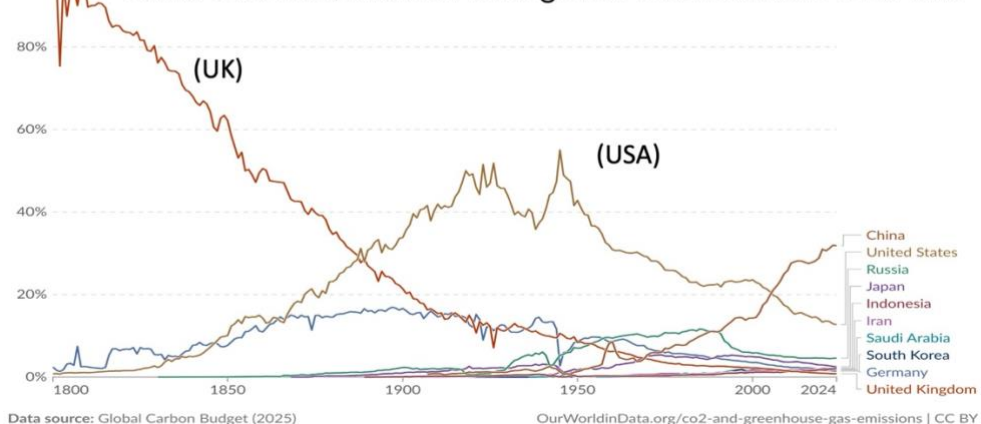
Top ten countries for territorial emissions, + UK; gigatonnes (2024)



Same countries, consumption per person, tonnes (2023)



Same countries, share of total global CO2 emissions over time



Income and Impact

Responsibility for emissions isn't shared fairly *within* countries, either.

Between 1990 – 2015, in just 25 years, the amount of man-made greenhouse gas in the atmosphere **doubled**. Oxfam and the Stockholm Environment Institute analysed this increase according to income groups, instead of countries.

On a global scale, the richest 10% includes anyone earning the average UK wage or more). 52% of these emissions, over half, could be attributed to this group. As the 21st century got going, even bigger expectations & habits of consumption enlarged footprints that had already been quite heavy. A rise in the 'global middle class', especially in China and India, links to rising emissions.

But the economically poorest 50% emitted only 7% of that doubling.

Meanwhile they're likely to suffer loss and damage first, and worst.

It's affluent lifestyles, not absolute population, that's brought us to crisis point: the very wealthiest 1% have an outsize responsibility. But this also means they have the best opportunities to make a difference by taking climate action, via behaviour change as well as active citizenship. For better or worse, they are often influential rôle-models with followers, and access to decision-makers.

Climate Justice

If the global top 10% matched their footprints to the EU average, total global emissions would go down by **a third**.

Special pleading from individuals in the global North to continue 'business as usual' often invokes traditions and family ties. A wish to visit grandchildren on the other side of the world, a habit of daily meat-eating, or driving a pet dog to a particular beauty spot for a daily walk... all these can be set against the costs already being paid by others in different classes or parts of the world, whose family ties and customs are already crushed, or in lethal jeopardy.

People indigenous to the global South are already vulnerable to land-grabs and extractive mining for minerals and resources. They could be less damaged by a sustainable global economy, than by the current one built on fossil fuels.

Climate systems are global: national borders mean nothing to clouds, rain and snow, or bodies of heat energy in atmosphere and oceans.

Very few in the global North are genuinely powerless to help; producers, consumers, exporters and importers, citizens and voters all have opportunities to be part of the change Earth needs.

Human-made CO₂e
in the atmosphere **doubled**
between 1991 and 2015.
Who's responsible?



The poorest 50% emitted only 7% of this:

annual income under US\$6k



The middle 40% emitted 41%

annual income between US\$6k-38k



The richest 10% emitted 52%

annual income US\$38k (ie. UK average) or more



The wealthiest 1% emitted 19%
all by themselves

annual income over US\$109k



data from 'The Carbon Inequality Era', SEI/Oxfam 2020

Sinks and sources of CO₂

Most extra CO₂ in the atmosphere comes from burning fossil fuels; coal, oil and gas, carbon sequestered in ancient ecosystems. 'Dead sinks'. But destroying **living** carbon sinks like forests, soils or sea-beds also releases CO₂. Double blows, as less CO₂ is being naturally fixed again once they're gone. And making cement involves 'fossil carbon', too. Limestone & chalk are also the remains of living creatures - mainly calcium carbonate, CaCO₃. Super-heating them to make molecules of 'lime' (calcium oxide, CaO) for cement, releases a CO₂ each time – even if renewable energy's used to do it.

Other greenhouse gases:

CO₂ is the most significant 'greenhouse gas' (GHG), but other atmospheric gases also trap heat. Water vapour does this very effectively, but condenses and evaporates so rapidly, and is so affected by temperature and pressure, that it's usually left out of calculations. The other greenhouse gases that are routinely counted are methane, nitrous oxide and the 'F-gases'.

Methane

The simplest hydrocarbon molecule, CH₄, this greenhouse gas is thought to be responsible for 30% of global warming. It occurs naturally, but is also a fossil fuel itself. Sometimes piped straight to consumers, often liquefied and shipped as 'Liquid Natural Gas' (LNG): either way, burning it releases CO₂. But if it escapes into the atmosphere, methane's an even more powerful GHG. Coal & oil deposits often include pockets of CH₄; mining, drilling and 'fracking' leak enormous amounts. Sometimes it's even 'vented' on purpose.

And wherever biomass is rotted anaerobically, by microbes that can live away from fresh air, methane is emitted. Methane bubbles out of ponds & swamps as 'marsh gas', and from biodegradable rubbish rotting in landfill sites.

Farming's a major source, too; wet-paddy rice fields are effectively beds of rotting biomass. Even more significantly, ruminant animals like cattle and sheep can only survive on grass because they host anaerobic gut microbes that digest cellulose for them. Methane's their waste product, burped out in tens of litres a day by each individual animal.

It's natural for them to do this. What's **not** natural is the sheer number of them now alive on Earth, feeding higher and higher levels of meat and dairy consumption. Unnecessary, and harmful to human health, even before counting the global warming potential.



Nitrous oxide

Nitrogen is vital to living things. The atmosphere is 78% N_2 gas but this is inert, not 'bio-available'. Plants can fix carbon out of thin air via photosynthesis, but they can't fix nitrogen. This limits how much they can grow.

Leguminous plants like clover, peas and beans, can host microbes on their root systems that capture nitrogen and fix it into organic molecules, making it bio-available to other living things as well. Farmers traditionally rotated crops around their fields, planting legumes every few years as 'green manure'. Ploughing these plants back into the soil would enrich it with bio-available nitrogen.

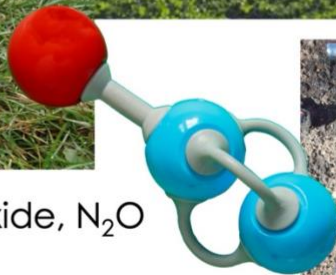
In 1910 it was discovered how to fix nitrogen chemically, on an industrial scale. Since then, rapidly growing populations have been fed thanks to chemical fertilisers, but at huge cost to biodiversity and climate. Making them takes huge amounts of energy, with associated CO_2 emissions. But when nitrogen fertiliser is over-used, nitrous oxide (N_2O) is released. Livestock manure/slurry and human sewage release nitrous oxide, too: and it's a powerful greenhouse gas. (It's also known as 'laughing gas'; an anaesthetic and recreational drug. It's not toxic, but damages lungs when taken to excess.) A smaller but still significant source of N_2O emissions is nylon manufacture. *Note: 'NOx' gases emitted by cars with internal combustion engines ('ICE') are nitric oxide (NO) and nitrogen dioxide (NO_2); toxic, but not greenhouse gases.*

F is for fluorine; the F-gases

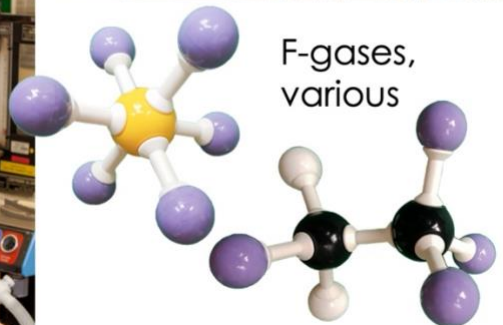
This fourth GHG is a catch-all name for a range of molecules (HFCs, PFCs, SF_6 and NF_3) that all contain the element fluorine. They're only ever man-made, in relatively small amounts to do specific jobs. But if they escape into the atmosphere (as 'fugitive gases'), they hold in a huge amount of extra heat.

