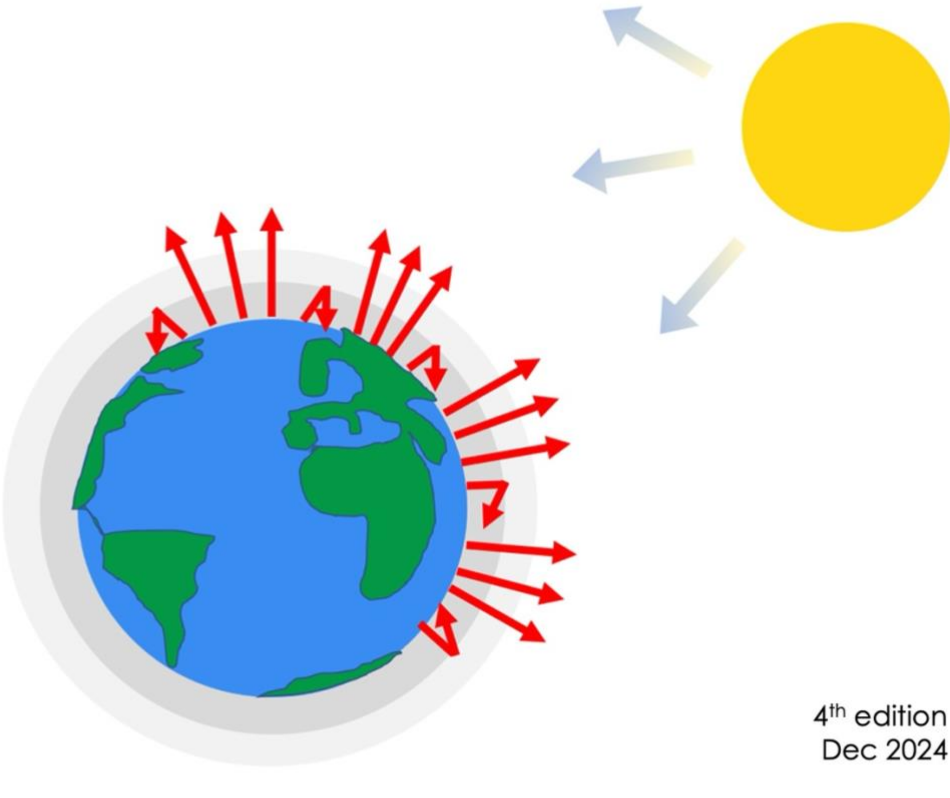
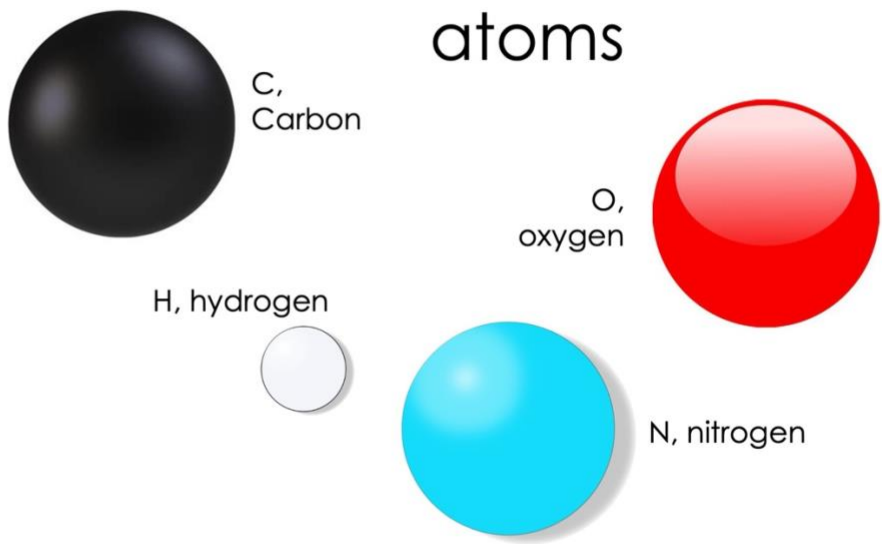
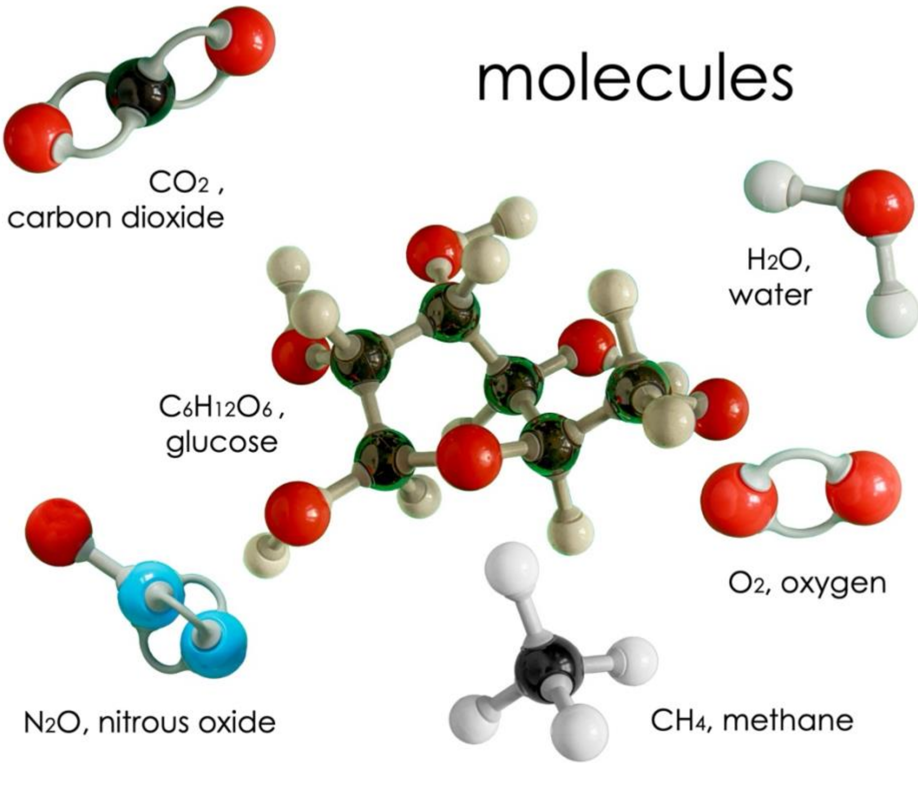
CLIMATE LITERACY & NUMERACY

Science basics, and some solutions - what choices do we have?



4th edition
Dec 2024


atoms
C,
Carbon
O,
oxygen
H, hydrogen
N, nitrogen


molecules
CO_2 ,
carbon dioxide
H_2O,
water
$C_6H_{12}O_6$,
glucose
O_2, oxygen
N_2O, nitrous oxide
CH_4, methane

CLIMATE LITERACY & NUMERACY 4th edition

By Dr.Susi Arnott, Walking Pictures (London, UK) email carbonelephant2020@gmail.com

Introduction

Climate breakdown is unfolding around the world. Understanding what's happening, and the choices ahead, can inform and motivate us to do something about it - as individuals, groups, and members of human society.

Extreme weather can be the most obvious sign: what's going on?

Climate and weather

Energy from the Sun warms different parts of the Earth, as we spin from night to day and orbit from summer to winter. Land and sea warm up then cool down again with the days and seasons, as oceans and atmosphere continually move heat around to balance it out again. And as temperatures and pressures vary around the planet, water evaporates into the atmosphere and falls back down to earth as rain or snow.

Climate is the result of these huge bodies of heat and moisture that move around our planet - in predictable ways, according to the time of year or 'season'. It's a long-term set of patterns.

Weather is what we experience when these currents and winds - warm or cool, wet or dry - pass by. It's short-term, and sometimes happens in sudden events. Although it changes by the minute and hour, averages are predictable if overall energy in the climate is stable.

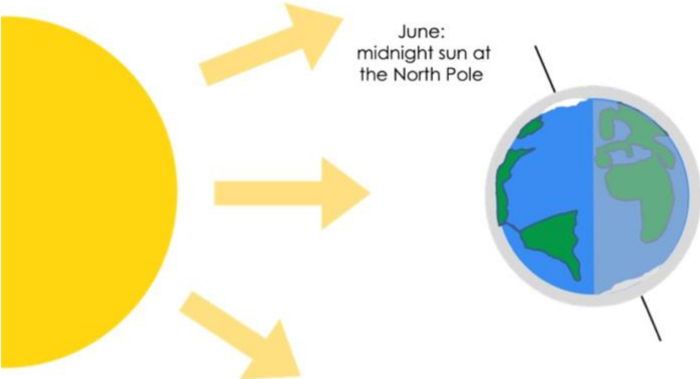
What's the 'Emergency'?

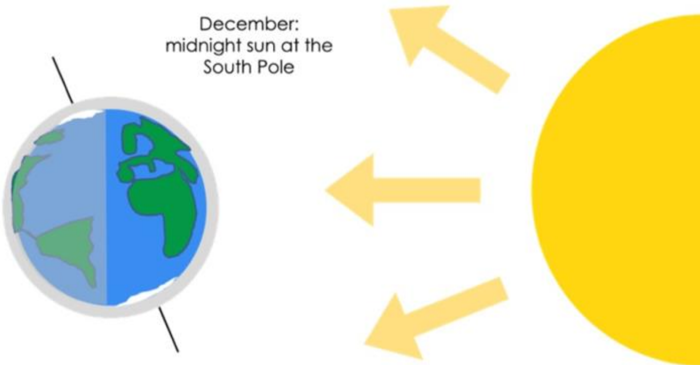
In recent decades, the Earth's atmosphere and oceans have been holding more and more heat. Regular climate patterns that ran for thousands of years have been disrupted, changing ocean currents and winds, altering seasons and fuelling extreme weather. Storms, floods, droughts, heatwaves and cold snaps happen more often, more severely.

As ice-caps and glaciers melt and the sea warms up and expands, sea-levels are rising; ecosystems and economies on coastlines and tidal river-banks are in direct danger. Indirectly, changing patterns of plant growth, uncontrollable wildfires, opportunistic diseases and food insecurity may all add to civil unrest and migration pressures.

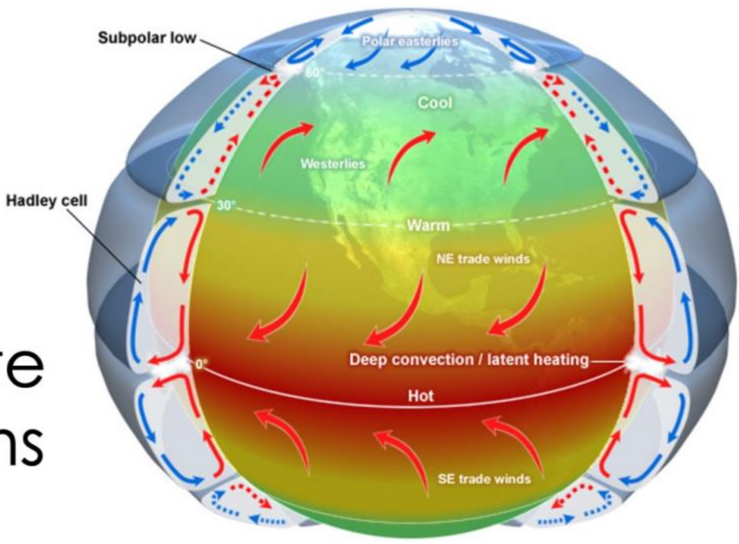
Where's that extra energy coming from? How can humans, just one species, be unbalancing a whole planet?

seasons





climate systems



Types of energy

Energy doesn't come from nowhere, or disappear, but it can change. The Sun bathes the Earth in **radiant** energy in all sorts of wavelengths, including the visible colours we call **sunlight**.

Some of this reflects straight back out again - that's how we can see Earth from space; some of it is absorbed as **heat** energy, warming up the land and oceans, the fields and roads and buildings around us.
Then in turn, some of this energy radiates back out again too, but in longer wavelengths: invisible, infra-red **radiant** energy.

Wind and waves are **kinetic** energy; water and air are moving around. When we use them to turn a turbine and move electrons around, it's converted to **electrical** energy. We can use this to do work right away, or keep it for later by converting it again: eg into **chemical** energy, stored in batteries.

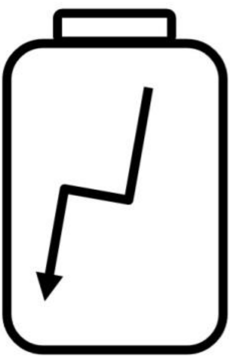
Our bodies use stored **chemical** energy too, from our food. Whether we get our food directly from plants themselves, or less directly by eating other animals, all of the energy in it was originally **sunlight**. This energy is captured and stored by plants and algae when they photosynthesise (see pp 8-9).

Carbon, and life on Earth

Plants capture and store **radiant** energy from the Sun, solar energy, and use it to build their bodies out of thin air. Their whole bodies are **chemical** energy stores, for themselves or for the animals that eat them.
We are just one of the 'carbon-based life forms' that make up life on Earth.

The entire food chain is powered by the Sun.
And it all depends on carbon, a special element, chemically just right for making big, complex molecules in almost infinite patterns and combinations. Solids, liquids or gases.

Many of these carbon-based molecules are energy stores, too.



States of matter

Like energy, matter doesn't appear or disappear, but it can **change**.
Add heat to solid ice and it melts into liquid water; add more heat, and the molecules evaporate into a gas ('water vapour').

