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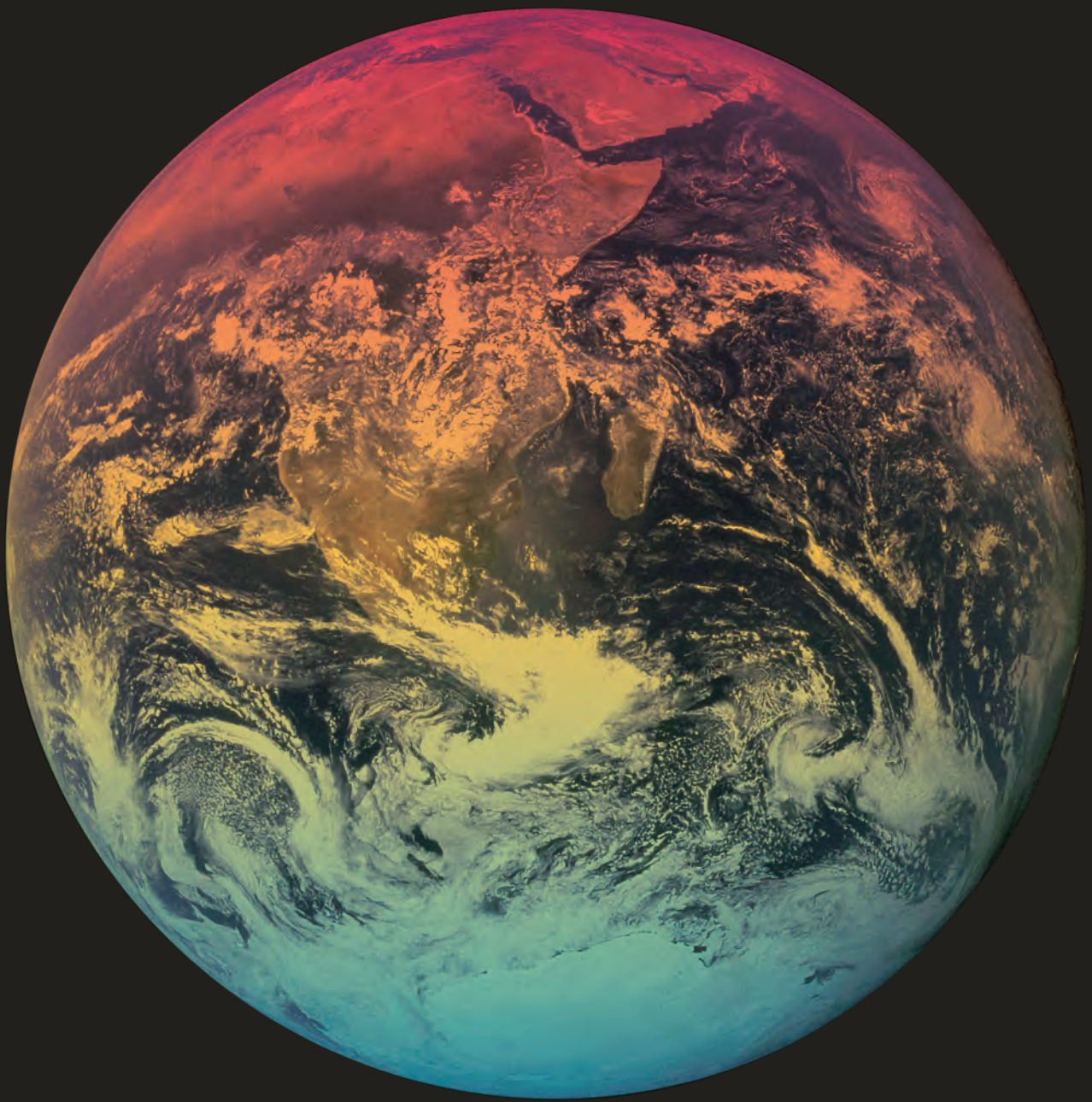

- TURNING TALK INTO ACTION / Jane Goodall
- CLIMATE PROMISES / Silvana Tenreyro
- CARBON AND INEQUALITY / Mya-Rose Craig
- EARTH VERSUS GROWTH / Tim Jackson
- EXTREME WEATHER / Ilan Noy

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OUR DEAR GREEN PLACE

Glasgow is the perfect city for COP26

Daniel Defoe was a spy and trader as well as a travel writer, so he got to know the world pretty well. In the early 1700s, he reported on a trip to Glasgow, finding it 'the cleanest and beautifullest, and best-built city in Britain, London excepted'. According to some etymologists, the word Glasgow has Celtic roots, and means 'green hollow' or 'dear green place'.