Many anaesthetics used in human & veterinary medicine are F-gases. (Including desflurane, recently restricted by the Scottish government for the sake of the climate.) More generally, F-gases include excellent refrigerants, circuit-breakers and electrical insulators. We're likely to use more & more of them as the Climate Emergency unfolds, and it will be vital to contain them; leaks and 'top-ups' must not continue to be treated as regular normal events.

Note: gases in the atmosphere react with each other. For example, methane and other volatile organic compounds combine with NO_x and other gases to make ozone. We need this to be in the stratosphere, but at ground level it's toxic. There's a lot of detail – but the amounts of the 4 main GHGs are key.



nitrous oxide, N_2O



F-gases,
various

Global Warming Potential (GWP)

CO₂ is by far the most abundant greenhouse gas. But per molecule, the other GHGs can hold much more heat in the atmosphere. Their Global Warming Potential ('GWP') describes how much more, compared to CO₂.

The GWP of nitrous oxide is 256: this means 1kg of N₂O heats Earth as much as 256kg of CO₂. F-gases vary widely, but are all even higher: Freon (tetra-fluoro-ethane) has a GWP of 1,430, while sulphur hexafluoride's is 23,500.

The most abundant GHG after CO₂ is methane. These molecules break down so fast that the warming potential tails off by a half, roughly every 8 to 9 years. Methane's official GWP over 100 years, its GWP₁₀₀, is 'only' 25.

But so much methane's being emitted, and time is running out so quickly, that some people count the shorter 20-year timespan. Methane's GWP₂₀ is 86.

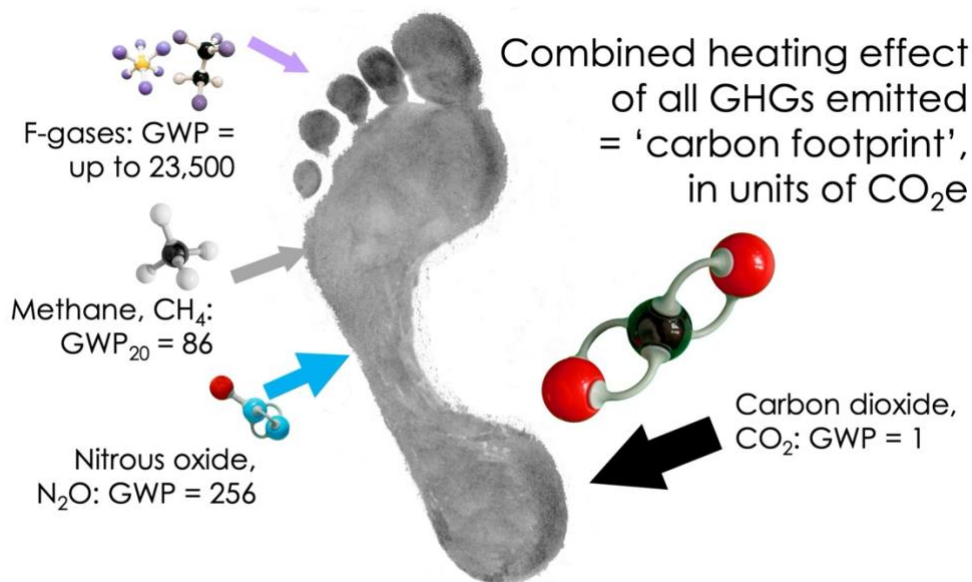
CO₂ equivalence and 'footprints'

To describe something's climate impact we could count the mass of each gas emitted, use GWPs to calculate how much heating each will cause, and list them individually. Alternatively, a **carbon footprint** adds these together into a single number. The unit is 'carbon dioxide equivalent', or CO₂e. This indicates how much CO₂ would have to be emitted, to have the equivalent impact on global heating. Footprints are measured by mass; grammes, kg, tonnes...

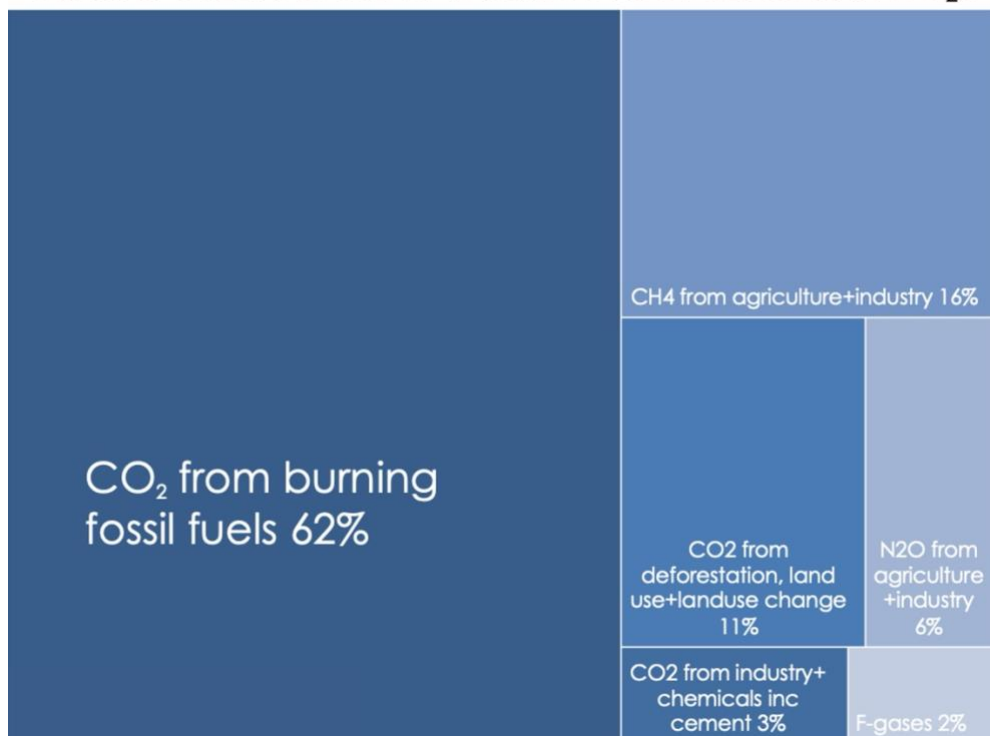
Factories, universities, hospitals; an oil terminal and a music festival, a data centre and a movie and a military invasion – they all have 'footprints', that can be directly compared. 'Carbon' is used as a shorthand for all greenhouse gases; 'de-carbonising' means reducing emissions of any or all of them.

Especially in the wealthier 'global North', it's easy and even socially engaging for some people to go flight-free, car-free, and meat and dairy-free in order to significantly reduce their individual footprint. This models a healthier lifestyle, and shows governments and corporations that many consumers do want to change. But it's harder for others to de-carbonise. Modern built environments are often dominated by private motor cars, the food industry is tied in with industrial agriculture, and hyper-consumption is still considered normal.

Freeing ourselves from a reliance on fossil fuels will include changes in how we travel and transport stuff; the food we eat, and how we heat and cool the spaces we use. Most people don't own the buildings they live or work in; other 'public/shared' footprints include education, health and justice systems and the military. Small tweaks to individual footprints mustn't distract from the need for social change, or use up all the energy we need to organise for it.



GLOBAL GREENHOUSE GAS EMISSIONS BY SECTOR, in CO₂e



Emissions ownership: whose footprints matter?

Who's responsible for GHG emissions of a journey in a motor car: the individual driver or passenger, city planners or government transport policy, the employer or tourist attraction inviting or requiring them to travel by car? They **all** have agency in these emissions: the Greenhouse Gas Protocol organises this paradox with 'Scopes'. Double-counting is a **feature**, not a bug.