And food we eat doesn't disappear when it's broken down; we digest it into smaller molecules, releasing chemical energy we can then use to stay warm, to maintain our bodies, or to move around and do work.
But that original food matter doesn't 'go away'. Some of the molecules might be literally 'incorporated' - becoming parts of our bodies - but most of them are offloaded as waste solids, liquids and gases.
They're all still **matter**, and they all still have mass.

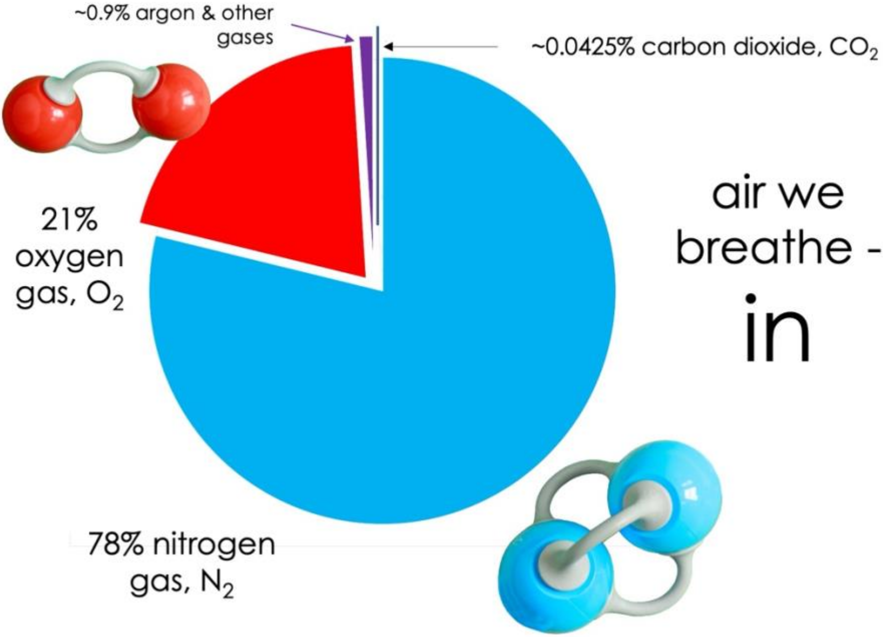
Atmospheric gases

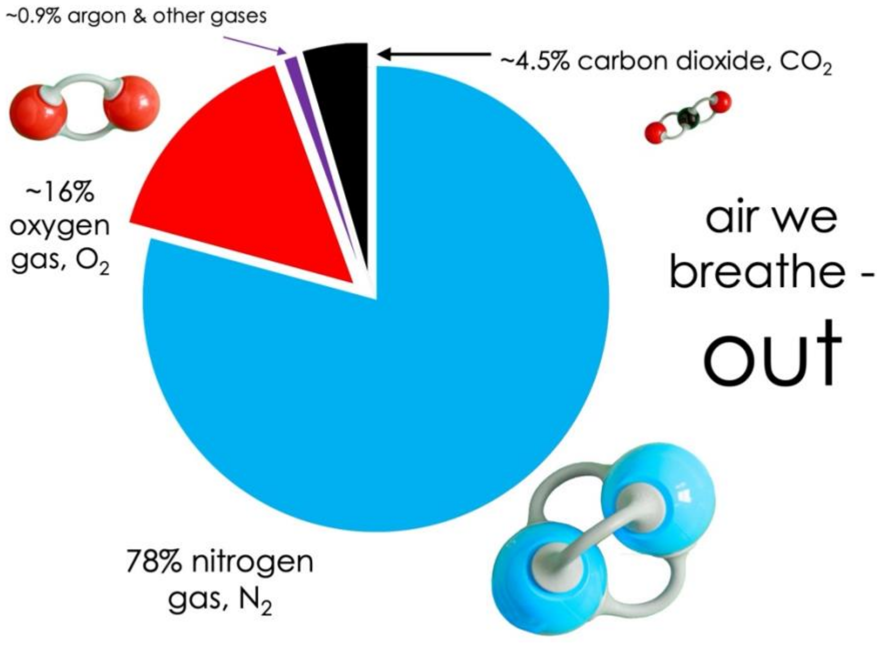
The air we breathe has mass, too. It's a mixture of gases – these pie-charts show them as slices or shares of the whole mixture. Some gases are made of just one element, some are compounds of two elements or more.

Fresh air we breathe **in** is 78% nitrogen (N_2): two nitrogen atoms bound tightly together, usually shown as blue. That's 78 in every hundred molecules, more than ¾ of the pie.
The next biggest proportion, 21%, is oxygen (O_2). 2 oxygen atoms, usually shown in red. Bonded together too, 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 un-reactive single atoms of elements like argon, neon, krypton and helium.

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

Air we breathe **out** has less O_2, more CO_2. That's because when we 'burn' food to release energy, our bodies use up some of the oxygen we breathed in, and release CO_2 and water (H_2O) as waste products.
In 1958, CO_2 was just 0.031% of the atmosphere. By July 2024, this had increased by more than a third, to 0.0425% of our atmosphere: that's 425 molecules, or 'parts', per million; 'ppm' for short.
Where's it all coming from?
Not just from people breathing out – we're talking massively more than that.
But it all comes back to energy, and life on Earth.


~0.9% argon & other gases
~0.0425% carbon dioxide, CO_2
21% oxygen gas, O_2
78% nitrogen gas, N_2
air we breathe - in


~0.9% argon & other gases
~4.5% carbon dioxide, CO_2
~16% oxygen gas, O_2
78% nitrogen gas, N_2
air we breathe - out

Out of thin air: photosynthesis

The word photo-synthesis means ‘light–putting together’. It describes the way plants and algae use solar energy to knit matter out of thin air, into biomass. They make their bodies and their energy stores from the raw materials of H_2O (water, ‘H-two-O’) and CO_2 (‘carbon di-oxide’), using sunlight. The 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.)

A carbon atom can join up to 4 other atoms at the same time - not many elements are this versatile. ‘Organic molecules’, compounds with carbon and hydrogen atoms joined together, can make an infinite range of possible rings and chains. That’s partly how life is so complex and varied.
Carbon’s been fixed out of the air, by photosynthesis, and these big new molecules hold chemical energy. Living cells use some for their energy, and knit others together into ‘biomass’. Into bigger and more complex molecules, cells, tissues, and complex creatures… the game of life has begun.

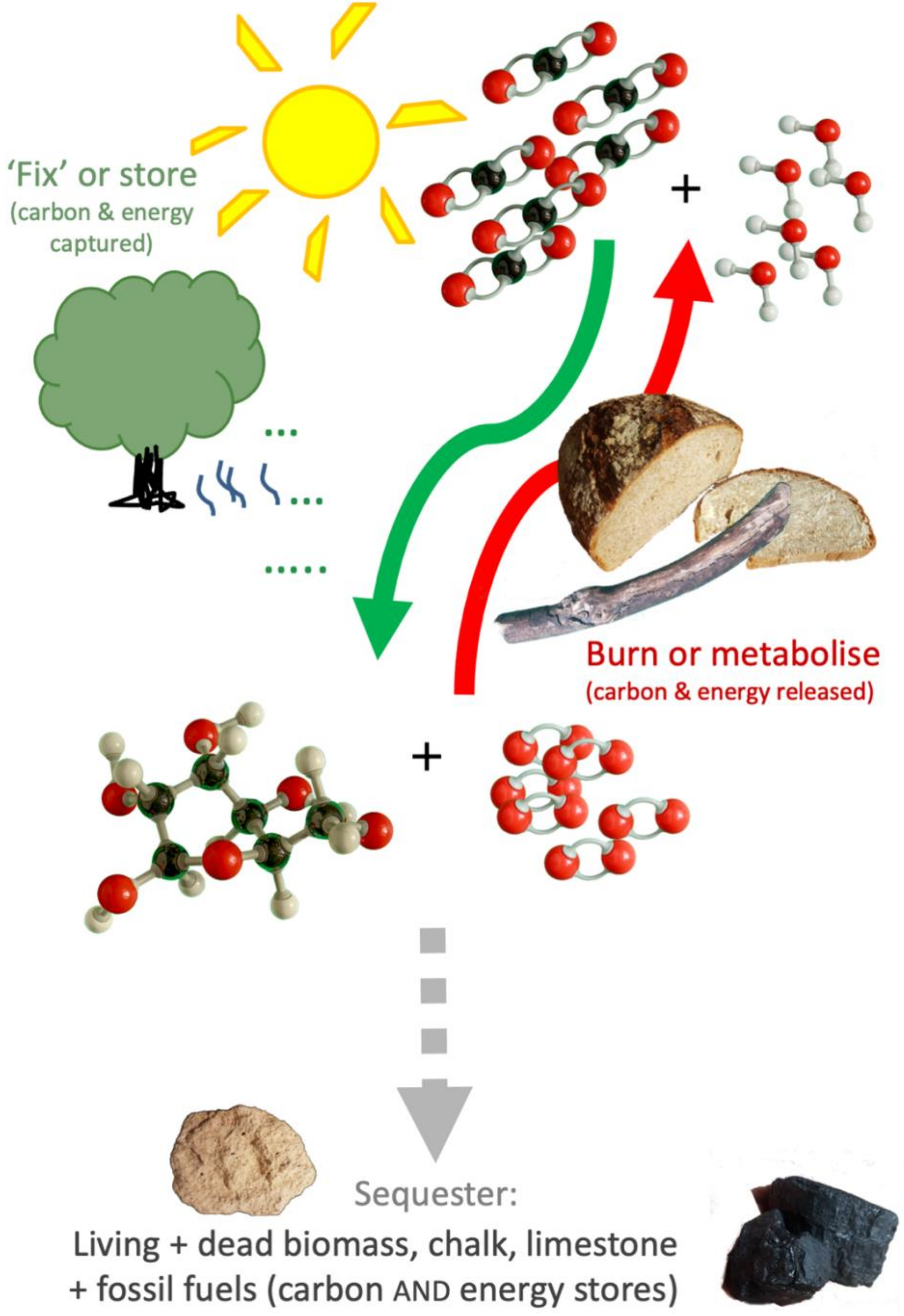
The carbon cycle

Some oxygen atoms are left over after fixing CO_2 into glucose; the waste product is O_2 oxygen gas. Reversing the process, to release stored energy, uses that oxygen up again.

Animals need oxygen, as well – breathing 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’.

When the same amount of carbon is being fixed out of the air into biomass, the carbon cycle is in balance; the amount of CO_2 in the atmosphere stays the same. There have even been times in the past when more CO_2 was stored away (‘sequestered’) than released into the atmosphere. Fossil fuels like coal, oil and gas are rich in ‘hydrocarbons’; literally, molecules containing hydrogen and carbon, stored into the Earth over millions of years.


'Fix' or store
(carbon & energy captured)
+
Burn or metabolise
(carbon & energy released)
+
Sequester:
Living + dead biomass, chalk, limestone + fossil fuels (carbon AND energy stores)

Carbon dioxide in the air

The 'Keeling Curve' graph relates CO_2 concentration (the vertical amount) to time (along the bottom). This graph could describe 'seasonal breathing'; globally, photosynthesis fixes more carbon out of the atmosphere during summer in the Northern hemisphere, as there's more land and vegetation there than in the Southern. This explains why CO_2 levels regularly cycle up and down every year.
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 CO_2. They match 'Milankovitch' cycles in how the Earth tilts and orbits around the sun, and the ice-ages these cycles match in turn. Now we can see climate history in a bigger context.

Human history, energy and carbon

Humans who could control fire could move into new ecosystems, survive extreme cold, begin settled 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 in firewood. And we used wind and water power.

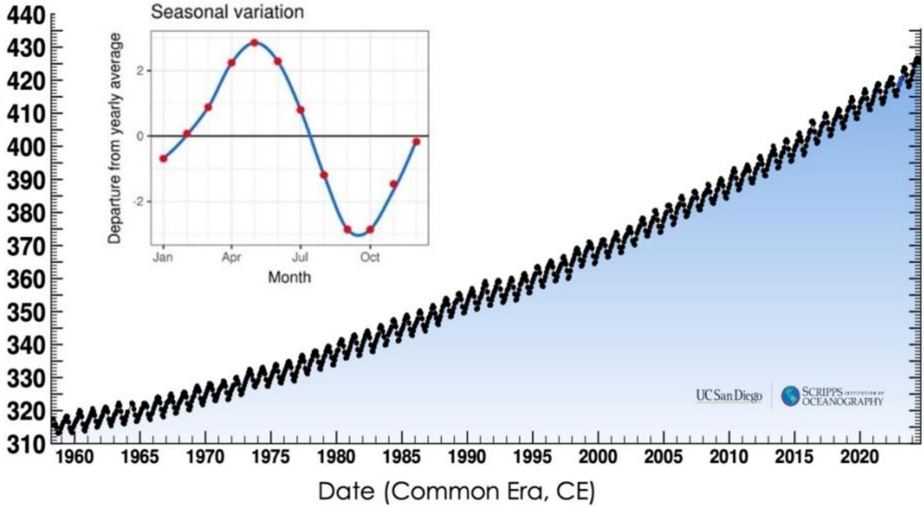
The industrial revolution of the late 18th century didn't come from nowhere. Machinery for textile production had already been invented, initially powered by water-mills. Burning coal to convert its stored chemical energy into heat wasn't a new discovery - but using this heat to make steam, then converting it again into kinetic energy to power machinery: this changed the world.
Now energy stores saved up over millions of years of photosynthesis were being spent in decades, then years. The carbon cycle was knocked way out of balance, as waste CO_2 far outweighed what was stored by photosynthesis. And this effect multiplied up when we started burning oil and gas as well.