This makes Glasgow the perfect place to hold a climate summit. In the 20th century, the city's reputation fell: in the 1960s, it was famed for gangs, unemployment and industrial decline; and in the 1990s, it was defined by low life expectancy and an urban environment pockmarked with demolition sites. This city knows the human costs when policy fails, an economy tanks and the environment is damaged.

In this issue, our writers show that policy is failing on a global scale. The evidence comes from first-hand experience, including Jane Goodall's 60 years of primate research and Mya-Rose Craig's knowledge of life in rural Bangladesh. And it comes from cutting-edge scholarship using reams of data and the latest modelling. Whatever the methodology, the story is the same: the climate crisis is not something on the horizon, it started years ago and we are doing too little to battle it.

We are making catastrophic measurement errors. Ilan Noy's article on extreme weather notes that this year's spring was the earliest since records began in Kyoto. The records go back 1,200 years. He explains how outdated analysis means we underestimate the costs. Some of the data we present is devastating: based on current trends, in 2050 by weight, there will be more plastic in the ocean than fish. A proper calculation of the toll—health, economic, social—that comes with environmental damage would demand we do more.

But taking action will be hard, as tensions quickly emerge. The UK's wealth rests on the historic use of coal, as John Turner explains, and so telling lower-income countries to clean up is tough. Carbon taxes work—they push up the price of energy—but this hurts the rural poor.

Against all the odds, there are reasons for optimism. People like things that are cheap. As Dimitri Zenghelis shows, the price of clean energy is tumbling: simply cutting costs is the new way to be green. And a sustainable economy can be a just one: by carefully picking through the policy detail, Cristina Peñasco and colleagues plot a route forward. While Glasgow bears the scars of its past, it is once again known for its innovation, green parks and the arts. The Dear Green Place is a city that offers both warnings and reasons to hope

Richard Davies
Director, Economics Observatory

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CLIMATE CRISIS: IN NUMBERS.

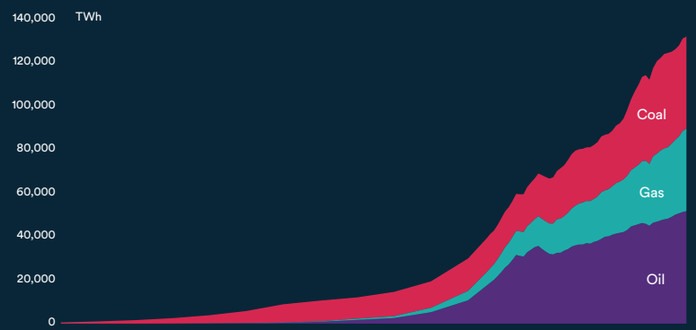
From fossil fuel consumption and carbon emissions to rising temperatures, biodiversity loss and economic harm, the latest data tell a disturbing story.

/ Dénes Csala / Richard Davies / Charlie Meyrick /

Fossil fuels—mainly oil, gas and coal—are being drilled, mined and burned at an ever-increasing rate. The historical comparison is stark: fewer than 20,000 Terawatt-hours (TWh) of energy from the main fossil fuels were used globally at the turn of the 20th century. Today, that figure approaches 150,000 TWh.