Scope 1 covers direct GHG emissions, eg burning fuel to heat a building, or to power an engine or machine; venting methane from your oil platform or farm; using an air conditioner that leaks F-gas refrigerant, or dumping a fridge. If this example is a company vehicle on business, exhaust fumes are 'Scope 1'.

Scope 2 covers indirect emissions caused by '*purchasing electricity, steam, heating & cooling for own use*'. If the journey's in an electric vehicle (EV), charging it up involves Scope 2 emissions. How the electricity was generated makes the biggest difference; coal's most harmful, followed quickly by oil and then gas-fired power stations. Wind or solar are almost zero in comparison.

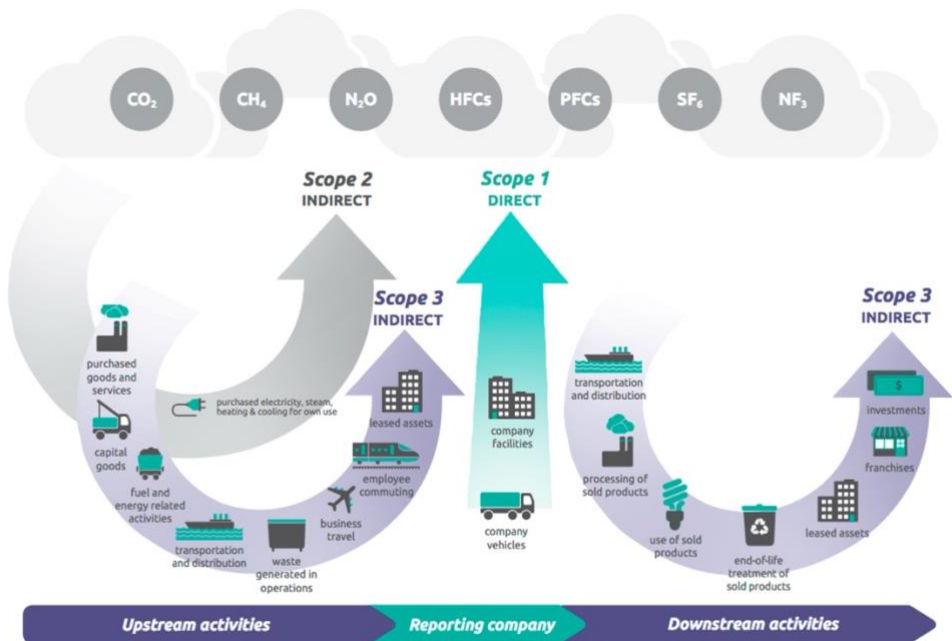
Scope 3 covers all other indirect emissions, in 15 categories! (See graphic) Upstream emissions are 'embedded' in raw materials or capital goods like the motor car itself, buildings, business travel and waste. Emissions downstream might involve include distribution, processing & waste disposal. Companies often deliberately omit a crucial category, '**use of sold products**'.

The phrase 'net-zero petrol' is greenwash; exhaust emissions still matter. And they belong in 'Scope 3' for whoever made and sold the motor car, and also for whoever extracted, refined and then sold the fuel on the forecourt. (Scope 3 was key to the Scottish parliament's refusing the Cambo oilfield.)

Beyond three Scopes? data, warfare...

Scope2+ has been suggested, to account for emissions associated with the amount of '**compute**' being used by a product, event or activity. Impacts of data centres are forecast to be catastrophic in the late 2020s, on climate as well as society; this would group their emissions with electricity generation.

And Scientists for Global Responsibility (SGR) have researched the 'bootprint' of warfare. Besides immediate emissions (S1) and electricity consumption (S2), supply-chain emissions from military supplies and their use (S3), they've proposed a **Scope3+**, to include destruction of landscapes and cities, healthcare of survivors, refugees and resettlement, reconstruction and landfill.



GHG Protocol scopes & emissions across the value chain



SCOPE 1: direct emissions
e.g. fuel burned on the premises
or by company vehicles/machinery,
plus 'fugitive emissions'

SCOPE 2: indirect emissions
from consumption of purchased
electricity, steam or heat'
(**Scope 2+**; use of data/compute?)

SCOPE 3: other indirect emissions
including bought-in or out-sourced goods & services;
the use of what you make and sell; investments,
franchises, waste disposal etc. AKA 'value-chain'
emissions; including upstream AND downstream
(**Scope 3+**; carbon costs of armed conflict?)

‘Carbon Neutral’ and ‘offsets’

Can some emissions be magically ‘neutralised’ by reducing other emissions, subsidising someone else to avoid some of theirs, or paying for extra negative emissions to happen somewhere else? Is a car journey ‘carbon neutral’ if you don’t eat meat that day, or pay for a more efficient cooking-stove in Sudan? ‘Comfort blanket’ offsets, like those sold with holiday flights, often involve tree-planting. But forests aren’t simple plantations, and land is finite. ‘Carbon-neutral’ promises by fossil fuel companies have already earmarked more than the available surface area of Earth. If carried out, they’d evict millions of people from their land, then run out of space anyway. The offsetting business can be compared to medieval Christian ‘indulgences’ from pardoners. And from the climate’s point of view, these ‘good deeds’ are offset when the passenger takes their flight, or the oil company keeps drilling.

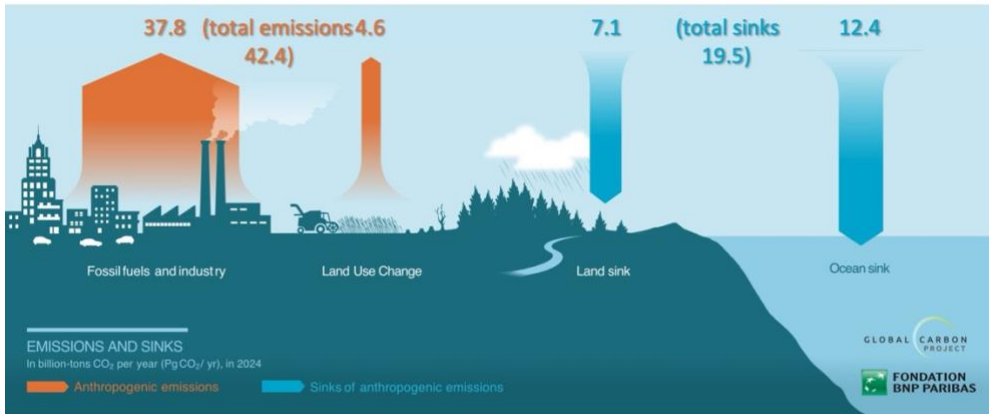
Doing sums; sources and sinks

More energy is radiating in than radiating out, so Earth’s heating up. The carbon budget works the same way. Photosynthesis ‘naturally negative’: fixing CO₂ out of the atmosphere into biomass, storing solar energy in the process; trees, seaweeds and other algae all do this. But deforestation, mining, factory farming and trawling all emit carbon, while obliterating ecosystem ‘sinks’; now wildfires are making a serious difference to the global sums. Total CO₂ in our atmosphere will increase until we stop emitting more than is stored away in sinks. This ‘net zero’ is the start; to stop further heating, the total must also reduce (NASA’s James Hansen suggests 350ppm max; see p11).

‘Net’ Zero, carbon capture and storage (CCS)

Industrial ‘sinks’ have so far been an expensive distraction. CCS can slightly reduce operational emissions but usually enables further combustion; for example, CO₂ captured during oil extraction is often pumped back into oilwells to squeeze more out. In Scotford, Canada, Shell links carbon capture to processing bitumen tar-sands. More CO₂ is emitted than captured, even **before** the product is burned. In comparison to natural sinks lost to wildfires and biomass energy projects, industrial carbon capture and storage has so far been at microscopic scale. Promoting it as a way of offsetting combustion of fossil fuels – or in the case of UK’s Drax power plant, burning trees – makes no scientific or economic sense. Yet it’s being promised as a get-out for the massive power demands of so-called ‘artificial intelligence’ and data centres.

GLOBAL CARBON BUDGET 2024



emissions – sinks = net increase
ie. 42.4 – 19.5 = 16.9 Gigatonnes

NATURAL SINKS (land and ocean)



INDUSTRIAL SINKS
(35-year cumulative only
0.38Gt, since 1990)



MEANWHILE:

continued destruction of natural sinks

International bodies & Climate Science...