Burning fossil fuels has taken CO_2 concentrations higher than they've been for millions of years. This is already changing the climate of planet Earth. 'Anthropogenic' literally means 'caused by humans'; some say we're now in a new geological epoch, the 'Anthropocene'.
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.

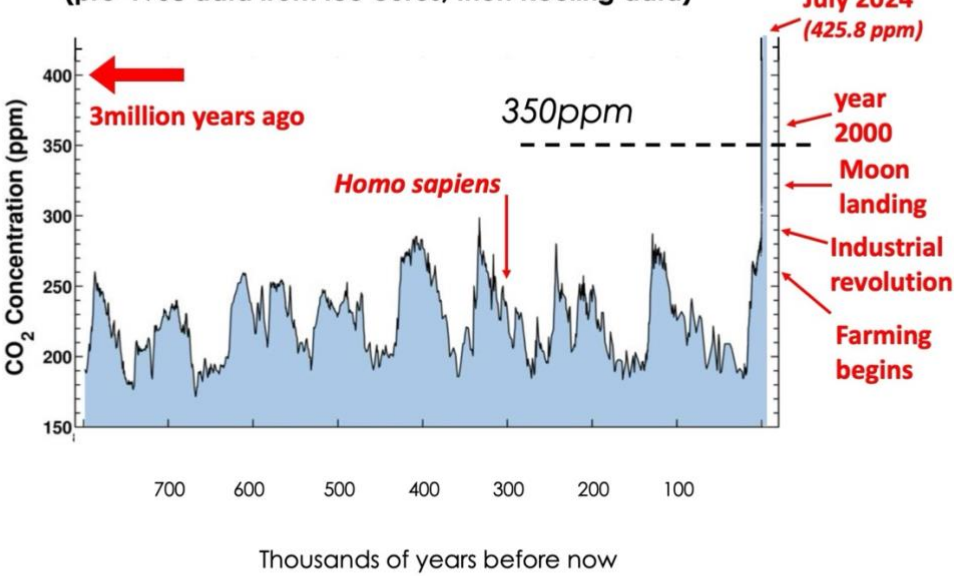
Atmospheric CO_2 since 1958(the ‘Keeling Curve’)

Monthly carbon dioxide concentration

parts per million



Atmospheric CO_2 over the last 800,000 years (pre-1958 data from ice cores, then Keeling data)



Greenhouse Earth

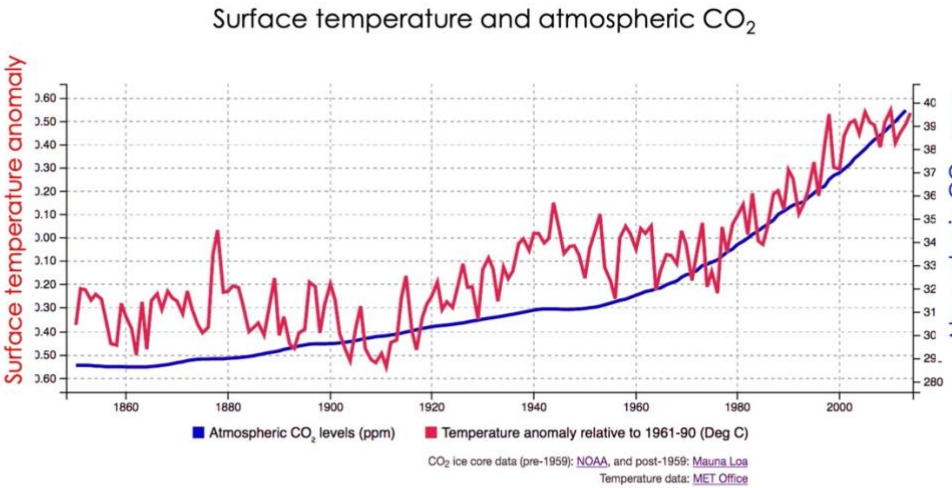
Temperature around the world varies over the years - and the average across years fluctuates, too. But along with carbon dioxide levels, there's been a general rise for more than a century (see graph opposite).

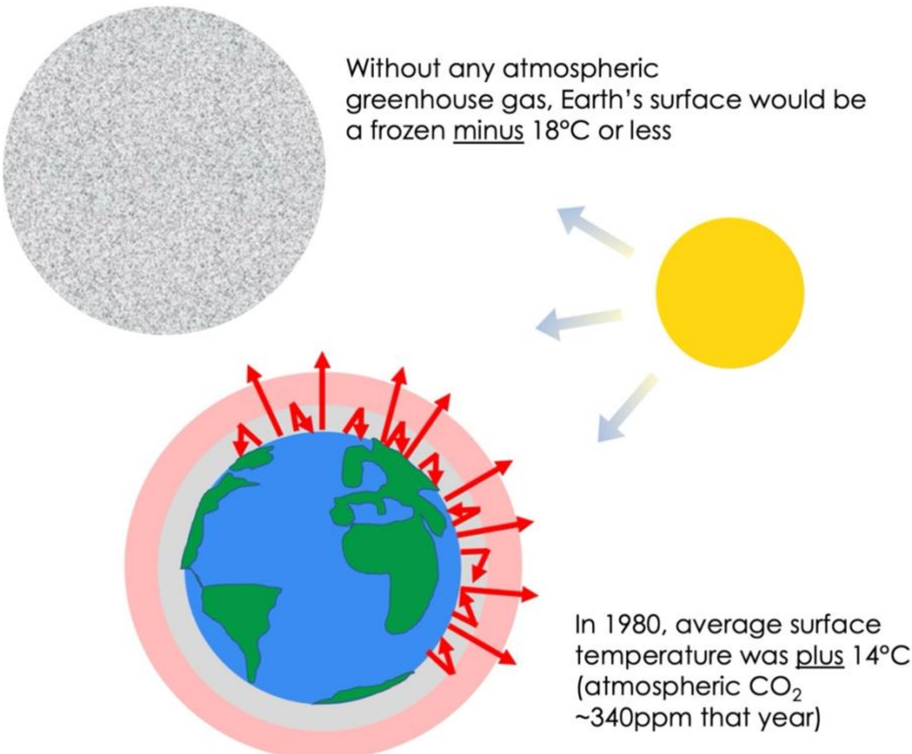
Sunshine lights up our planet, and about 30% of it reflects straight back out again; that's how Earth can be seen from space! Apart from clouds, the atmosphere is 'see-through': transparent to visible light.
But some of the sunshine's energy warms up the Earth and oceans. Then some of this heat energy radiates back out into the air again, as infra-red radiation. Most of the atmosphere is transparent to this as well. But not the CO_2 molecules: they absorb infra-red energy, and it heats them up. Like in a greenhouse, visible light shines in and bounces out, but the infra-red doesn't all shine out again. This is 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. Atmospheric CO_2 trapped enough warmth for life to evolve and flourish.

Global heating

With more CO_2 in the atmosphere, more heat energy is stopped from escaping: the oceans, land and air all warm up more. Over the last 200 years, rising levels have changed climate systems, increasing the likelihood of extreme weather events. More heat energy means cyclones, floods and droughts are more likely, and are more serious when they happen, not least because warmer air can hold 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 CO_2, water vapour molecules trap infra-red heat energy from radiating out again, in a feedback loop.

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 may be weakening. Farming, housing needs and day-to-day survival would be devastated if and when these grind to a halt. Whole ecosystems – and the human activities depending on them – evolved around predictable seasons and weather patterns.
Now these are changing within decades, even years.
Most living things, including humans, can't evolve quickly enough to cope.


Surface temperature and atmospheric CO_2
Surface temperature anomaly
Atmospheric CO_2, ppm
Atmospheric CO_2 levels (ppm)
Temperature anomaly relative to 1961-90 (Deg C)
CO_2 ice core data (pre-1959): NOAA, and post-1959: Mauna Loa
Temperature data: MET Office


Without any atmospheric greenhouse gas, Earth's surface would be a frozen minus 18°C or less
In 1980, average surface temperature was plus 14°C (atmospheric CO_2 ~340ppm that year)

Impacts make the news, but not causes

More heat energy and water vapour in climate systems leads to more extreme weather events, happening more frequently. These events attract media attention, but global heating itself is often left out of the story.
UK news items about ‘lovely weather’ avoid the fact that heatwaves kill. We’ve gone well beyond ‘normal’ variation: 2023’s step-change is only partly explained by natural cycles like the El Niño, and 2024 has broken records too. 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.

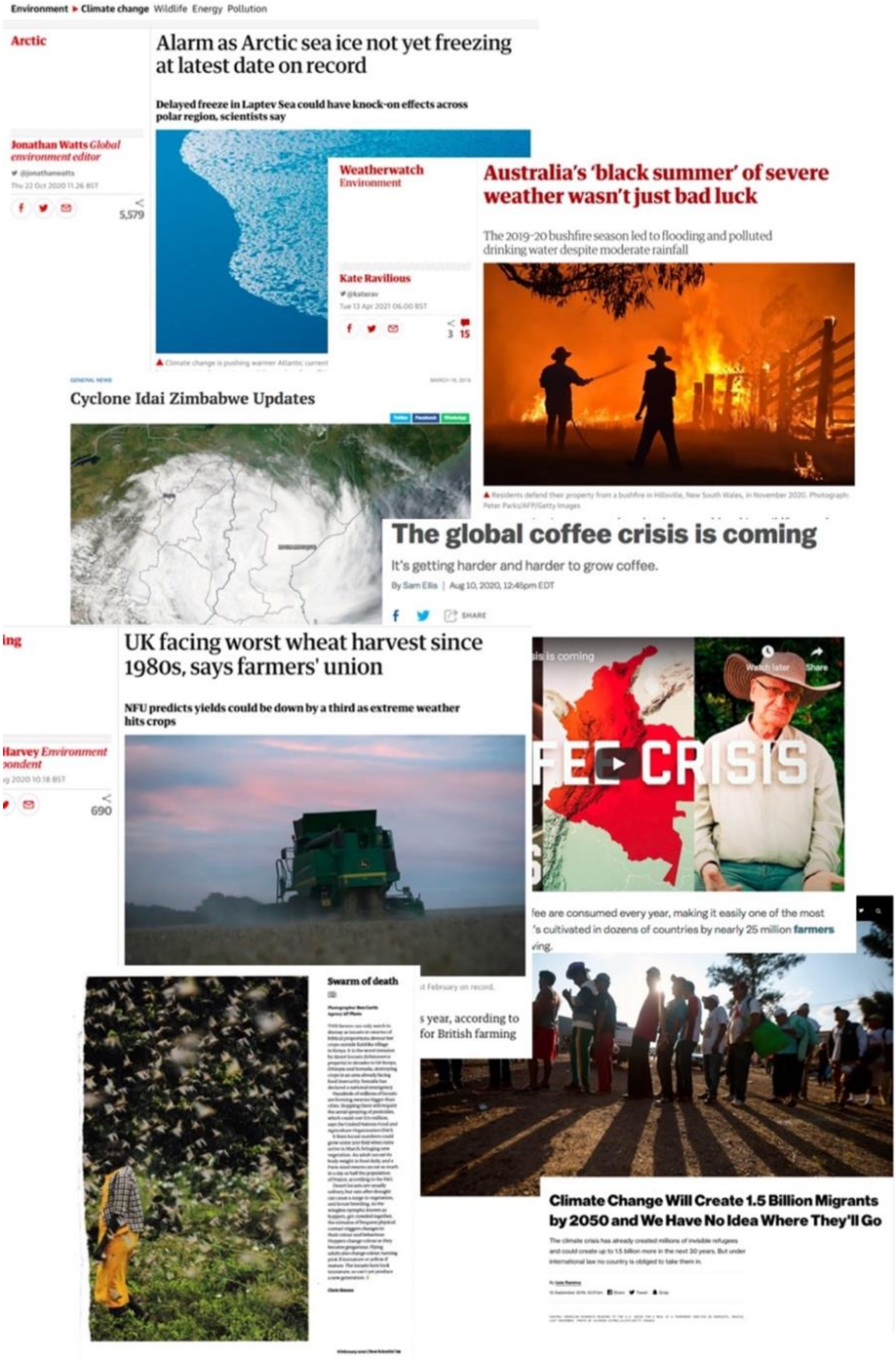
Oceans, carbon dioxide and heating

Oceans absorb about 90% of the increased heat, but also much of the excess CO_2. It dissolves in water to make carbonic acid, which weakens shells of animals like sea urchins, corals, crustaceans and shellfish – even some plankton. Rising CO_2 is endangering individual creatures, whole species and entire ecosystems, which is in turn damaging fisheries & human communities. And heat destroys whole ecosystems – for example, coral reefs, built by animals called ‘polyps’. These co-habit with photosynthetic algae, which they have to eject 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.

Tipping points?

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, and soak up heat instead. The more snow and ice melts, the more the seas and land heat up, in a feedback cycle; once past a ‘tipping point’, there’s no chance of recovery.

Damaged ecosystems are another feedback loop. Forests of trees or seaweed, meadows and peatbogs, are all ‘carbon sinks’: full of carbon that’s been fixed out of the atmosphere, into biomass. Ploughing or trawling or digging them up releases carbon back out again; then hotter, drier heatwaves lead to wildfires that add more CO_2, in another loop. Recent wildfires have massively reduced how much existing forests can take back up again.
And a really worrying prospect is melting permafrost: biomass frozen underground is a carbon sink. But as temperatures rise, it becomes a carbon source.