Global fossil fuel consumption

Terawatt-hours, by fuel type

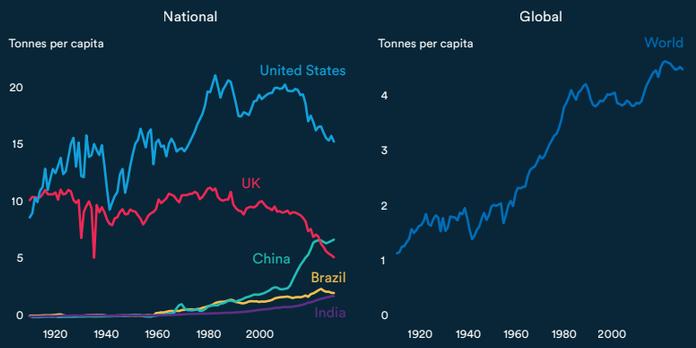


Source: Smil, 2017 / BP Statistical Review of World Energy

Burning these fuels results in the emission of greenhouse gases. Carbon dioxide (CO_2) has long been recognised as the principal driver of climate change. The amount released per person varies by country and over time. China and India have generated vast emissions in recent history in their efforts to industrialise. The United States, despite efforts to decarbonise, remains a clear front runner in per capita terms.

CO_2 emissions

Tonnes per capita



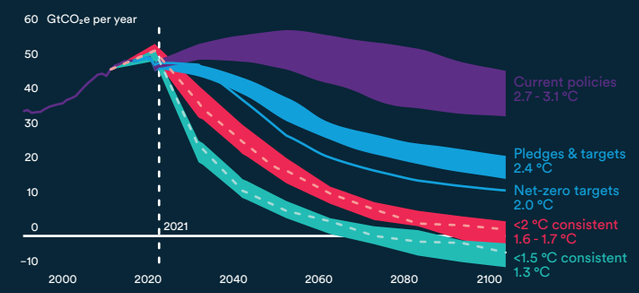
Source: Global Carbon Project

Scan for a live and interactive version of this dashboard

Limiting greenhouse gas emissions sits at the heart of climate policies worldwide. Without efforts to curtail fossil fuel consumption, global temperatures could rise by 4.1-4.8°C by the end of the century. Under current pledges, a 2.4°C rise is predicted. But climate experts state that an increase beyond 1.5°C will trigger irreversible environmental and ecological damage, as well as enormous economic costs.

Global greenhouse gas emissions and warming projections until 2100

Global CO_2 emissions

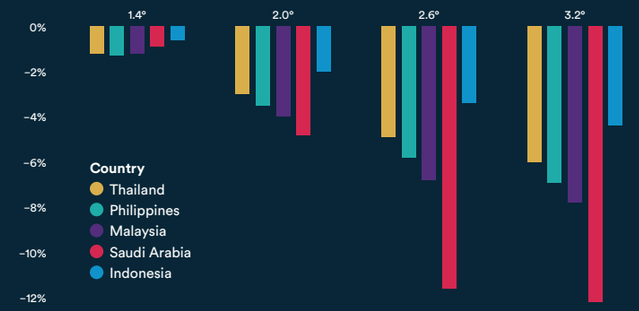


Source: Climate Action Tracker, May 2021 briefing

Focusing on economic costs alone, it is predicted that emerging markets in more vulnerable locations are likely to bear the brunt of the climate crisis. With just a 1.4°C temperature increase, the Philippines is set to experience a 1.3% decline in GDP. Under a 3.2°C increase, the loss would be almost 7%. Countries dependent on fossil fuels are also at risk. Saudi Arabia could experience a 12% drop in GDP should the average global temperature rise by more than 3°C.

GDP loss by temperature increase scenario

Percentage change in GDP, for some of the most affected countries

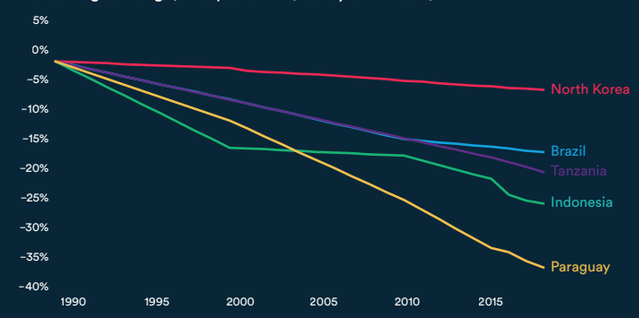


Source: Climate Action Tracker, May 2021 briefing

Oil, gas and coal are not the only natural resources being used unsustainably. The world's forests are being depleted rapidly, and this limits the planet's ability to absorb excess carbon in the atmosphere. Demand for timber has left many forests barren, on the brink of disappearing entirely. In Brazil, home to the Amazon rainforest, land covered by trees has fallen by 15% since 1990. In Paraguay, forest area has declined by over a third during the same period.