In 1988 the United Nations founded the Inter-governmental Panel on Climate Change ('IPCC'). This panel of scientists assess research from around the world to regularly agree a current 'state of knowledge' about the science, the need to mitigate emissions to reduce harm, and impacts plus necessary adaptations.

In 1992 the Rio 'Earth Summit' declared that '*states have... responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states*'. The United Nations Framework Convention on Climate Change (UNFCCC) was established, which can require countries to take action based on IPCC findings.

...requiring action

The UNFCCC held their first Conference of Parties ('COP1') in 1995, in Berlin. COP3 in Kyoto, 1997, specified key GHGs and proposed limits to emissions. COP21 in Paris, 2015, set a temperature rise 'ceiling' we must stay beneath, of 1.5-2°C above pre-industrial average; in 2018 this 'band' was stripped down to strictly 1.5°C; hence the slogan '1.5 to stay alive'. A **limit**, not a target.

Promises were made and broken; around the world, the public began to demand action. Extinction Rebellion took off, and Swedish schoolgirl Greta Thunberg sparked the 'Fridays for Future' school-strike movement. In the UK, protestors provoked Parliament into declaring 'Climate Emergency' in 2019. Other public and private bodies followed suit, but real action's been weak.

In August 2021 the IPCC finally stopped expressing any doubt about climate change, and reported 'Code Red'. But by the time of COP30 in Belem (Brazil), 2025, a quarter of all delegates were there on behalf of fossil fuel industries. 532 individuals were there to promote CCS alone – more than all national delegates from G7 countries combined, and often unashamedly from fossil fuel companies themselves. The Centre for International Environmental Law calls this '*corporate capture, not climate governance*'. Even United Nations Secretary-General António Guterres lost his patience. (See tweet opposite.)

Fossil fuels are often behind economic instability and armed conflict, as well as global heating. In April 2026, a different conference was held in Santa Marta, Colombia, shifting focus away from GHGs and onto the industry itself. The 'International Conference on Transitioning Away from Fossil Fuels' built support for the Fossil Fuel Non-Proliferation Treaty, but it's struggling now.



Where are we heading?

The basics are simple, but predicting actual climate change depends on what governments, corporations and consumers actually do – not their ‘pledges’.

The first graph opposite is from the IPCC in 2023, predicting actual emissions, not promises. Most of the ‘remaining budget’ of 400 giga-tonnes (Gt), from 2020 onwards, for a 67% chance of staying below 1.5 °C of warming, has already been used up; by wars, wildfires, and ‘business as usual’.

Emissions are still increasing; it’s long past time to make gradual changes.

The initial Paris Agreement spoke of limiting heating to between 1.5-2°C. More work proved how deadly this would be for people around the world, and a revision in 2018 adjusted the limit to 1.5°C.

The two lower curves show the sort of ambitious scale of change we need even to stay within 2° of heating, and how quickly it should be made.

How bad could it get? ‘Tipping points’

If global heating continues, some systems will fail; like someone leaning backwards on a chair, there are points after which they can’t recover.

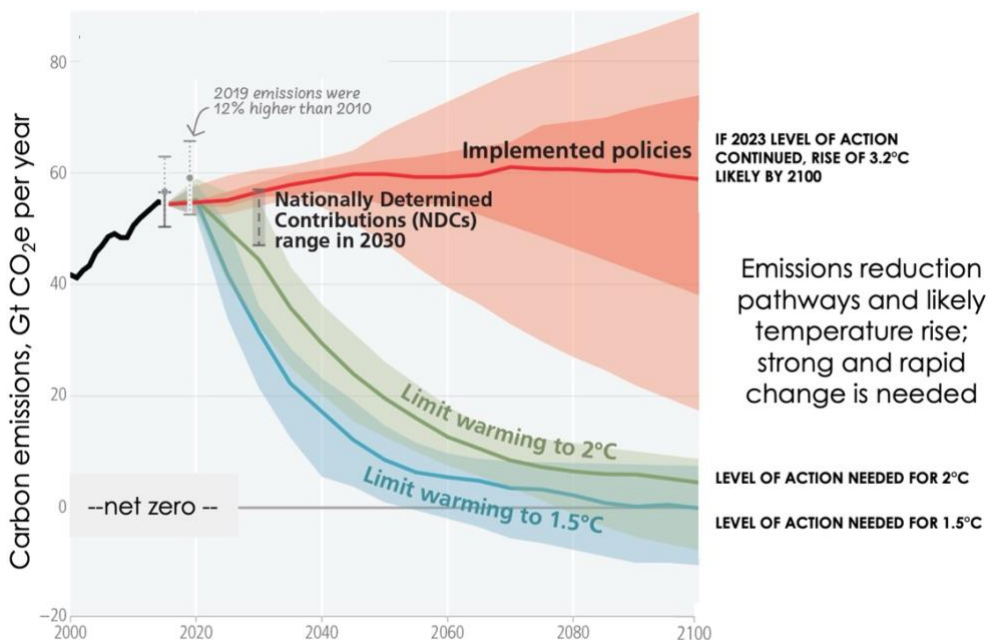
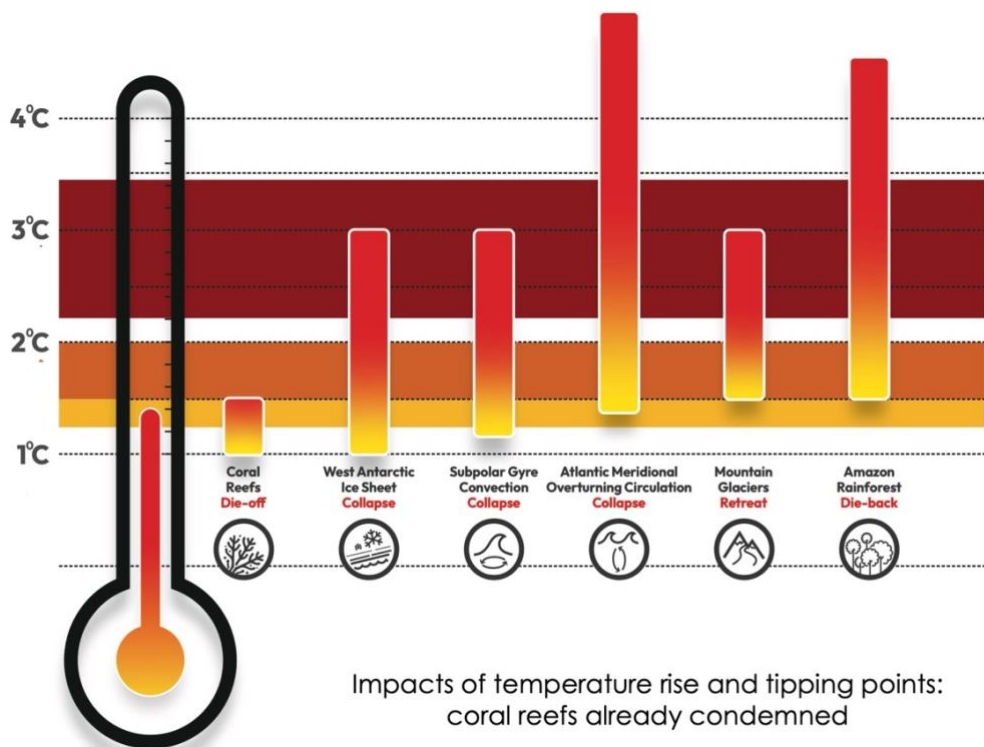
These ‘tipping points’ have been assessed and linked to global temperature rises; see the picture opposite, from a group of scientists at University of Exeter (funded by the Bezos Earth Fund, amongst others!).

In October 2025 they announced it’s already too late for coral reefs. And the Amazon rainforest might already be a source of carbon emissions, not a sink.

Not just ecosystems, but climate systems themselves, have ‘tipping points’ (see p14 on feedback loops). An example of huge global relevance, and immediately important to the UK where this is being written, is the Atlantic Meridional Overturning Circulation (AMOC).