Environment ▸ Climate change Wildlife Energy Pollution

Arctic

Alarm as Arctic sea ice not yet freezing at latest date on record

Delayed freeze in Laptev Sea could have knock-on effects across polar region, scientists say

Jonathan Watts Global environment editor

5,579

Weatherwatch
Environment

Australia's 'black summer' of severe weather wasn't just bad luck

The 2019-20 bushfire season led to flooding and polluted drinking water despite moderate rainfall

Kate Ravilious

3 15

Cyclone Idai Zimbabwe Updates

The global coffee crisis is coming

It's getting harder and harder to grow coffee.

By Sam Ellis | Aug 10, 2020, 12:45pm EDT

SHARE

UK facing worst wheat harvest since 1980s, says farmers' union

NFU predicts yields could be down by a third as extreme weather hits crops

690

FEE CRISIS

Watch later

Share

fee are consumed every year, making it easily one of the most

's cultivated in dozens of countries by nearly 25 million farmers

s year, according to

for British farming

Swarm of death

Climate Change Will Create 1.5 Billion Migrants by 2050 and We Have No Idea Where They'll Go

Who's vulnerable?

High-income countries won't escape climate chaos, but are still mainly concerned with their own extreme weather events. Meanwhile, Pacific Island states lying low in the ocean are already eaten away by rising sea-levels.
In 2014, President Anote Tong of Kiribati bought land on nearby Fiji for his people to re-settle as their own homes begin to disappear.
And villages in Greenland are already subsiding into melting permafrost.

In high temperatures, sweat can keep us cool enough to stay alive - unless the air around our bodies is already too full of water vapour. A thermometer wrapped in a wet cloth mimics a sweating body and takes this into account, showing the coolest it can stay by evaporating/sweating.
Once this 'wet-bulb' temperature exceeds 32°C, humans are unable to do any work. If it goes over 35°, we die. Other animals die, too, and crops fail.

Even in the UK, the heatwaves of 2022 caused over 3,000 excess human deaths. The heatwaves of 2024 are killing many more around the world, even as this edition goes to the printer. 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.

UK Climate Change Committee & risk

Back in 2008, the UK government passed a Climate Change Act – this legally requires the government to significantly reduce UK carbon emissions.
It also set up a Committee on Climate Change to advise the government:
on **mitigation**, reducing emissions to directly reduce the harm, but also
on **adaptation**, to cope with the results.

Their latest Risk Assessment for the UK is simplified in the illustration opposite: which risk have you already felt, which worries you most for the future?

Action on climate change could be driven by empathy and a sense of natural justice. But simple self-interest demands it, too; the UK isn't self-sufficient in energy or food, and massive biodiversity loss has made natural systems less resilient. Social breakdown often happens when food, clean water, sanitation and power supplies start to fail.

The Guardian picture essay

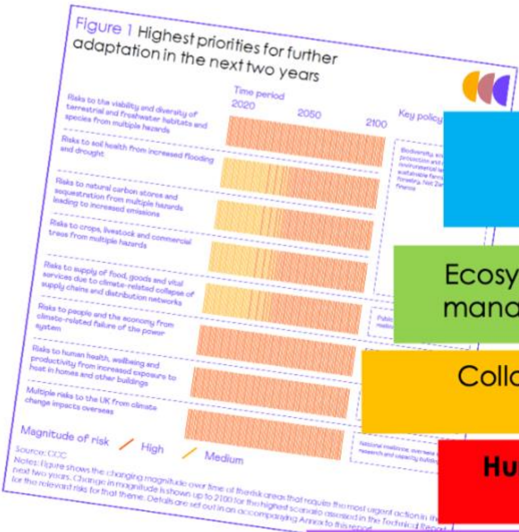
Waiting for the tide to turn: Kiribati's fight for survival

Guardian, 2019-05-04

▲ Salt water from sea incursions and storm surges has isolated some houses 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 CO_2 coming from?

The Keeling curve is about atmospheric concentration. Emissions data is given in mass; kilograms, tonnes, mega (millions) or giga (billions) of tonnes.
And the same data can be framed in different ways.

In 2020 China had the biggest 'territorial CO_2 emissions' of any single country. These are emitted within the country itself, and China's are largely from burning coal – the dirtiest fossil fuel, emitting most CO_2 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.
(A top-ten chart for this criterion would begin 'Qatar, Singapore, Brunei, Kuwait'…). Meanwhile less industrialised countries with simpler lifestyles contribute very little to the warming blanket, but take the force of impacts.

These emissions data are all about how quickly we're adding every year – but it's the <u>total</u> that's causing the heating. Data can also show where most of that total came from, over time.

The bottom graph shows those same 'top ten' countries, plus the UK, using 'historical' or 'cumulative' data. Why include the UK?

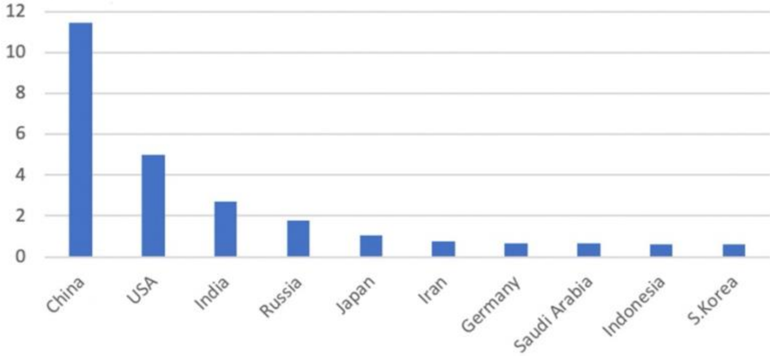
Who started it?

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

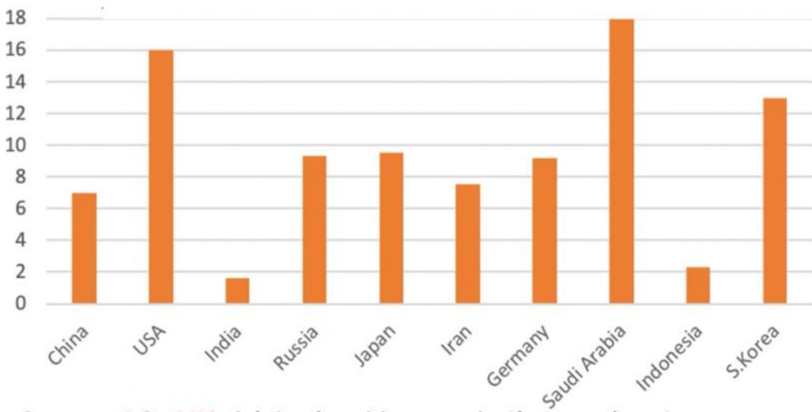
As the United States' economy mushroomed, and oil grew more significant, they began to take over as top emitters. Their agricultural **and** industrial production rates both soon outstripped Europe's.

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 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', p.28-29).

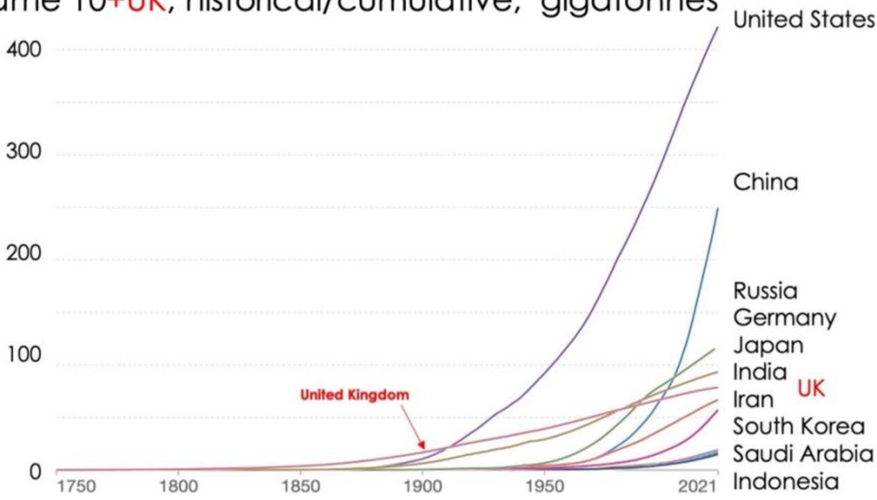
Top ten countries for territorial emissions, gigatonnes (2021)



Same 10 countries, consumption per person, tonnes (2020)



Same 10+UK, historical/cumulative, gigatonnes



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, not countries: the world's richest 10% (earning an average UK wage or more) were behind over half of that doubling. Rapidly increased expectations & consumption enlarged their already weighty footprints.

A rise in the 'global middle class', especially in China and India, also links to a rise in total emissions. The associated climate risk and damage hasn't benefited the poorer half of the world's population - they're likely to suffer first and worst.

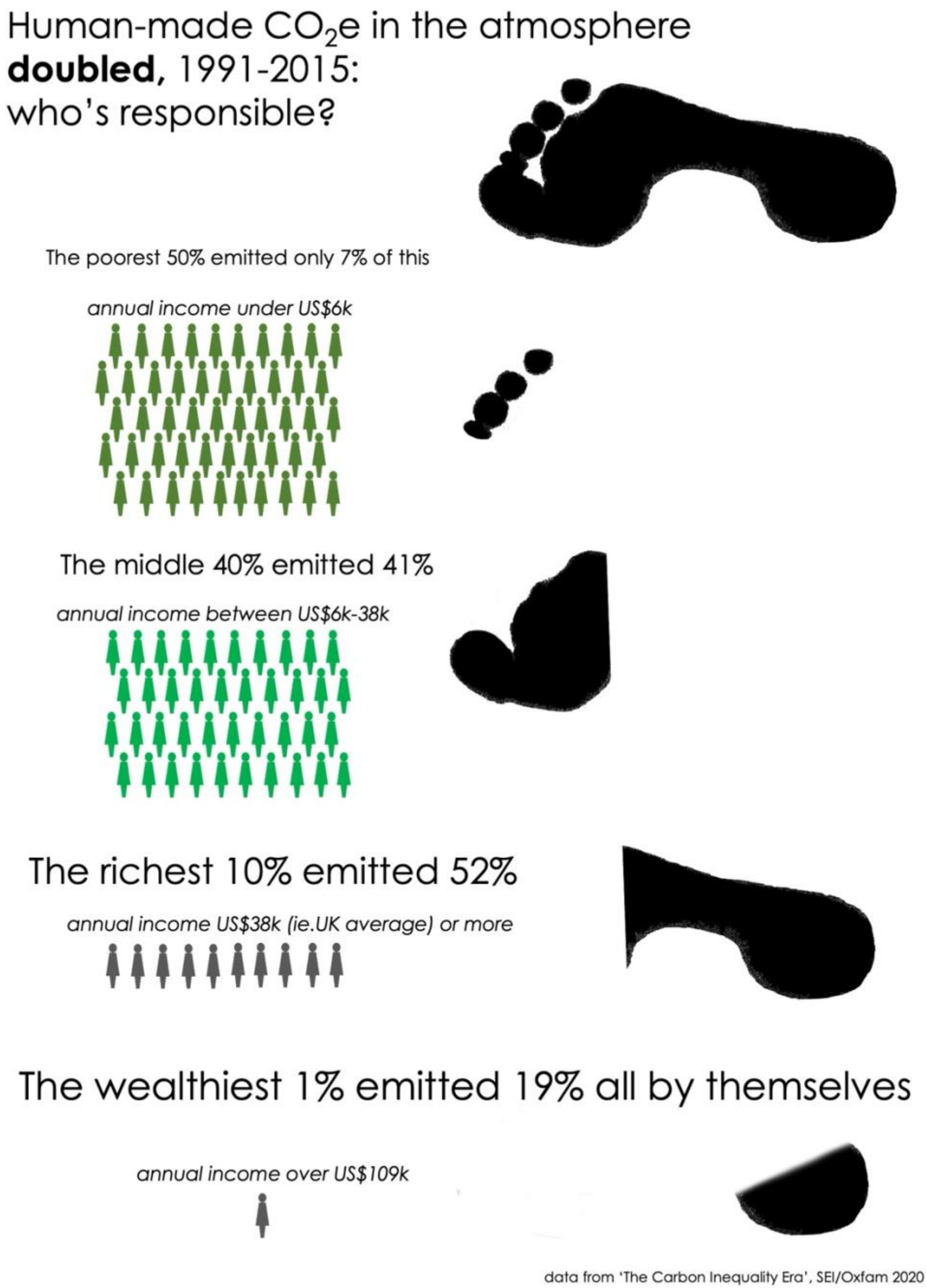
It's affluent lifestyles, not absolute population, that's brought us to crisis point: the wealthiest 1% have an outsize responsibility. But this also means they have the best opportunities to make a difference by taking climate action, via behaviour change as well as active citizenship. For better or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

Climate Justice

Climate systems are global: national borders mean nothing to clouds, rain and snow, or bodies of heat energy in atmosphere and oceans. Producers, consumers and citizens all have opportunities to be part of the change Earth needs, but 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 in lethal jeopardy.

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


Human-made CO_2e in the atmosphere
doubled, 1991-2015:
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

Sources of CO_2

Most extra CO_2 in the atmosphere comes from burning coal, oil & gas. These hydrocarbon ‘fossil fuels’ hold solar energy from millions of years ago; their carbon was fixed and stored (‘sequestered’) by photosynthesis in ancient ecosystems.
But destroying ‘carbon sinks’ like forests, soils or sea-beds also releases CO_2. Double blows, as less CO_2 is being naturally fixed again once they’re gone.
And making cement involves other ‘fossil molecules’; limestone & chalk (also the remains of living creatures) are mainly calcium carbonate, $CaCO_3$. Super-heating to make ‘lime’ molecules (calcium oxide, CaO) releases a molecule of CO_2 each time – even if the heat is from a renewable energy source.