Forest area by country

Percentage change, in square km (base year = 1990)

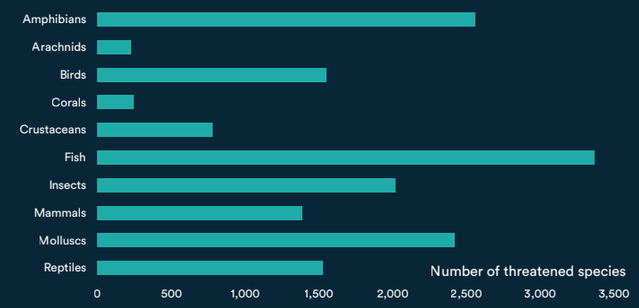


Source: World Bank

Human actions are harming the animal kingdom too. The loss of biodiversity triggered by rising temperatures, more frequent extreme weather events and the destruction of natural habitats means an increasing number of species—both animals and plants—now face extinction. The loss of natural capital rarely factors into economic decision-making, suggesting that many calculations grossly underestimate the severity of the risks we face. Once these species are gone, they will be lost forever.

Endangered species

Number of species on 'red list'



Source: International Union for Conservation of Nature Summary Statistics

Is the UK on track?

The UK government is failing to meet its ambitious goals for emissions reduction. Additional funding and policy interventions are needed to reach net zero.

/ Sam Stephenson /

The UK government, which holds the COP26 presidency, has ambitious targets to reduce greenhouse gas emissions. The plans, set out in 2020, are known as nationally determined contribution (NDC) targets. Compared with 1990 levels, they would see a reduction of 68% by 2030 and 78% by 2035.

This poses a challenge since the country is not currently on track to meet these goals. Projections produced by the Department for Business, Energy and Industrial Strategy (BEIS) expect emissions to fall by 52% (relative to 1990) and the Climate Change Committee believes that the UK is off-track to meet its 2030 carbon budget, a less strenuous target.

In the past 12 months, several strategies to reduce emissions in key sectors, including transport, industry and hydrogen production have been released by the government. One policy—the phasing-out of petrol and diesel cars by 2030—would have a significant impact. Apart from this, no new steps that would reduce emissions substantially have been announced or enacted. Can the UK live up to its 2030 commitments?

PROGRESS AND PLANS

Most progress has been recent. Between 1990 and 2010, the amount of CO_2 released per year fell by 16%. In the following decade, progress was better, with a 30% decline. This was achieved mainly through reductions in the industrial and power production sectors. Advances in the past decade have been driven by the switch from coal to gas for electricity generation and the growth in renewable electricity. Other sectors, notably road transport and the services sector, have seen no change in emissions since 1990.

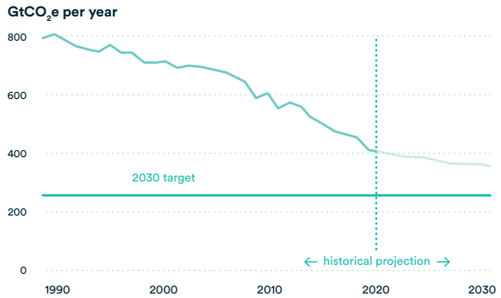
Policy has played an important role. The Emissions Trading System (ETS) caps total emissions and allows trading between companies; the Large Combustion Plant Directive places limits on power plants. Both are European Union regulations. There are also UK-specific policies, such as the Carbon Price Floor, which provides a 'top up' on the ETS allowance price to drive greater decarbonisation.

In November 2020, the government released a ten-point plan for a Green Industrial Revolution, which aims to mobilise £12 billion in government spending to decarbonise the UK economy. The plan would expand renewable energy production and remove gas boilers from homes. Yet since its launch, few policy announcements have been made, the Green Homes Grant (which provided up to £5,000 towards home energy improvements) has been scrapped, and it has become clear that only £4 billion of the planned spending is new.