This is a network of ocean currents (involving both heat and salinity) that includes the ‘Gulf Stream’. It has moderated temperatures in Northwest Europe for millenia, but already shows signs of weakening. If and when it stops, the whole region would have much colder winters, while summers would still get hotter and drier; catastrophic for agriculture across Northwest Europe. Meanwhile knock-on effects on other global climate systems, including the South Asian monsoon, would be unpredictable but very significant.

There’s everything to play for, but the game is lop-sided.



Fossil Fuel companies and power

Political & financial influence keeps economies around the world in thrall to fossil fuel interests. Historically, they've been behind political coups and invasions; they're often even owned or subsidised by governments. Constantly in the corridors of power, they influence policy-makers (see opposite).

Ironically, fossil fuel companies themselves have researched and confirmed their own climate impact. In 1986, an internal document named 'The Greenhouse Effect', from Royal Dutch Shell (now 'Shell'), included this: *"...by the time the global warming becomes detectable it could be too late to take effective countermeasures to reduce the effects or even to stabilise the situation..."* This report was published in 1988, just as the IPCC was founded.

Yet they cynically co-opt public concern about climate to monetise concepts like 'net-zero petrol' or 'negative emissions' (see p30). 'Greenwashing' brands can cost very little, compared to their profits. For example Adani, the coal & shipping giant, recently sponsored a gallery on 'Energy Transition' at London's Science Museum. Meanwhile they were mis-selling 'dirty' lignite to their own Indian Government (see London's 'Financial Times', May 2024).

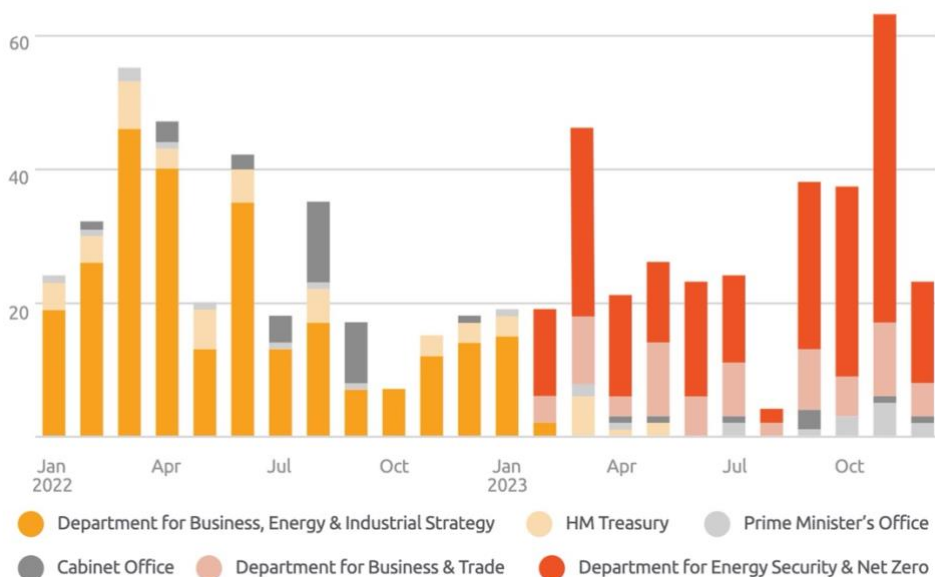
The persuaders

The science of harm caused by smoking was known for decades before effective legislation curbed advertising and sales. Just like the tobacco companies, fossil fuel producers have invested in advertising their addictive products, while promoting doubt and uncertainty about the harms they cause. Another parallel is timeframe: climate breakdown was forecast for decades, but is becoming undeniable in the 2020s just as time runs out.

Speaking truth to power, or bringing science to politics, might seem best left to 'experts'. But expert scientific opinion has long been available to policy makers, from village level to national governments and international bodies. In the teeth of the evidence, fossil fuel interests - and consumer capitalism itself - has too often won the argument. Too many decision-makers value short-term interests over long-term survival.

Big businesses can simply buy public agreement, with the compliance of journalists and politicians alike; their 'greenwash' includes false solutions (see opposite). Without better public understanding of the material realities, they may continue to persuade by simply using 'green' words and phrases. This handbook aims to enable readers to make informed decisions for themselves.

Distribution of oil and gas lobbyist meetings with ministers across government departments, 2022-2023
Analysis conducted by Global Witness, 2024⁹



How is the oil and gas industry torpedoing the Green Deal?

False solutions that will lock us into a fossil-fueled future



Fossil gas

As bad or worse for the climate as other fossil fuels.



Carbon capture and storage

A risky and expensive technology, unproven at scale, that locks us into fossil fuel consumption.



Hydrogen

Hydrogen, both green and low carbon, is a dangerous distraction that keeps the door firmly open to continued fossil fuel use.



Carbon markets and offsets

Shifts burden of reduction emissions away from its own operations.



Corporate Europe Observatory

#FossilFreePolitics

Individual and system change

Economic systems built on fossil fuel and over-consumption have brought us to the brink. Systems must change, involving individuals in our billions. From community energy to collective transport to normalised, affordable, low-carbon food production, decarbonised choices must be simpler and cheaper.

Research from Leeds University shows that two-thirds of global emissions relate directly or indirectly to household consumption. For a sustainable future, the global average individual footprint must be around 2.8 tonnes CO₂e by 2030, and continue to reduce after that.

High emitters can make the biggest difference, most quickly. Firstly, their choices have bigger impacts (see p21). Secondly, they generally have more control over their lives. And in turn, their decisions will inform the system changes needed by wider society.

The scale of change needed is enormous, and it will only get harder as breakdown unfolds – ‘later’ may soon be ‘too late’.

Who is seeing the future?

London’s regulatory body for insurers (IFoA) already acknowledge that the industry is undermining itself by underwriting fossil fuels, yet insurance companies continue to enable new oil and gas exploration and extraction.

Reform or revolution?

In 2024 Stephen Humphreys, Professor of International Law at the London School of Economics, was asked what individual action would be effective in the face of climate chaos. He replied: *“Civil disobedience.”*

That’s not for everyone. But we can listen to each other’s concerns, embed climate and nature into political and media agendas, and demonstrate our concern in public. To quote UN Secretary-General António Guterres again:

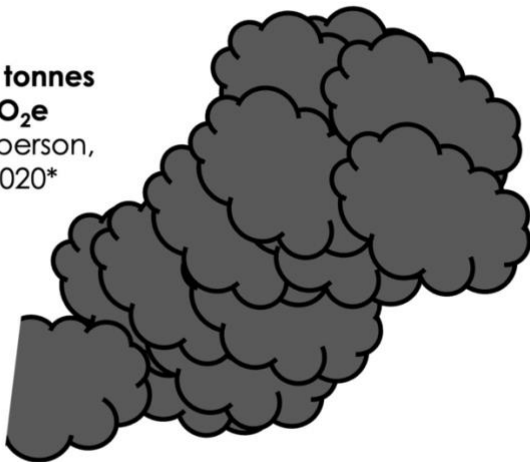
“We owe a debt to young people, civil society and indigenous communities for sounding the alarm and holding leaders accountable. We need to build on their work to create a grassroots movement that cannot be ignored.”

Even Pope Leo, leader of 1.25bn Catholics, has called on citizens to take an active role in political decisions:

“only then will it be possible to mitigate the damage done... God will ask us if we have cultivated and cared for the world that he created for the benefit of all and for future generations”.

Getting UK average
footprints into shape:

**12.7 tonnes
of CO₂e
per person,
UK 2020***



**Global average
needs to be 2.8t
by 2030****



Sources: *Berners-Lee, 2020
and **Ivanova et al., 2020



A just transition

Social inequalities are already deep and unfair. Climate breakdown affects everyone, but the most immediately vulnerable are generally the least responsible, and the least able to buy their way into short-term comfort.

The costs of adapting, or failing to do so, are rising all the time. And adaptation needs to go hand-in-hand with ‘mitigation’ – reducing emissions. ‘Carbon’ is shorthand for all GHGs here, too; ‘de-carbonising’ means reducing footprints.