CO_2’s not the only Greenhouse Gas (GHG)

CO_2 is the most significant ‘greenhouse gas’ (GHG), but other gases trap heat in the atmosphere too: mainly methane, nitrous oxide and the ‘F-gases’.

Methane

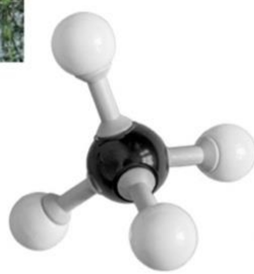
The simplest hydrocarbon molecule, CH_4. Sometimes piped straight to consumers, often liquefied and shipped as ‘Liquid Natural Gas’ (LNG); either way, burning it releases CO_2. But if it escapes into the atmosphere, methane’s an even more powerful GHG.
And wherever biomass is rotted anaerobically, by microbes that can live away from fresh air, methane is emitted.

Coal & oil deposits often include pockets of CH_4; mining, drilling and especially ‘fracking’ leak enormous amounts. Sometimes its even ‘vented’ on purpose.

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 beds of rotting biomass.

Even more significantly, ruminant animals like cattle and sheep can only live on grass because they host anaerobic gut microbes that digest cellulose for them. Methane’s the 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 by humans.

carbon dioxide, CO_2



methane, CH_4

It’s not just CO_2… nitrous oxide

Nitrogen is vital to living things, and there’s plenty of N_2 nitrogen gas in the atmosphere. But it’s fairly inert, and not ‘bio-available’; plants can ‘fix’ carbon out of thin air via photosynthesis, but they can’t fix nitrogen.
Leguminous plants like clover, peas & beans host microbes on their root systems that can capture nitrogen and fix it into organic molecules, making it available to other living things as well.
Farmers used to rotate crops around their fields, planting legumes every few years as ‘green manure’, to enrich the soil with nitrogen.

Then it was discovered how to fix nitrogen chemically, on an industrial scale. Chemical fertilisers feed growing populations – but at huge cost to biodiversity and the climate. Making them takes huge amounts of energy, but when any nitrogen fertiliser is overused, nitrous oxide (N_2O) is released. Livestock manure/slurry and human sewage release nitrous oxide, too: and it’s a powerful greenhouse gas.

Cars with internal combustion engines (‘ICE’) emit nitric oxide (NO) and nitrogen dioxide (NO_2) as well – known as ‘NOx gases’. They’re toxic, but N_2O is relatively harmless - except for the greenhouse effect.
(It’s also known as ‘laughing gas’; an anaesthetic and recreational drug – so you can remember the chemical formula by thinking of two blue eyes, one red nose; “N-two-oh”. N_2O damages lungs when taken to excess.)

It’s not just CO_2… 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 – chemical symbol ‘F’.
None of them occur naturally; they’re manufactured in relatively small amounts, to do specific jobs. But if they escape into the atmosphere (as ‘fugitive gases’), they make a big difference to the amount of trapped infra-red radiation that would otherwise escape, and the heat energy being stored.

Many anaesthetics used in human & veterinary medicine are F-gases; the Scottish government recently acted to restrict use of desflurane. But more generally, F-gases include excellent refrigerants, circuit-breakers and electrical insulators: we’ll need more & more of them as the Climate Emergency unfolds. It will be vital to contain them; leaks and ‘top-ups’ must not be considered normal any longer.


nitrous oxide, N_2O


F-gases,
various

Global Warming Potential (GWP)

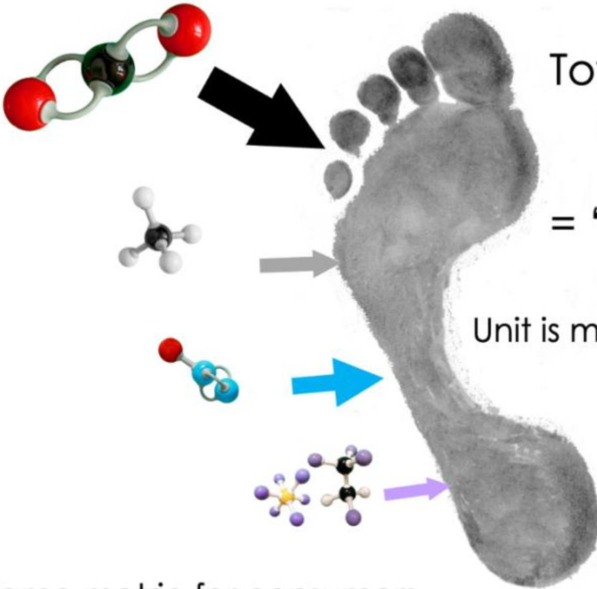
CO_2 is still the most abundant greenhouse gas. But per molecule, the other greenhouse gases, 'GHGs', have the potential to hold even more heat in the atmosphere. Their 'GWP' value describes how much more, compared to CO_2. The GWP of nitrous oxide is 256: this means 1kg of N_2O heats Earth as much as 256kg of CO_2. F-gases vary a lot, 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 CO_2 is methane. These molecules break down so fast that the warming potential 'tails off' by half every 8 to 9 years. Methane's official GWP over 100 years, its GWP_{100}, is 'only' 25. But the Emergency's unfolding so quickly, and so methane's being emitted, that some people count the shorter 20-year timespan, before so much has broken down. Then methane's GWP_{20} is 86.
(nb Water vapour holds heat, too, but has a lifespan of just hours or days in the atmosphere as it evaporates and condenses again – depending on the temperature! So it's not usually included in emission calculations.)

CO_2 equivalence and 'footprints'

Many human activities emit more than one greenhouse gas. To describe their climate impact, we could count the mass of each gas individually, use GWPs to calculate how much heating each one will cause, and list them individually. But carbon footprints add these all together, describing the climate impact of something in one number. The unit is a 'carbon dioxide equivalent', or CO_2e, describing how much CO_2 would have to be emitted to have the equivalent impact on global heating. And it's measured by mass; grammes, kg, tonnes.

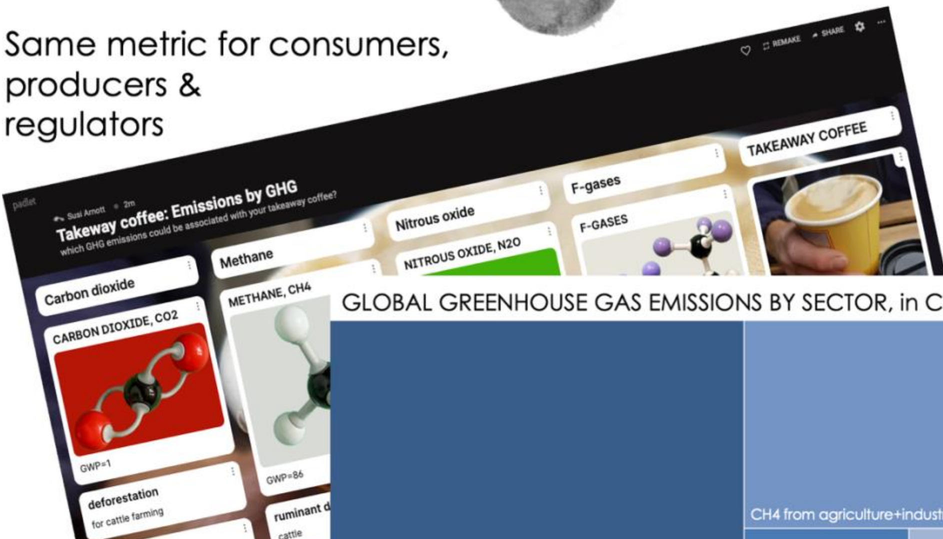
Factories, universities, hospitals; a music festival and a military invasion and an oil terminal all have 'footprints'. In the wealthy world, we can practice by thinking about a takeaway cup of coffee (see opposite); each type of GHG can be involved along the supply chain - from deforestation to refrigerating milk, boiling water or heating the coffeeshop. It's a useful exercise in thinking about how we might live more sustainably.
But the idea of 'a personal carbon footprint' mustn't be a distraction. A massive reduction in GHG emissions can only be achieved if we stop burning fossil fuels.

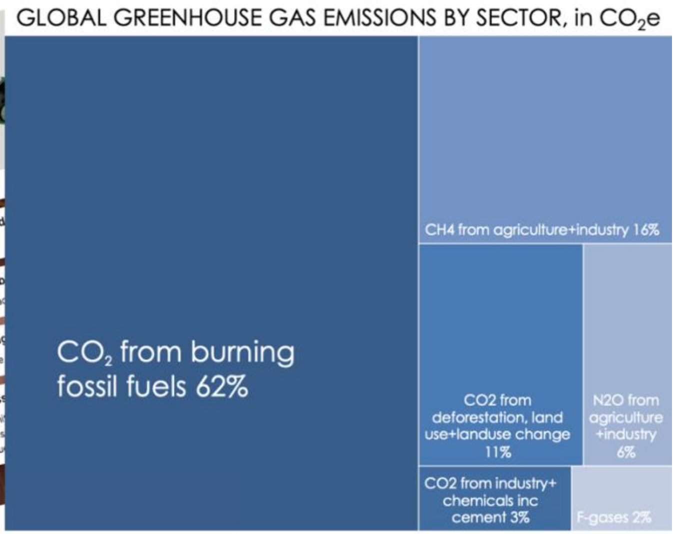


Total heating effect of all greenhouse gases emitted = 'carbon footprint'

Unit is mass of 'carbon dioxide equivalent', or CO_2e; how much CO_2 would have same impact

Same metric for consumers, producers & regulators





2021 Data: IPCC WG3, via Project Drawdown

Emissions ownership: whose footprint?

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? The media normalising or promoting private motoring?

They **all** have agency in these emissions: the Greenhouse Gas Protocol organises this paradox with 'Scopes'. Double-counting is a **feature**, not a bug.

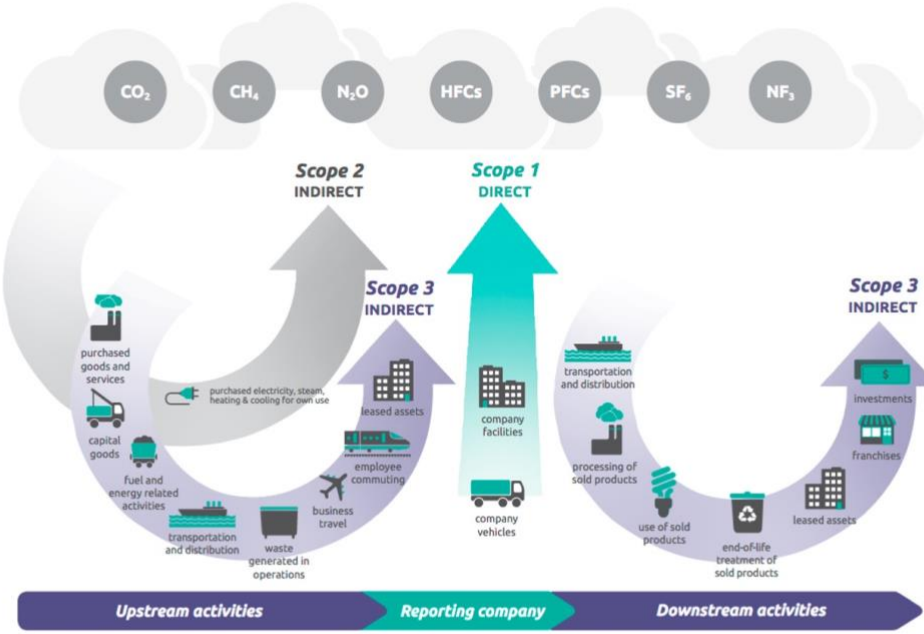
'Scope 1' covers direct GHG emissions, eg burning fuel to heat a house or a factory, or to power its machines; using an air conditioner that leaks F-gas refrigerant; or venting methane from your oil platform.
If this journey's in a company car, exhaust fumes are part of their 'Scope 1'.

'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' examples are emissions 'embedded' in raw materials or capital goods like the motor car itself, other machinery and buildings, business travel and waste. 'Downstream' includes distribution, processing & waste disposal. Companies often deliberately omit category 11, 'use of sold products'.
The phrase 'net-zero petrol' is greenwash; exhaust emissions from a car journey 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 emissions were ignored in company proposals to exploit the Cambo oilfield. But they were key to the Scottish parliament's refusing permission.

Scopes-based accounting crops up in national, local and corporate regulatory requirements. For example, the Science-based Targets initiative (SBTi) uses it to accredit emissions targets as meaningful or not, requiring Scope 1 & 2 emissions to be zero by 2030, with Scope 3 down to max. 5-10% by 2050 (see also p30). But failure to take serious action until now, puts these calculations too far into the future. Every indication is that before 2050 arrives, systems & societies will have either pro-actively transformed to avoid disaster, or will have already collapsed due to climate breakdown.



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 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.
Also known as 'value-chain' emissions;
including upstream AND downstream

Doing sums: negative emissions?

It’s simple arithmetic; to reduce the total, add less than is being ‘taken away’. Gigatonnes of carbon have been stored in biomass like peat bogs, forests and coral reefs. Photosynthesis is the key ‘natural negative’ emission: fixing CO_2 out of the atmosphere into biomass, and storing solar energy in the process. (see pp 8-9). The ocean has physically soaked up a great deal of CO_2 so far. But this makes it more acidic, and it can’t hold as much as it heats up.
Yet we’re destroying ecosystems with deforestation, mining, factory farming and trawling. This emits carbon right away, but also damages their future ability to store more away. Wildfires now make huge impacts on the sums.