To meet its targets, the UK is making a bet on new technologies, such as carbon capture and storage, which allows the continued use of fossil fuels without releasing greenhouse gases. Two projects are expected later this year. But even if the plan to capture ten tonnes of CO_2 annually by 2030 is met, it will account for less than 3% of current emissions—a small contribution towards the 45% emissions cut that is required this decade.

Emissions targets

UK emissions up to date and projected reduction to 2030



Source: BEIS, 2020

THREE CONCERNS

On top of this challenge, there are three concerns about the remainder of this decade.

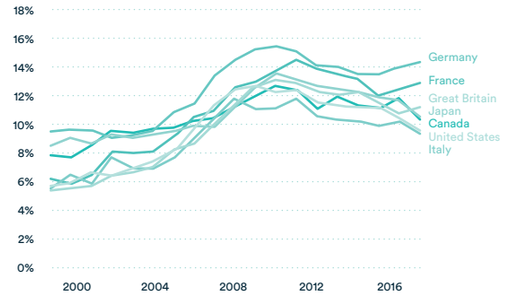
- **Time:** Much of the infrastructure required to decarbonise takes time to build. There is limited time to design and scale new technology, such as carbon capture and storage, or existing low carbon technologies, such as nuclear power.
- **Scale:** Between 2010 and 2019, the UK installed 8.5 gigawatts (GW) of offshore wind capacity. The government has committed to quadrupling this to 40GW in the next decade. Millions of homes also need to be retrofitted during this period. The government has committed to installing 600,000 heat pumps by 2028; studies suggest the rate needs to be millions per year.
- **Political buy-in:** Political will for climate action is hard to sustain, as first shown when the US Senate refused to ratify the Kyoto Protocol in the 1990s. Since the net-zero target was passed in 2019, policies to reduce emissions have faced an uphill battle. An all-party parliamentary group has come out against one of the few meaningful policies implemented by the government: the ban on new all-petrol and diesel cars from 2030.

Looking ahead, it is clear that tax and regulation will need to play a more robust role. The fossil fuel industry receives £10 billion in subsidies annually. Other proposed fossil fuel investments—such as the Cumbrian Coal Mine and North Sea exploration—would exacerbate the challenge. Cancelling these would be in line with recommendations made by the International Energy Agency. US President Biden plans to introduce a programme of payments and penalties for utility companies to rapidly increase the amount of renewable energy they provide.

Technology will be important but over-reliance on it is a risk. Investment in innovation and new green technologies has slowed across the G7 over the last ten years, meaning we may not be able to innovate our way out of the climate crisis.

Innovation

Environmental technology patents as a share of national total, G7



Source: OECD

Tough personal choices will be needed too, as our demand for fuels and energy sources has to fall. Policies that reduce the number of flights or encourage the use of trains instead of cars should be central to future climate policy.

We are starting to see initial glimpses of this in responses to the pandemic. The growth in low-traffic neighbourhoods and the increase in bike usage are positive developments. Initiatives such as these have a number of secondary benefits, including increased safety for children and more outdoor space for families and local residents.

This illustrates the other side to being a climate leader. Mitigation action can bring significant benefits and, for the UK, a first-mover advantage. While it may make our lives more difficult, the disruption caused by missing our targets is likely to be far worse

The real cost of a hurricane.

Climate change is making extreme weather more common. The costs of floods, fires and other natural disasters are being underestimated.

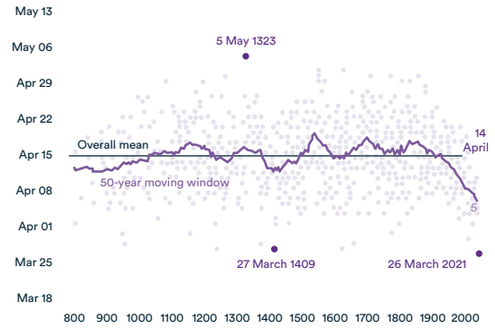
/ Ilan Noy /

Stacy Kranitz / Climate Visuals Countdown

The cherry trees in the gardens of Kyoto's main temple blossomed on 26 March this year, the earliest show of colour since the custodians of the temple started recording that date, more than 1,200 years ago. Sea levels are rising and will continue to rise in the years to come. Climate change is heating up the world.