Life on Earth is already responding to global heating, land-use change and ocean acidification. That means extinction for some species, even ecosystems. All humans will have to adapt, whether or not they change in other ways. Some propose a ‘Green New Deal’ to revive worker-led prosperity, but with an environmentalist slant. Others say we need to change direction more radically, with ‘degrowth’: deliberately and purposefully shrinking some types of production and consumption in the interests of sustainability, social justice and well-being.

What does that mean for ordinary people in low-income countries, who’ve never had the option to consume their fair share of energy and resources? Economists and scientists debate whether a ‘right sort of growth’ even exists.

Meeting basic needs on a changing Earth

Around the world, across caste and class, humans share some basic needs. Air, food, water & sanitation; shelter and thermal comfort, through to social belonging and esteem, education and employment, friendship and purpose. Meeting these needs for everyone, not just the globally wealthy, will mean sharing a lot more than we’re used to. But the alternatives are a blasted planet, wars over food and water supplies, and a desperate society.

For Earth’s energy balance to find equilibrium again, and for human societies to survive, we need to

- i) restore natural ecosystems (not least, to boost photosynthesis and ‘sinks’)
- ii) decarbonise energy, transport, food and ‘stuff’ to meet basic needs for all
- iii) find ways to continue doing this as the planet changes around us.

Extreme weather, rising temperatures and sea-levels have already made ‘business as usual’ impossible. Systems we live by will either collapse – or change more positively, because we’re thinking ahead and taking action. Footprints and Scopes are useful tools to analyse, plan and prioritise for safer futures. The coming decades will be tough; we’ll do well to have lifestyles that are ‘Just’, resilient and sustainable as the Climate Emergency unfolds.

Getting a 'carbon sense'

Rome-Glasgow
by private jet
(one-way)
~11.3t (BBC)

Economy return flight,
UK-Hong Kong,
~3.5t

Foodprint of typical UK
meat-eater's diet,
per year
~3t

Foodprint of thoughtful
UK vegan diet,
~0.5t

Average UK
motorist's car use
(7,400 miles p.a.) –
petrol or diesel
~3.92t

Average UK
motorist's car use
(7,400 miles p.a.)
- mid-sized
electric car
~1.33t

7,400 miles
by electric bus
~45 kilogrammes

Average Bangladeshi total
personal footprint
per year (2021)
0.7t

Meeting basic needs for everyone: Energy ('E')

Fossil fuels now power most of the globalised world, but supplies are limited. Burning them all before they run out anyway would cause deadly heating. Meeting needs with less energy ('E'), and decarbonising what we do use, can happen sooner rather than later if processes and activities continue to be electrified, and the electricity ('ē') is generated using renewable energy. Mining minerals for renewable power systems is harmful to ecosystems and indigenous populations, but arguably no more so than fossil fuel extraction continues to be. And the overall aim must be to reduce consumption.

The biggest users, the well-off, can use less energy without hardship for their 'thermal comfort' (heating or cooling), heating water, cooking, powering machinery and gadgets. But social justice demands organised roll-out. For housing and industry alike, heat pumps use small amounts of electricity to concentrate and move heat from one place to another. Insulation, shading and smart ventilation will be important in 'retro-fitting' as well as new-builds. As the 2020s unfold we must resist an explosion of energy demand by data centres; no 'green computing' would compensate for the resulting emissions.

Meeting basic needs for everyone: Travel & Transport ('T&T')

Active travel uses our **bodies**, to walk or cycle, often making journeys quicker, as well as healthier. System change to support this requires legislation and investment; civil society can support safer streets and village/town centres.

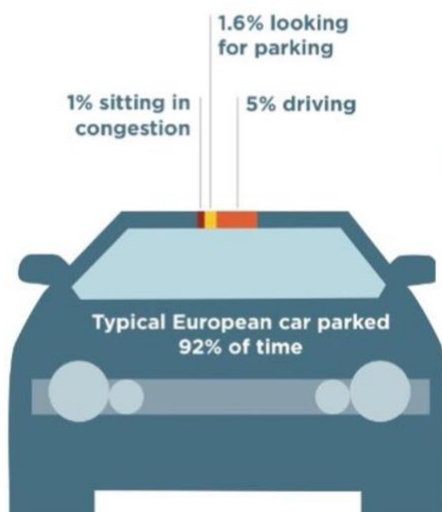
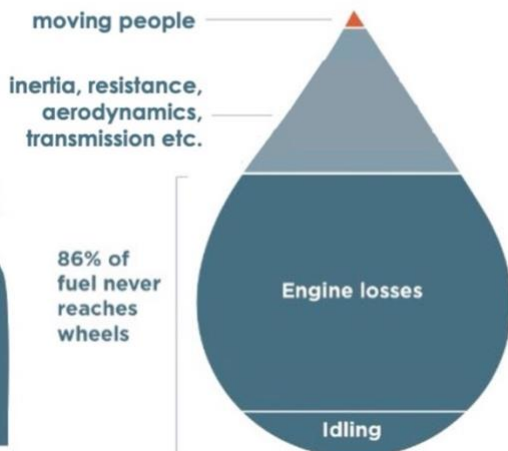
Most private cars are hardly ever driven; public transport powered by ē is a far better investment than road-building. Cities and villages and lifestyles that were designed around individual private car use will need imaginative change, but this will also lift the heavy health toll of collisions and air pollution.

At the other extreme, shipping companies are already trialling wind-power again. And 40% of shipped goods (by weight) are themselves fossil fuels. So there's a double benefit to stopping their production and use, reducing damage to the oceans as well as to the atmosphere.

'Luxury' travel can cost a lot of carbon, whether by surface or air. But the biosphere simply can't afford non-essential flying. Producing so-called 'sustainable aviation fuels' use up other people's land, crops, food and energy, and still emit GHGs when they're burned. Holding public bodies to their 'Net Zero' commitments means resisting airport expansion, and supporting well-planned long-distance electric rail travel instead.



50% OF LAND IN MOST CITIES IS OCCUPIED BY
ROADS, STREETS, CAR-PARKING, DRIVEWAYS, SERVICE STATIONS etc.



Meeting basic needs for everyone: Food

People in high-income countries throw away a third of the food and drink they buy. So for many of us, 'reduce' is again the first strategy. And already, as climate breakdown unfolds and shrinks harvests around the world, resilience must include more self-sufficiency.

The UK is massively dependent on land overseas, where other people live and farm. As the climate emergency continues, they'll be less able to feed themselves, let alone continue to support consumers in the UK.

Few of us here grow our own food, and system change is going to matter as much as individual choice (see map opposite). Between 50-100 x more land is used to produce a kilo of beef or lamb protein, than plant-based protein. A healthier world won't demand NO red meat or dairy foods, but they must be seen as treats rather than continual habits. Reducing them can make the single largest saving of GHG emissions under this category, with direct benefits to health and well-being as well as the natural world and biodiversity. System change may need formal legislation, but farming groups and unions are already self-organising around climate action – for their own survival.