‘Carbon Neutral’ and ‘offsetting’

This proposes that some emissions can be magically ‘neutralised’; either by reducing other emissions, subsidising someone poorer than you to avoid theirs, or paying for extra negative emissions to happen.
‘Comfort blanket’ offsets, like those sold to let people feel OK about flying, often involve tree-planting. But forests aren’t simple plantations, and land is finite. ‘Carbon-neutral’ promises by fossil fuel companies have already allocated 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 to continue.

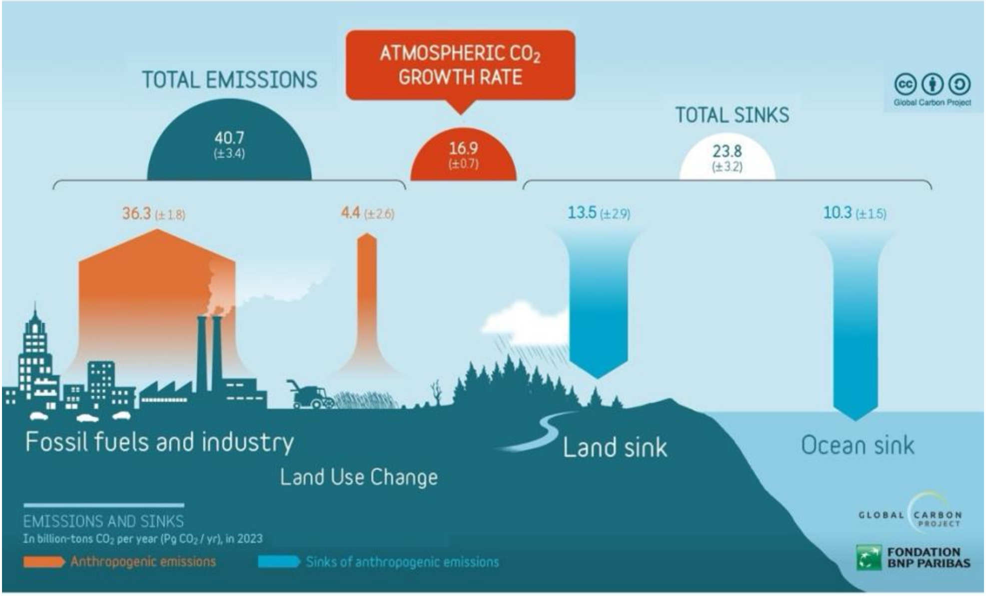
From the climate’s point of view, attempted ‘good deeds’ are offset by flying.

‘Net’ Zero, or real Zero?

‘Net Zero’ means ‘Emissions - minus Sequestrations = equals Zero’.
Under the Science-Based Targets initiative (SBTi), a given year’s emissions are calculated, and plans put in place to reduce them by at least 90% before a certain date. ‘Offsets’ don’t count, only plans for pro-active sequestration. But this is most likely to be industrial ‘greenwash’ directly linked to further emissions. For example in Scotford, Canada, Shell links carbon capture to processing bitumen tar-sands. More CO_2 is emitted than captured, even **before** the products are sold and burned. Technological ‘fixes’ have so far been an expensive distraction: resource-intensive and only trialled at experimental scale - unlikely to avoid climate ‘tipping points’ (see p.14).

In comparison to natural sinks lost to wildfires and biomass energy projects, industrial ‘negative emissions’ have so far been microscopic (see p37).

Global emissions and sinks, 2023



Biological 'carbon sinks'

Experimental industrial 'negative emissions'

International bodies & Climate Science…

In 1988 the United Nations founded the Inter-governmental Panel on Climate Change, IPCC, to assess research from around the world & confirm an agreed 'state of knowledge'. Their 3 working groups ('WGs') focus on physical science, likely impacts and adaptation needed, and ways to mitigate and reduce harm.

…demanding action

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'*. That same year, the United Nations Framework Convention on Climate Change (UNFCCC) was established, requiring countries to take action based on IPCC findings. The first 'conference of parties' (COP) met in Berlin, in 1995. COP3 (Kyoto, 1997) specified the GHGs and proposed the first clear limits to emissions.

COP21 (Paris, 2015) set a temperature rise 'ceiling', of 1.5-2°C above pre-industrial average, that we must stay beneath. A follow-up IPCC report in 2018 ('SR15') pointed out how deadly a 2°C rise would be, and strongly advocated 1.5°C. Hence the slogan '1.5 to stay alive': as a **limit**, not a target.

But UN demands are not being met – so the public are beginning to make demands for themselves. Following SR15, Swedish schoolgirl Greta Thunberg sparked the 'Fridays for Future' school-strike movement, and Extinction Rebellion took off. In Spring 2019, civil disobedience in the UK provoked Parliament into declaring a 'Climate Emergency'. Other public and private bodies followed suit, and targets were announced; but not coherent policy. Then came COVID-19.

Emissions reduced slightly – but soon regained momentum.
August 2021 brought part 1 of the 6th Assessment Report (AR6) from the IPCC. For the first time, scientists stopped expressing any doubt and 'Code Red' was declared.

But COP 28 was in UAE, and chaired by the CEO of the Abu Dhabi national oil company. In 2024, COP29 was in Baku, Azerbaijan; home to the Caucasian oilfields businesses and service industries. Scientists and activists now question the value of these UN bodies.
Even António Guterres, United Nations Secretary-General, is losing patience.


SCIENCE SAYS NEW OIL & GAS = DEATH
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END FOSSIL FUELS
António Guterres
@antonioguterres
Climate activists are sometimes depicted as dangerous radicals.
But the truly dangerous radicals are the countries that are increasing the production of fossil fuels.
Investing in new fossil fuels infrastructure is moral and economic madness.
11:46 AM · Apr 5, 2022 · Twitter Web App
COP28
UAE

Fossil Fuels and power

Political & financial influence keeps economies around the world in thrall to fossil fuel interests; often even owned or subsidised by governments, directly or via tax breaks. The host country for 2024’s COP29 is the former Soviet republic of Azerbaijan, an oil and gas producer with huge capacity for expansion.
But the dangers are increasingly obvious to other powers – the US Pentagon and UK’s Ministry of Defence have both published strategic responses to geophysical and geopolitical impacts of burning fossil fuel.

In the run-up to COP28, Pope Francis issued ‘Laudate Deum’, praising protestors for filling a space left empty by society as a whole and stating:

> *“The ethical decadence of real power is disguised thanks to marketing and false information, useful tools in the hands of those with greater resources to employ them to shape public opinion.”*

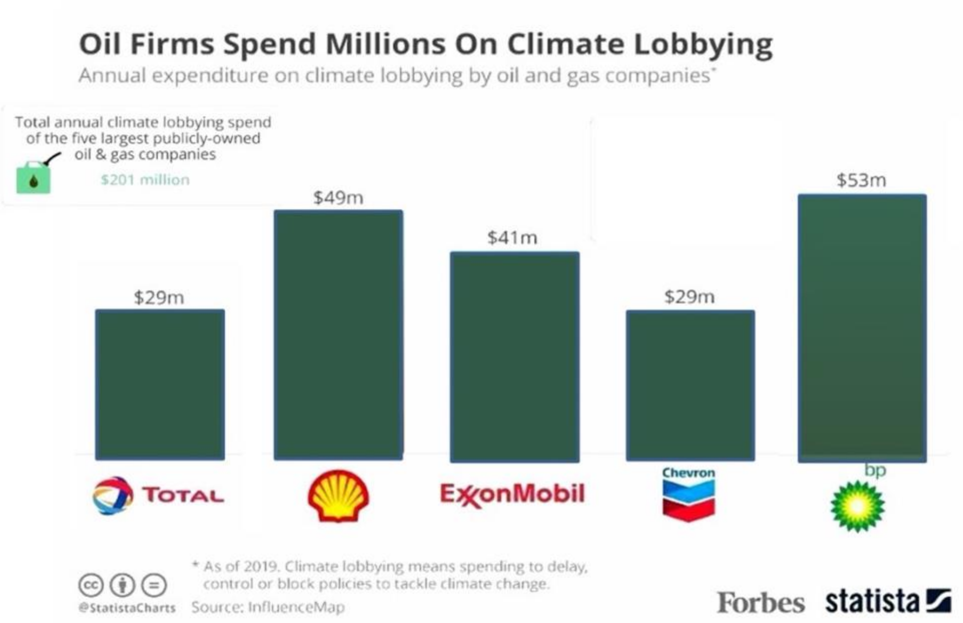
And in 2024, an international group of Islamic scholars published ‘Al Mizan – a covenant for the Earth’, endorsing the Fossil Fuel non-proliferation treaty.

Whose targets?

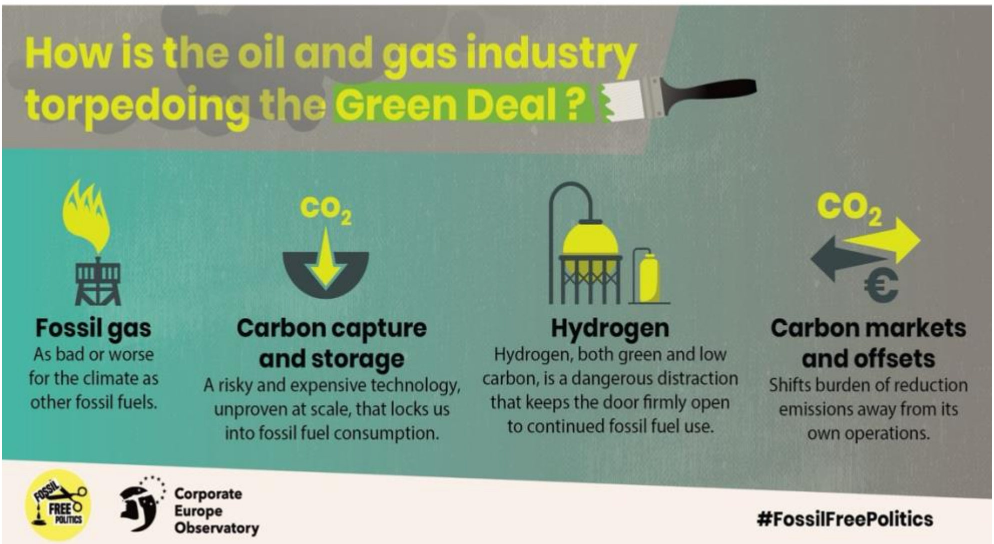
The IPCC’s AR6 imagined a range of possible ‘shared socio-economic pathways’ (SSPs) that countries, corporations & consumers might follow.
If we follow the ‘Sustainability’ pathway, SSP1, they estimate average temperatures will rise by ~1.6 to 1.8°C (devastating enough). Their worst-case scenario is SSP5, ‘Fossil-Fuelled Development’, heating the world by 4-5°C within decades; the impacts are impossible to predict.

Fossil fuel industries still thrive, using public concern about climate to co-opt and monetise concepts like sustainability and carbon capture (see p30).
Small investments allow them to ‘greenwash’ their brands. 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).

Fossil fuel companies invest in politicians:



False solutions that would lock us into a fossil-fueled future:



Where are we heading?

The Climate Action Tracker (CAT) shows current policies bringing between 2.2 to 3.4°C of heating. But even 2° is likely to lead to further crop failures, social breakdown, global conflict and mass starvation: we can't know in advance when collapse would happen.

The IPCC estimated a 'remaining budget' of 400 giga-tonnes (Gt), from 2020 onwards, for a 67% chance of staying below 1.5 °C of warming. But most of that budget has already been used up; by wars, wildfires, and 'business as usual'.

Fossil fuel use via oil & gas fields and coalmines already in use, or under-construction, would emit 936Gt, over twice the IPCC 'budget'. That's **before** any new gas, oil or coalfields are commissioned. Existing operations must be reduced, and permitting any more to go ahead would be suicidal.

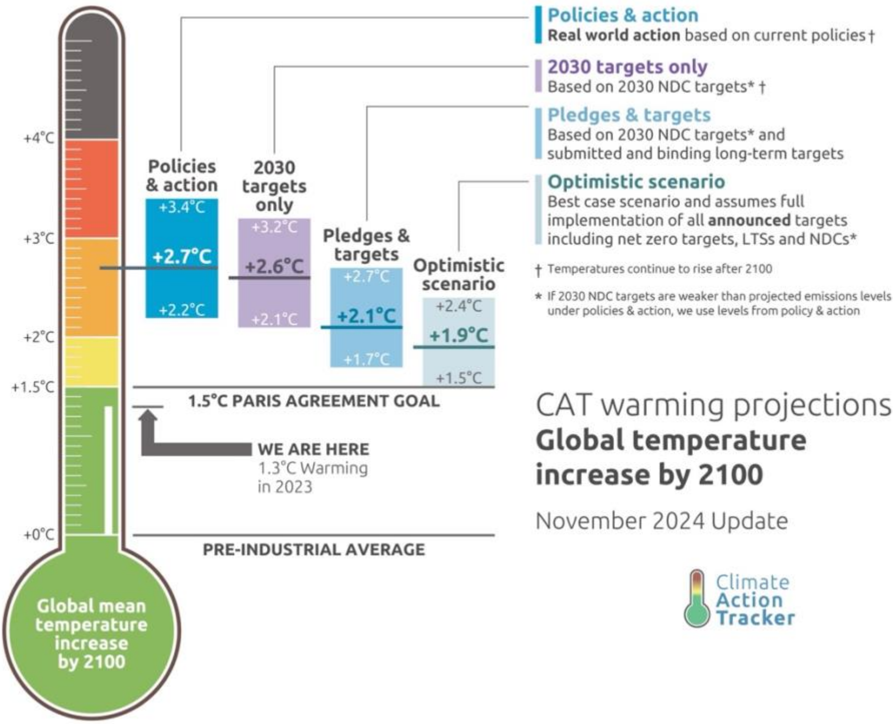
The concept of 'stranded assets', reserves counted on balance sheets but which can't be exploited, terrifies financial markets. Yet these 'assets' will have no value at all, if we damage global ecosystems and populations so heavily that human societies collapse. Insurance companies are already concerned.