Spring comes early

First full-flowering day of the cherry blossom in Kyoto, Japan

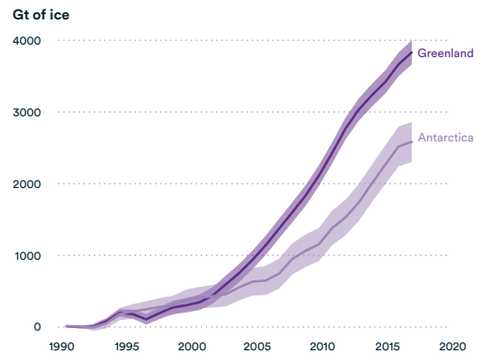


Source: NOAA, based on Aono, Kazui, 2008; Aono, Saito, 2010; and Aono, 2012

These two phenomena—rising temperatures and sea levels—are widely reported, in part because they are easy to measure. But an even more important trend—one that is wreaking havoc on economies—is the increasing frequency and intensity of extreme weather. This year alone has seen heatwaves, floods and wildfires in New York City, Germany, India, Siberia and China.

Disappearing glaciers

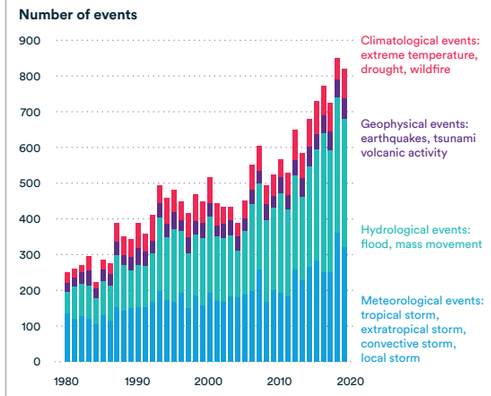
Cumulative ice mass loss of ice sheets



Source: IMBIE/EEA/ESA

Extreme weather

Number of relevant loss events by peril



Source: Met Office, based on Munich RE

EXTREME WEATHER ATTRIBUTION

Following a flood in his Oxford neighbourhood in 2003, and a fatal heatwave in France in the same year, Myles Allen (a professor of geosystem science at the University of Oxford) and his colleagues realised that the link between man-made climate change and extreme weather events can be quantified. This approach has become known as 'extreme event attribution' (EEA).

Using EEA, we can now link the costs of an extreme weather event to the greenhouse gases emitted in the past century. The example of Hurricane Harvey, a tropical cyclone that hit Houston, the Texan city home to more than two million people, shows how.

The Gulf of Mexico, the body of water through which the storm passed before hitting land in Texas, is becoming warmer because of climate change. As a result, the air above it contains more moisture. That led directly to Hurricane Harvey dumping huge amounts of rain on Houston in the last few days of August 2017.

By comparing two scenarios—one with the greenhouse gases that society has added, one without them—the climate scientists estimated that the probability of the flooding event had increased by two-thirds due to the emissions. Put differently, around 38% of the rainfall during those few days fell because of climate change. Without the warmer temperature, the hurricane would have been less likely and less damaging.

Lieut. Commander Mark Moran, NOAA Corps, NMAO/AOC

ECONOMIC COSTS OF HURRICANE HARVEY

Damage from extreme weather events can occur during or immediately after a hazard event. The damage is usually measured in the 'stock' of physical units (for example, the number of houses or bridges, kilometres of roads or tonnes of crops) or the overall cost of these physical units (their market price or the cost of rebuilding them). Sometimes the damage is more difficult to measure—for example, destruction of cultural assets and heritage, and the environment. These all count towards a country's stocks of assets.

This damage can reduce economic activity after the disaster. These losses can include:

- **Individual activity:** Declines in firms' revenue owing to business interruption or individuals' loss of income.
- **Reduced connectivity:** Interruptions to transport networks or stoppages in the flow of inputs through supply chains.
- **Macroeconomic impacts:** Price and exchange rate changes, increases in government debt and negative effects on stock markets.