Meeting basic needs: Stuff

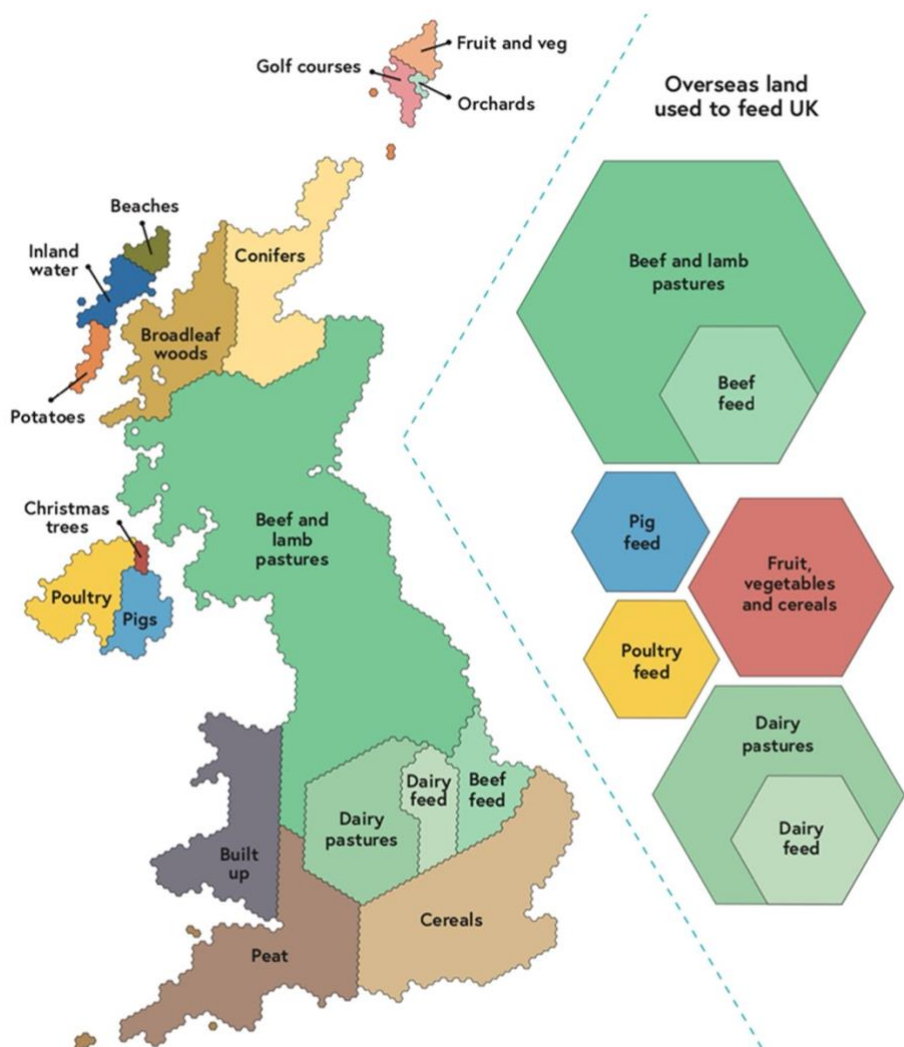
Global inequalities are serious here, too. For most individuals, strategies again begin with 'reduce'. How much stuff do you really need, how much more would be 'enough'? In industrialised countries, devices and gadgets pile up – and clothing waste can be monstrous.

The focus on re-cycling can be seen as a strategy to promote more consumption, especially of plastics (generally made from oil). Meanwhile the second-hand or waste 'stuff' is often simply exported to a poorer country.

Stuff never actually 'goes away' - even biodegradable waste breaks down to produce methane and/or carbon dioxide. Remember the concept of embedded emissions (Scope 3, p28) and consider carefully whether you really need a new smartphone or laptop. Arriving at a truly 'circular economy' will take years; meanwhile reconditioned IT equipment is a cool solution, strengthening supply chains that will be absolute requirements as the Emergency develops.

Building & construction are almost headings in themselves (see end pages for links to specialist networks). Action under this heading can have creative benefits, and save money as well as carbon.

UK land area shown by purpose (not actual regional use)



Source: The National Food Strategy, Pt.II

The combined land area used for rearing beef & lamb for UK consumption is larger than the UK itself

Using your financial & commercial capital

We're all somewhere in supply chains, with the influence that brings (see p.38); goods and services all have footprints. Resilient lifestyles developed before things get too tough, will become more and more valuable; making individual carbon-literate choices now, can only support system change.

Where your earnings and savings are invested, even who holds your overdraft or mortgage or debt, can make a huge difference. Pension fund decision-makers need the collective consent of members. If you have one, investigate and discuss it with family, friends, and colleagues; this can be a good start for those wider climate conversations. Campaigns asking banks and insurance companies to stop enabling fossil fuel industries are gaining traction.

The insurance sector is a 'canary in the coalmine' for climate chaos. The UK is the first country in the G20 to require large companies and financial institutions to report on climate-related risks.

Individuals can be alert under this category, too; even bank debt is traded. Rich and poor, we're all part of the system that can either facilitate fossil fuel infrastructure, or invest in a sustainable future.

Using your socio-cultural & political capital

We influence each other by what we wear and do, opinions we voice, even who we 'follow'. We have social, cultural and political capital as individuals, whether at home, school, work or play. And as groups, we can be powerful.

Share your 'climate literacy' (and use it to watch out for 'greenwash' or off-setting scams). Consciously and visibly advocating for meaningful climate action helps re-set what others see as 'normal'. We're very social animals; speaking up enables others to do the same. Saying out loud that there's a problem, and making informed demands for change, strengthens us all.

Whether in neighbourhood groups or local authorities or government, Trades Unions or works councils or sports clubs, make sure your line managers and colleagues and elected representatives know what matters to you. And if you already represent others officially, don't waste that privilege by being a bystander to climate breakdown.

75% of adults in Great Britain are "*very or somewhat worried*" about climate change. But even doom-laden stories of extreme weather events can be pivoted into discussions of genuine climate action. There's so much to protect.



Urgency and agency

Our intricate biosphere has been badly damaged by human activities, but we're all still woven into it. Assessing our impacts, and prioritising action to resolve them, shines light onto social, economic and political inequalities. We've all got responsibilities and opportunities, but the climate and nature crisis is hitting hardest at people with least (see p20 on Climate Justice).

Since 2016, 'Climate Emergency' has been declared by local and national governments and organisations around the world. Few have lived up to their promises, targets and commitments.

Active and informed response from the general public might have to lead the way. If civil society takes the Emergency seriously, we may stop making things quite so much worse.

But if collapse becomes inevitable, and we've already started to practice sustainability, there'll be something for survivors to build upon.

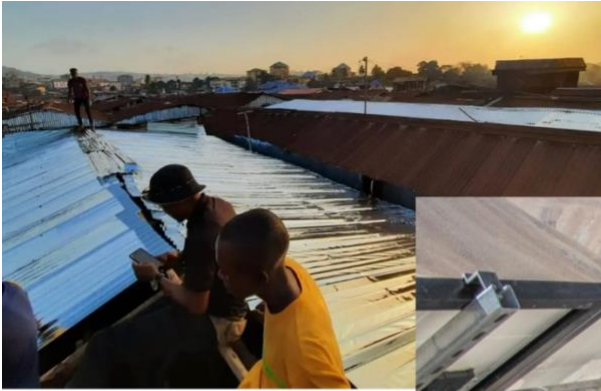
Pro-active change

Climate action has been compared to mobilisation by 'The Allies' to fight the Second World War. Nobody questioned spending what it took to win, when the alternative was so devastating. Even financially, we can't afford not to act; in 2022 alone, weather & climate disaster events cost the USA \$165bn. Some property is already un-insurable.

Keeping average global heating to below 2 °C will take verve and valour. The planet's already changing: like living with damaged lungs, this demands lifestyle changes that could even improve well-being. **Adaptation** can weave together with **mitigation**, reducing emissions by meeting basic needs for humanity in de-carbonised ways.

Those of us with bigger footprints have most to offer in emissions reductions – while many in the global South are taking meaningful action, despite far fewer resources. (In the picture opposite, men in Pakistan are rescuing solar panels from massive floods, made very much more likely by the burning of fossil fuels in other countries.)

Some of us have opportunities to do more than others. Here in London, medical professionals have been using up annual leave to protest (see p51); some have even been arrested in attempting to be heard. Let's not leave it all to other people.



Reflective film being installed on roofs of informal housing in Freetown, Sierra Leone (MEER.org)

Electrifying rural schools with solar in Afghanistan



Resisting fossil fuels in Uganda



Saving solar panels from floods in Pakistan

A community debates strategies for climate adaptation in remote N.E. Kenya



We've been selected as the climate change committee; now my main objective

Radical change is coming, either way

We need the Greenhouse Effect: it's what made Earth warm enough for life to evolve. But at the time of writing, the past 11 years have been the hottest 11 since records began; 2024 still holds the record, but 2026 is gruelling and might 'win' before this handbook gets to you.

On geological or ecological timescales, climate breakdown is happening in the blink of an eye. Ecosystems have little or no chance of adapting in time; they cannot survive what humans are doing. 'Business as usual' is already becoming distorted; even wealthy countries are already feeling the change.

Physical and psychological health

It's easy to feel 'gas-lit' or alienated by media consumerism, especially when everyone else seems to agree not to say anything. Speaking up can be a huge relief, and encourage others to explore their concerns.

Active travel and public transport, especially electrified, means cleaner air and healthier bodies. (The current situation disables many people, who will be allies in Climate Action if future transport planning is thoughtful.)