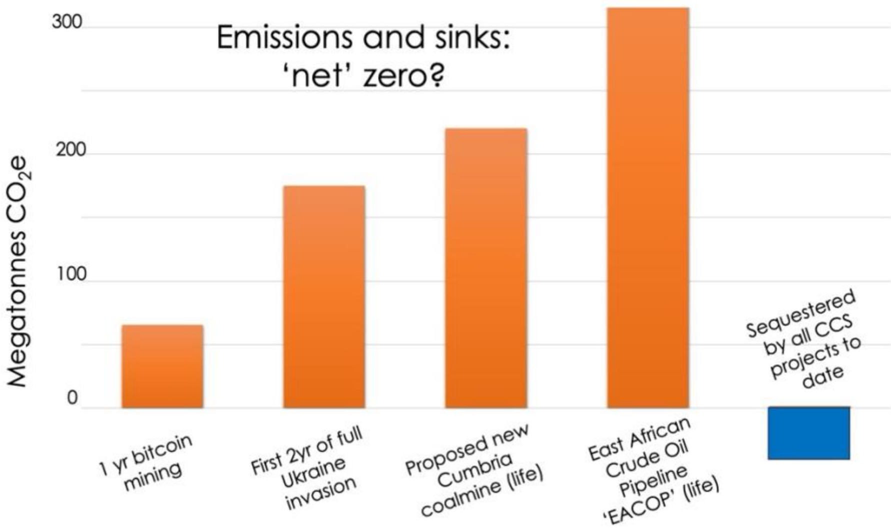
'Business as usual' bumps us into bankruptcy, soon – the UK's budget share (50 tonnes per person) runs out by the end of 2025. Gradual change is no longer enough – we've run out of slack.

Paradoxically, the empty declarations of a 'Climate Emergency' made by governments and businesses demand active and informed response from the general public. If civil society takes the Emergency seriously, we may stop making things quite so much worse. But if collapse is inevitable, and we've already started to practice sustainability, there'll be something for survivors to build upon.

A positive 'tipping point'

Some tipping points of climate change might already be breached; but another tipping point is of social concern and engagement. An informed and motivated public may show courage and constructive resistance rather than guilt and 'learned helplessness'.
They may even bring about genuine climate action.





data: deVries et al, 2020 in Cell Press/Joule; deKlerk et al for Initiative on GHG accounting of War, 2024; UK Secretary of State, in re planning permission; Climate Accountability Institute; International Energy Authority

Individual <u>and</u> system change

Economic systems built on fossil fuel and over-consumption have brought us to the brink of breakdown. They will have to change, and individuals can help.

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 2.8t by 2030, and continue to reduce after that.

This is less than a quarter of the current UK average, and Climate Justice is at stake. High emitters can make the biggest difference, simply because their choices have bigger impacts (see p21) and can bring totals and averages down the fastest. And they'll usually also have more control over their time and financial decisions. In turn, their decisions can inform and advocate for the system changes that remove constraints for the less well-off; from community energy to collective transport to normalised, affordable, low-carbon food production.

The scale of change needed is enormous, and it will only get harder as breakdown unfolds – 'later' may soon be 'too late'.
Systems will have to change, and societies re-organise.

Reform or revolution?

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 and 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."*

Getting UK average footprints into shape:

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

12.7 t
per person, UK 2020*
(inc.public/shared)

Global average needs to be 2.8t
by 2030**

Adaptation as well as mitigation?

For human societies, social inequalities are already too deep. Eventually we'll all suffer, 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. Some notion of carbon footprints helps prioritise; whose changes have most impact?

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 even a fair share of energy and resources?
Economists and scientists debate whether a 'right sort of growth' 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.

'Business as usual' is breaking our support systems; day by day, year by year, rising temperatures and sea-levels are changing our options. The systems we live by will inevitably change, whether because of breakdown or to avoid it.

So here is one view of tasks ahead:

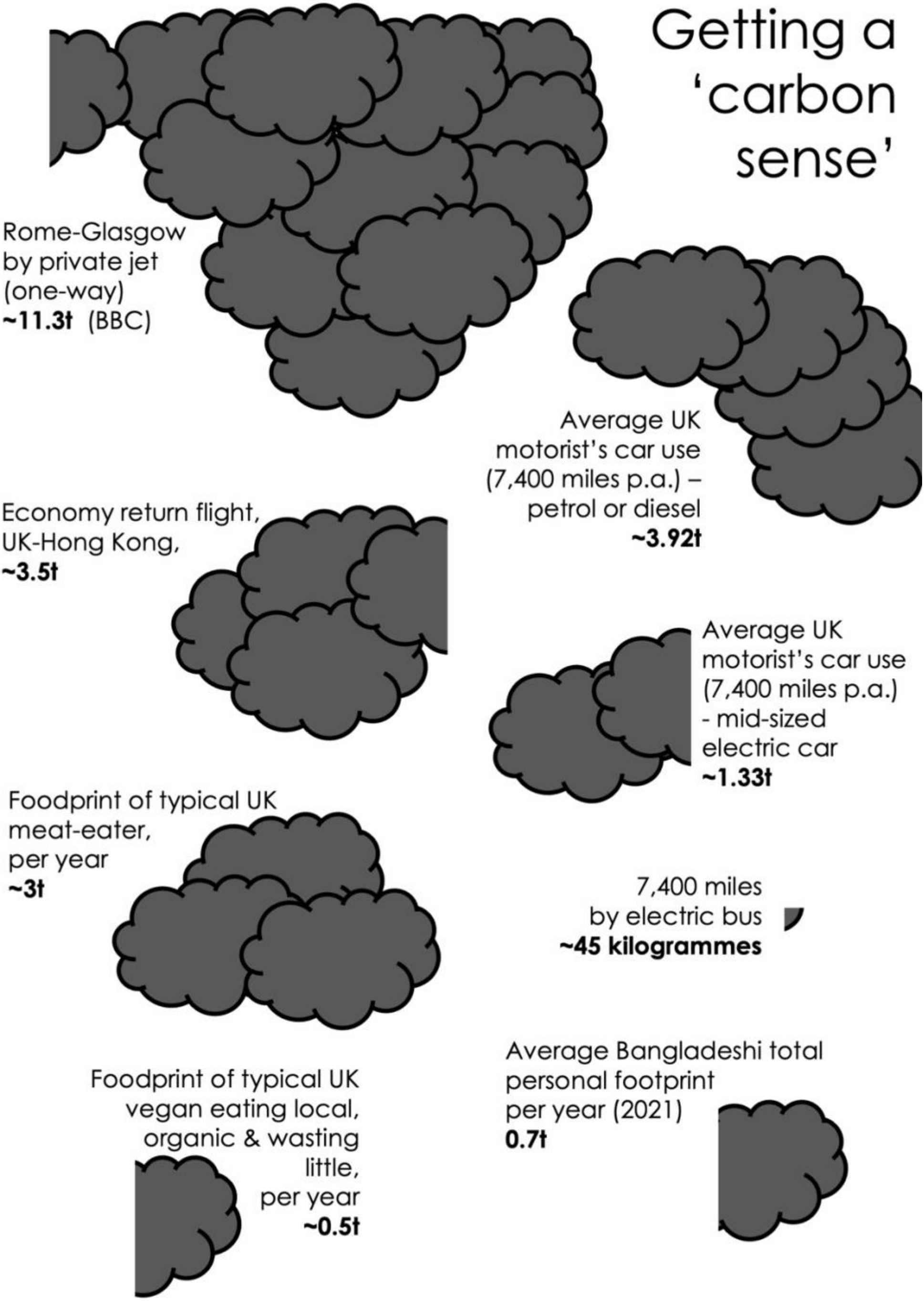
i) reduce levels of greenhouse gas in the atmosphere

ii) meet basic needs for all, in decarbonised ways

iii) find ways to do this as the planet continues to change around us

Societies, as well as ecosystems, will be re-organising themselves. We'll do well to have resilient, sustainable lifestyles as the Climate Emergency unfolds.

Getting a 'carbon sense'



Meeting basic needs for everyone: Energy (‘E’)

The simplest way to decarbonise energy (‘E’) is to electrify everything possible, and use renewable sources to generate that electricity (‘ē’). Wind turbines and solar power have their own footprints, to manufacture and install, but quickly compensate for these embodied carbon-costs. (Burning trees on the assumption they’ll grow again just doesn’t reflect reality.)

Renewable sources can replace fossil fuels, not just add to them: bringing the total demand down will be key. Electrifying industry is vital, but so is domestic energy use and insulation.

‘Thermal comfort’ (heating or cooling), heating water, cooking, running gadgets & machinery can all use less without hardship. Sharing living spaces and resources is one way forward; some technological ‘fixes’ will help as well.

Heat pumps use small amounts of electricity to concentrate & move heat from one place to another; both heating & ‘air-con’ regularly work this way in continental Europe. Retro-fitting insulation, shading and smart ventilation will be as important as improved design for new-builds.

Capital investment is needed up front, but running costs are far lower, with improved air quality and respiratory health as obvious ‘co-benefits’.

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

System change includes legislation and investment. Electric private cars aren’t a magical solution; investing in public transport powered by electricity is a far better choice than building even more roads.

The COVID-19 pandemic promoted remote collaboration; finding local suppliers & consolidating deliveries brings T&T use down even further.

Using and supporting public transport can quite literally save lives, given the huge toll of road traffic collisions and air pollution. Short journeys are often actually quicker, as well as healthier, by 'active travel' - walking and cycling.

Shipping companies are already trialling wind-power again. And 40% of shipped goods by weight are fossil fuels themselves. So there’s a double benefit to stopping their production & use, reducing damage to the oceans as well as to the atmosphere.

And the biosphere simply can’t afford any non-essential flying; burning fuel at altitude makes the emissions extra-harmful, and so-called ‘sustainable aviation fuels’ use up other people’s land, crops, food and energy. Government commitments to ‘Net Zero’ mean no new runways or airport expansion.


abellio

Meeting basic needs: Food

There will always be some emissions associated with food production, but there are also very obvious ways to reduce them.
Almost all of us in high-income countries eat & drink more than we need – and throw away a third of what we buy – so for many of us, ‘reduce’ is again the first strategy.
Meat-based diets are wasteful in themselves, too. Energy & biomass are lost at every step in a food chain, and GHG emissions build with every ‘layer’; a quick fix is to eat plants ourselves, not feed them to other animals first.

Protein needs (rather than cravings) can be met with far less meat & dairy than many people consume. Reducing these can make the single largest saving of GHG emissions under this category, with direct benefits to health and well-being as well as to the natural world and biodiversity, in UK and beyond.

This map shows how much the UK depends on other people’s land for our food. If we just let the climate emergency unfold, they won’t be able to feed themselves, let alone support our lifestyles - and our own farming systems already struggle with disturbed seasons and climate.
System change might need governmental legislation, but farming groups and unions are already self-organising around climate action.

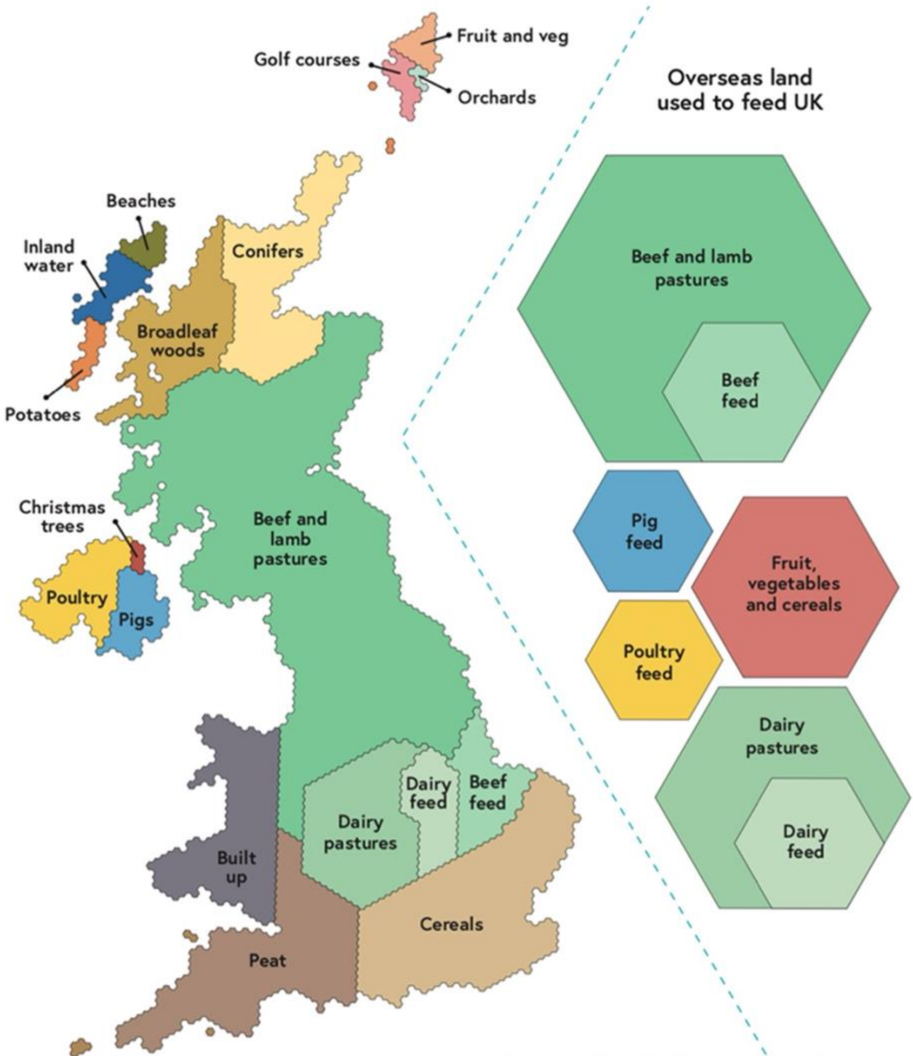
Meeting basic needs: Stuff

Individual strategies again begin with ‘reduce’. How much stuff do you really need, how much more would be ‘enough’? Devices and gadgets, furniture and accessories pile up – and clothing waste can be monstrous. The focus on re-cycling can be seen as a strategy to promote more consumption.