The damage associated with Hurricane Harvey was estimated at around $95 billion. This made it the second costliest hurricane in US history, after Katrina, which flooded New Orleans in 2005 and killed around 1,800 people. Fortunately, the death toll associated with Hurricane Harvey was much smaller.

Nevertheless, infrastructure was damaged and commercial property along the gulf was destroyed. The follow-up losses to small and medium-sized enterprises were especially severe. But research shows that these indirect losses largely dissipated about two years after the hurricane. This is not unusual in a high-income country, where recoveries are often well-funded through insurance or assistance from the state. In contrast, the recovery in low-income countries can take much longer.

NEW PERSPECTIVES, NEW POLICIES

Combining the EEA calculations with an accounting of economic and social impacts gives economists a new perspective. Traditionally, economists have used 'integrated assessment models' (IAMs) to predict the cost of climate change. But these models are based on the average temperature experienced in a country and not on the extremes, where most of the costs of climate change typically are.

We can compare the EEA costs associated with Hurricane Harvey with the climate change costs that come from a typical IAM. We find that the EEA costs associated with this single hurricane are larger (by a factor of about three) than what Nobel laureate William Nordhaus predicts using his IAM model for the whole of the United States for that year.

The comparison is not perfect, but it does suggest that current estimates of the climate change costs obtained from IAMs may be significant underestimates. This would have big implications for policy, suggesting that aggressive emissions reduction policies—such as much higher carbon taxes—should be considered.

Better modelling and analysis lead to a second important finding—the inequality and injustice of climate change, even in rich countries. Combining findings on rainfall with hydrological modelling of flooding, we can analyse the precise locations in Houston where flooding was due to climate change.

About half of the 105,000 homes that were flooded can be pinned on climate change. In other words, without the impact of climate change, about 50,000 homes would not have suffered flood damage.

Examination of detailed maps and census information shows that Latinx-owned homes were much more likely to flood, and that low-income homeowners in this group were more likely to suffer. This pattern was especially pronounced in areas outside the officially designated flood zone recognised by insurers, resulting in many families facing far tougher financial hardship than those from other groups.

Taken together, the science of extreme weather attribution and the economics of natural disasters present us with a clear warning: we are underestimating the costs of climate change to our economies and to the justice and fairness of our societies ●

Life saver and polluter.

Healthcare systems face a growing burden from environmental hazards like air pollution and extreme weather events. As major contributors to greenhouse gas emissions, they are also seeking to reduce their carbon footprint.

/ Laure de Preux / Dheeya Rizmie /

Healthcare systems are first in line when health is harmed by extreme weather. Heatwaves, for example, can increase hospitalisations and deaths as chronic diseases—such as respiratory or cardiovascular illness—are exacerbated. Emergency hospitalisations can rise by up to 26% for metabolic diseases and 21% for infectious diseases, driven by heat stress.

Heat is just one of many problems. Visits to emergency departments also surge during peaks of air pollution, which now occur frequently in the world's largest cities. Flooding leads to drowning, hypothermia and electrocution. Droughts, wildfires, increasing allergens and water contamination are associated with greater temperature variation. The changing climate is conducive to infections and pathogens, such as mosquito-borne diseases. Such traumatic events have also been associated with depression, anxiety and post-traumatic stress disorders.

The effects are unequal, and tend to linger. Research on the impact of temperature shocks in England over a decade shows that the elderly, children and disadvantaged groups are most at risk and likely to require hospital care. With ageing populations, such shocks are resource-intensive in part because they last: temperature effects, for example, can put the healthcare system under pressure for ten days after extreme heat. This can go up to 21 days when looking at respiratory ailments and cold weather.

The cumulative costs of extreme weather events for the NHS alone are estimated at £20.8 million annually. The cost due to particulate matter and nitrogen dioxide was estimated to be £42.9 million in 2017. Projecting no improvements by 2035, the direct health effects of air pollution could cost the NHS as much as £5.3 billion.

The true cost is much larger when considering premature mortality, absenteeism and productivity losses. By achieving the World Health Organization's air quality recommendations, the UK economy could save £1.6 billion each year in working days gained and reduced mortality.