A shift from intensive livestock rearing towards plant-based diets is likely to result in improved human health, alongside reducing cruelty.

(The meat industry seems to brutalise humans, as well as livestock.)

And so much is already getting better: Solar Aid, the charity helping young Christopher do his homework in the photo opposite, was set up by a former geologist for the oil industry.

Living sustainable lives: values

Making sustainable lifestyles for ourselves, each other and the biosphere is the exact opposite of 'sacrifice'. We can avoid things getting as bad as they might, and actively gain benefits, too.

It's been said we find it easier to imagine the end of the world, than a change to our economic system. Yet bold imagination, flexibility and inventiveness are what make us human.



NEWS FEEDS:

Carbon Brief (global coverage, UK-based): <https://www.carbonbrief.org/>

Energy & Climate Intelligence Unit, ECIU: <https://eciu.net/>

Yale Environment 360: <http://e360.yale.edu/>

DATA SOURCES AND REFERENCES:

Carbon Tracker: <https://carbontracker.org/>

Climate Action Tracker: <https://climateactiontracker.org>

Global Carbon Project (inc.atlas): <https://www.globalcarbonproject.org/>

Intergovernmental Panel on Climate Change (IPCC): <https://www.ipcc.ch/>

Keeling curve: <https://keelingcurve.ucsd.edu/>

Our World in Data: <https://ourworldindata.org/>

Scripps Institution (global concerns, USA-based): <https://scripps.ucsd.edu/>

UK Climate Change Committee: <https://www.theccc.org.uk/>

UN Framework Convention on Climate Change: <https://unfccc.int/>

World Resources Institute: <https://www.wri.org/>

OTHER RESOURCES:

Anderson, Kevin – his urgent, informed blog: <https://climateuncensored.com>

Campaign Against Climate Change, Trades Unions: <https://www.cacctu.org.uk/>

Carbon Independent (includes a calculator): <https://carbonindependent.org/>

Client Earth (using law to change the system): <https://www.clientearth.org/>

Climate Interactive (visualising futures): <https://www.climateinteractive.org>

Energy Saving Trust: <https://energysavingtrust.org.uk/>

Ethical Consumer: <https://www.ethicalconsumer.org/>

Extinction Rebellion: <https://rebellion.global/>

Global Witness (investigative): <https://globalwitness.org>

Greener Jobs Alliance: <https://greenerjobsalliance.co.uk/>

Make My Money Matter: <https://makemymoneymatter.co.uk/>

National Emergency Briefing (UK, Nov2025): <https://nebriefing.org>

Parents for Future (to campaign in solidarity): <https://parentsforfuture.org.uk/>

Scientists for Global Responsibility: <https://www.sgr.org.uk/>

They Work for You (all UK parliaments): <https://www.theyworkforyou.com/>

Wikipedia (ask here first; far more reliable than ‘AI’): <https://wikipedia.org>

FURTHER READING:

Mike Berners-Lee, *How Bad are Bananas?* (Profile Books, 2nd edition 2020)

Jason Hickel, *Less is More* (Penguin, 2020)

Greta Thunberg, *The Climate Book* (Penguin Random House, 2022)

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<https://www.susiarnott.co.uk/home/the-climate-emergency/climate-literacy-zine/>

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Any errors are the author's responsibility.

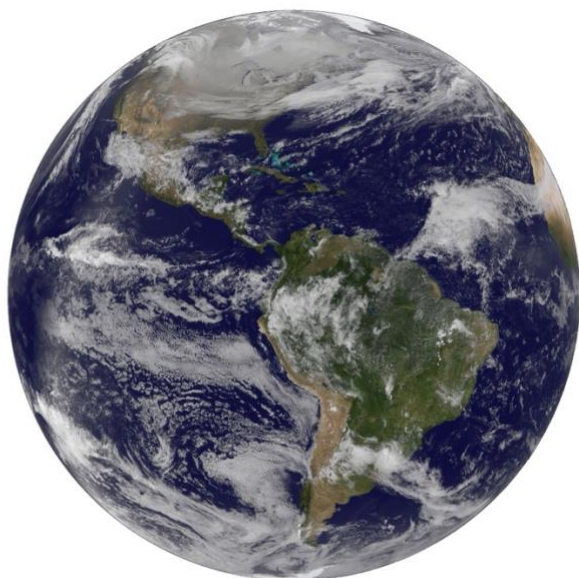
With thanks to the following for illustrative references & data (public realm and/or creative commons cc-by-sa unless otherwise stated). Every attempt has been made to verify and accredit sources; please notify Susi of any omissions or corrections at carbonelephant2020@gmail.com.

p3: Climate systems graphic from the Comet Programme, with permission. p11: Scripps Institution of Oceanography, with annotations from the author. p.13: data as credited, actual graph source unknown. p15: news tear-sheets from *The Financial Times* 2026-07-31 (Rhine), *The Guardian* 2026-08-10 (Typhoon), *The Independent* 2026-08-10 (Canada fires), *The Guardian* 2026-07-20 (Ice), *The Financial Times* 2026-08-12 (harvests); IPBES 'driver' cards adapted from *The Biodiversity Collage game*. p17: Kiribati news tear-sheet from *The Guardian* 2019-05-04; Risk Assessment graphics adapted from Climate Change Committee RA 2022. p19: data from Global Carbon Project, cumulative graph from *Our World in Data*. p21: data from 'The Carbon Inequality Era' SEI/Oxfam 2020. p23: fracking image Joshua Doubeck, cement factory Stephen Burton. p25: crop-spraying photo Oliver Dixon, SF₆ circuit-breaker Greg Goebel, anaesthetist Crispin Hughes. p27: GWP data from 'How Bad are Bananas?' by Mike Berners-Lee, infographic using data from IPCC WGIII, as used by Project Drawdown in 2021. p.29: Scopes graphic from the GHG Protocol. p.31: graphic adapted from Global Carbon Project, Scotford CCS image Chris Schwarz/Govt. Alberta, Amazon aflame from MS Powerpoint stock images. p33: Sci4XR roadblock by Crispin Hughes, António Guterres via Twitter (now X), COP28 by Anthony Fleyhan, via FlickrR. p.35: Graph from IPCC AR6 SPM p22, with annotations; infographic from Global Tipping Points Report 2025, p5. p37: graph from Global Witness, via Fossil Free Parliament, infographic from Corporate Europe Observatory. p38: Stephen Humphreys quoted in *Guardian*, June 8th 2024; Pope Leo quoted in BBC news, Oct.1st 2025. p39 Insure Our Future protest image by Crispin Hughes. p41: data sources 'How Bad are Bananas?', carbonindependent.org, National Travel Survey & Scarborough et al in 'Climatic Change 2014' via 'Ethical Consumer'. p43: roof + loft + solar panels by Crispin Hughes, heat pump via Wikipedia and in public domain, car infographic adapted from Ellen McArthur Foundation. p45: map infographic from UK National Food Strategy 2021. p47: Annie Kenney & Christabel Pankhurst uncredited/public domain, protest image Crispin Hughes, citizens assembly from Demsoc.org. p49: reflective roofing from MEER.org, solar array image Robert Foster for USAID, Vanessa Nakate via Twitter @vanessa_vash, flooded solar panels photo credit Fareed Khan/AP, screengrab from film 'Devolution & Resilience' by Hilda Kathure, with permission. p51: Medics protest and 'Daily Distraction' reader by Crispin Hughes, boy doing homework by Patrick Bentley for Solar Aid.
Back cover: blue marble from NASA Earth Observatory (public domain).

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Earth's heating up, and climate systems are breaking down.
How can humans, just one species, be making this happen?
This handbook is for anyone wanting to understand the basics,
and make up their own mind about what should happen next.

Part 1 looks at energy, climate and weather.
What is the greenhouse effect, and what's
carbon dioxide got to do with life on Earth?

Part 2 looks at where the different greenhouse gases come
from, and how they're accounted for. 'Climate justice' must
work across class and wealth, as well as geopolitics.

It's an Emergency for all of us.
Part 3 is an overview of actions to take and campaign for,
as individuals, groups, and citizens.
A healthier world is still possible.



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