Stuff never actually 'goes away' - even biodegradable waste breaks down to produce methane and/or carbon dioxide. Remember the concept of embedded/embodied carbon, and consider carefully whether you really need a new smartphone or laptop. Arriving at a truly ‘circular economy’ will take years, but meanwhile reconditioned IT equipment is a cool solution.

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

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

Goods and services all have footprints - and we're all somewhere in supply chains, with the influence that brings (see p.38). Resilient lifestyles will be more and more valuable as the climate emergency develops.

UK is the first country in the G20 to require large companies and financial institutions to report on climate-related risks: the insurance sector is a ‘canary in the coalmine’ for climate chaos. 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 facilitate fossil fuel infrastructure or invest in sustainability.

Pension funds are some of the biggest operators; decision-makers need the collective consent of investors. As individuals you can investigate & discuss with family, friends, and colleagues; this can be a good start for those wider climate conversations. And as groups, campaigns asking banks and insurance companies to stop enabling fossil fuel industries are gaining traction.

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 & 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'. Speaking up enables others to do the same; standing up and asking for change encourages us all to see the possibilities for a better future.

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 about genuine climate action.

There’s so much we all want to protect!


RESERVE BANK OF INDIA
1000
CENTRAL BANK OF KENYA
1000
THE UNITED STATES OF AMERICA
ONE DOLLAR


VOTES
FOR
WOMEN

Radical change is coming, either way

66 million years ago, an asteroid hit Earth and changed the whole biosphere. Massive tsunamis were followed by climate chaos as CO_2 levels rocketed and ash-clouds blocked the sun.

Grimly, man-made ('anthropogenic') climate change won't be this sudden. Less like falling off a cliff, more like smoking ourselves to death. 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 invested in advertising their addictive products but also in promoting doubt and uncertainty about the harm they cause.

We need the Greenhouse Effect: it's what made Earth warm enough for life to evolve. But without serious change to 'business as usual', anthropogenic greenhouse gases will promote feedback loops taking the climate into super-charged chaos. Ecosystems and social systems are likely to collapse.

Pro-active change

There's another option: constructive 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. Some of us have opportunities to do more than others, but we really are in it together on our single planet.

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

Electrifying rural schools with solar in Afghanistan

Protesting against fossil fuel industry in Uganda

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

Global justice and the natural world

We are at a time of reckoning, across the generations and the planet. Assessing impacts and prioritising action to resolve them, will shine light onto social, economic and political inequalities.

We're part of an intricate biosphere, albeit badly damaged by human activities. Most people already relate to nature one way or another, and many would appreciate more access to the natural world.

Physical and psychological health & wellbeing

Reflecting on what we're sacrificing to 'business as usual' can bring wider recognition and appreciation of the world around us.

A shift from intensive livestock rearing towards healthier plant-based diets is likely to bring improved human health improvements, alongside reduced cruelty. (The meat industry seems to brutalise humans, as well as livestock.)

Active travel and public transport, especially once that's been electrified, means cleaner air and healthier bodies. (The current situation disadvantages and even disables many people, who would be allies in Climate Action if transport planning is thoughtful.)

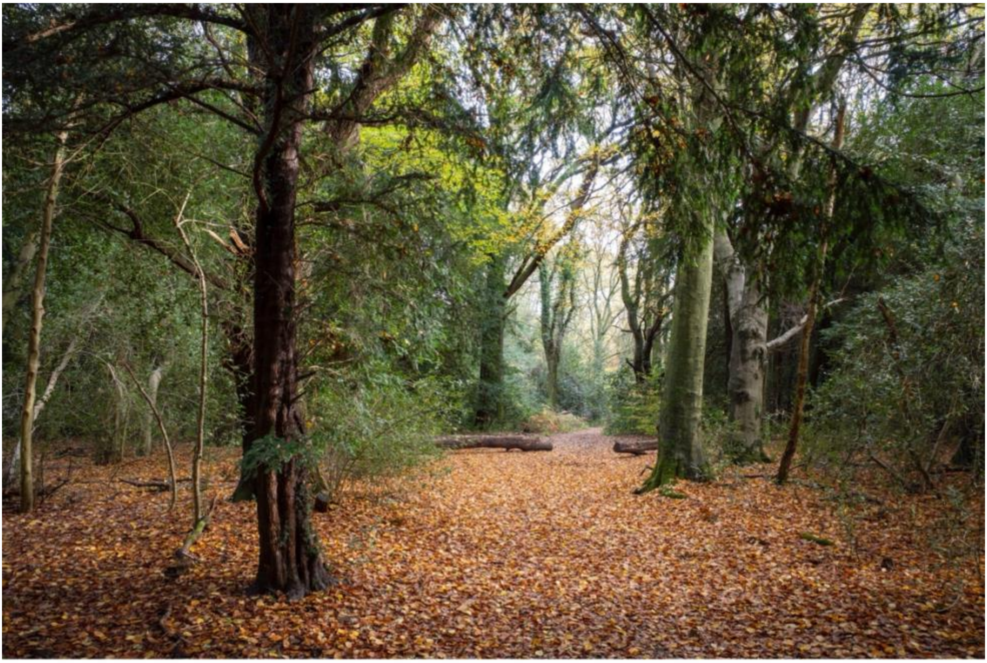
It's easy to feel 'gas-lit' or alienated by consumerism, especially if others aren't speaking out. Doing something, and speaking out, alleviates the anxiety of doing nothing and staying silent.

Some things are 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. (Jeremy Leggett, who's now turned his attention to re-wilding.)

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, but we'll 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 and inventiveness are what make us human.




Christopher, in Zambia 2013
image: Patrick Bentley for SolarAid, cc-by 2.0

NEWS FEEDS:
Carbon Brief: https://www.carbonbrief.org/
Energy & Climate Intelligence Unit, ECIU: https://eciu.net/
The Climate Question (BBCR4): https://www.bbc.co.uk/programmes/w3ct3kk2

RESOURCES:
A footprint calculator and more: https://carbonindependent.org/
The Energy Saving Trust: https://energysavingtrust.org.uk/
The Ethical Consumer: https://www.ethicalconsumer.org/
Make My Money Matter: https://makemymoneymatter.co.uk/
Jeremy Leggett blog: https://jeremyleggett.net/
Kevin Anderson blog: https://climateuncensored.com
Greener Jobs Alliance: https://greenerjobsalliance.co.uk/
Client Earth: https://www.clientearth.org/
Extinction Rebellion: https://rebellion.global/
Climate Interactive (visualising futures): https://www.climateinteractive.org

FURTHER READING:
Greta Thunberg, *The Climate Book* (Penguin Random House, 2022)
Jason Hickel, *Less is More* (Penguin, 2020)
Mike Berners-Lee, *How Bad are Bananas? (Profile Books, 2010 and 2020)*

REFERENCES & DATA SOURCES:
Carbon Independent: https://www.carbonindependent.org
The Keeling curve: https://keelingcurve.ucsd.edu/
Global Carbon Project (inc.Atlas): https://www.globalcarbonproject.org/
World Resources Institute: https://www.wri.org/
UN Framework Convention on Climate Change: https://unfccc.int/
Intergovernmental Panel on Climate Change: https://www.ipcc.ch/
UK Climate Change Committee: https://www.theccc.org.uk/
Our World in Data: https://ourworldindata.org/
Carbon Tracker: https://carbontracker.org/
Climate Action Tracker: https://climateactiontracker.org
UKFIRES (Industrial Strategy): https://ukfires.org/resources/
Ivanova (2020): https://iopscience.iop.org/article/10.1088/1748-9326/ab8589

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ACKNOWLEDGEMENTS:

Prompted by work with the Carbon Literacy Project (CLP). Walking Pictures have developed and accredited 3 courses with CLP and supported many learners to develop their own courses. This 'zine partly complements these but should in no way be held to represent the views of CLP.

Fellow Scientists for XR Ian Campbell, Tristram Wyatt and Cedric Knight, are thanked for their input & feedback. Crispin Hughes provided most of the professional photography.
Text and other images by the author unless otherwise stated.
With thanks to the following for illustrative references & data (public realm and/or creative commons unless otherwise stated). Every attempt has been made to verify and accredit sources; please notify us 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 inspired by Dr.Thomas Rongo, Alfred Wegener Instititute; p.13: data as credited but graph source unknown; p15: news tear-sheets from The Guardian 2020-10-22, 2021-04-13, 2020-08-10, 2020-08-10, Vice 2019-09-13, New Scientist 2020-02-05, Zimbabwe satellite image 2019-03, news source unknown*; p17: Kiribati news tear-sheet from The Guardian 2019-05-04, Risk Assessment graphics adapted from Climate Change Committee RA 2022; p19: 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, landfill site Matt Fascione; p25: crop-spraying photo Oliver Dixon; SF_6 circuit-breaker Greg Geobel, anaesthetist Crispin Hughes; p.27: data from 'How Bad are Bananas?' by Mike Berners-Lee; 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: S4XR roadblock by Crispin Hughes, António Guterres via Twitter (now X), COP28 by Anthony Fleyhan, via FlickR; p.35: Fossil Fuel lobbying adapted from Forbes magazine, False Solutions from Corporate Europe Observatory; p37: CAT thermometer from Climate Action Tracker; p39: protest images 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 + cyclists by Crispin Hughes, high-speed train Siemens Press/RailUK; p45: map infographic from 2021 UK National Food Strategy; p47: Annie Kenney & Christabel Pankhurst uncredited/public domain, protest image Crispin Hughes, citizens assembly from Demsoc.org; p49: reflective roofing MEER.org, solar array image Robert Foster for USAID, Vanessa Nakate via twitter @vanessa_vash, screengrab from film 'Devolution & Resilience' by Hilda Kathure, with permission; p51: Patrick Bentley for Solar Aid. Back cover: blue marble from NASA Earth Observatory (public domain).*

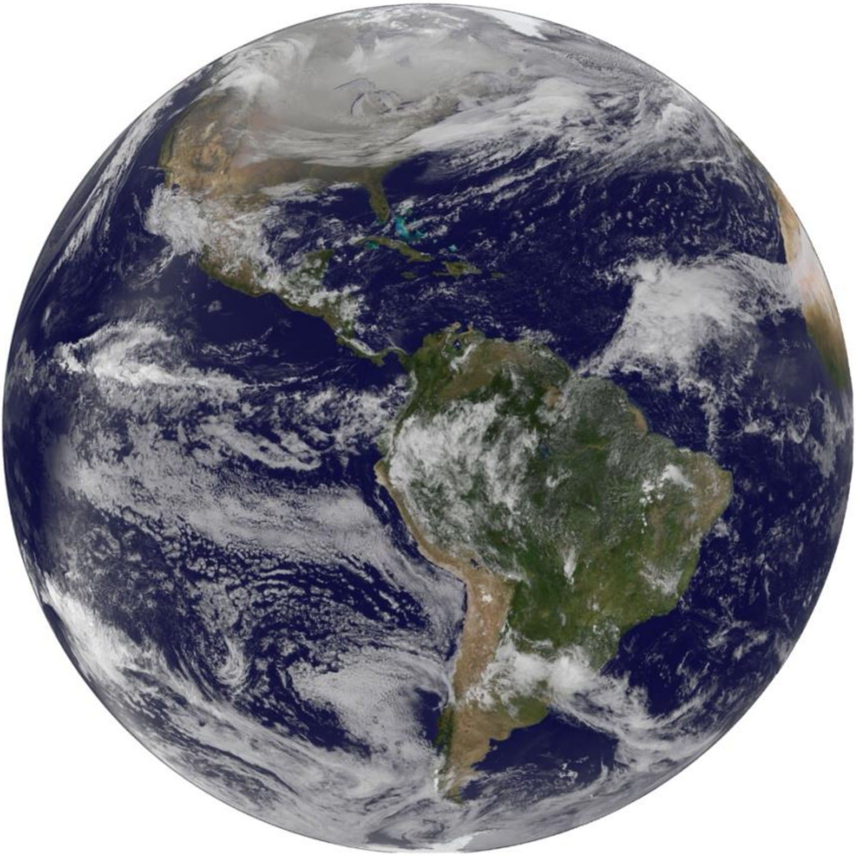
Published in Great Britain by Walking Pictures Publishing
www.susiarnott.co.uk

Fourth edition, August 2024 ISBN 978-1-7393786-3-9
Reprinted with amendments December 2024

Printed in UK

walking pictures ltd.

BY SA



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