To put this in perspective, the annual budget of Public Health England for preparedness for pandemics and environmental disasters was just £18.2 million in 2017 (and has since been getting smaller). So the cost of just one of the health problems that climate change brings dwarfs the entire prevention budget.

DO NO HARM

Healthcare systems are also large-scale polluters. The NHS, for example, represents 4-5% of the UK's carbon footprint. It is the biggest employer in the UK: both employees and patients commute to hospitals and GP surgeries. It also uses tonnes of single-use products each day, many of which need to be incinerated.

The NHS spends over £50 million a year on carbon permits. Things have improved, with a 26% emissions reduction since 1990. In 2020, it also became the world's first national healthcare system to commit to becoming a net-zero provider. Building improvements, renewable energy and electric transport will help to achieve this.

Pricing emissions into treatment evaluation may change recommendations. For example, one study shows that when accounting for the social cost of transport emissions, home dialysis is a more cost-effective option than hospital treatment. Taking account of carbon properly is likely to reshape the NHS fundamentally ●

Scan to read other ECO articles on health

PRICING THE SEAS.

The oceans have become a waste-sink for plastics—just like the atmosphere is for greenhouse gas emissions. A higher carbon price may help tackle both problems.

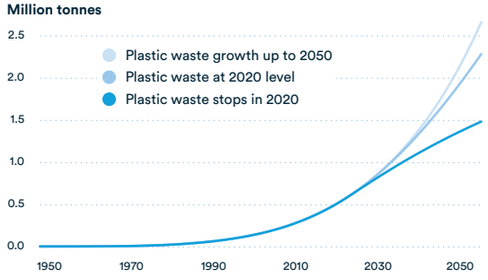
/ Johannes Lohse /

Plastics are great materials: durable, light and easily mouldable. This explains their widespread use—over the past five decades, annual production has increased by approximately 9% a year, reaching a total of 380 million tonnes.

But only a small fraction—9%—of all the plastic ever produced has been recycled. Some plastic waste is safely stored in landfills or has been incinerated. Still, about 30% of the yearly production currently leaks out into the environment from where it ultimately ends up in the ocean, causing multiple problems for the marine ecosystem.

Swimming in plastic

Projected ocean microplastics by emissions scenario

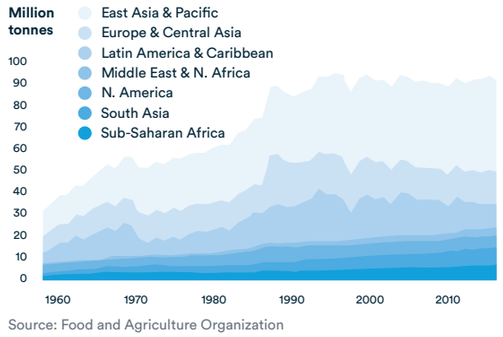


Source: Lebreton et al, 2019

Ocean plastic spoils beaches and harms wildlife. Fishing lines, ropes and nets make up over half of the plastic pollution in the Pacific Ocean. Known as ghost gear, this discarded equipment poses a serious threat to ocean wildlife. As demand for fish increases around the world, so too will plastic. According to one study, at the current rate, by 2050 there could be more plastic in the sea than fish.

Bulging nets, for now

Fish caught, by continent



Source: Food and Agriculture Organization

Once in the ocean, plastic breaks down into smaller particles called microplastics. These are ingested by fish, seabirds and marine mammals, from where they enter the human food chain. Microplastics may have toxic effects on humans and marine life that are not yet fully understood.

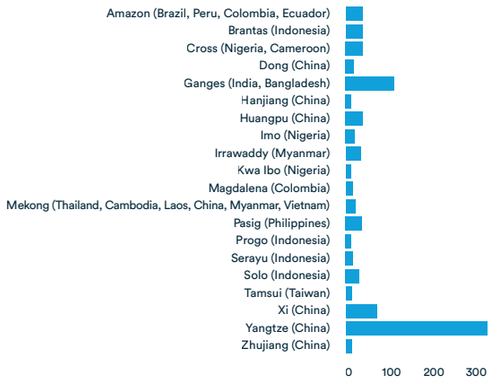
Other harms of plastic pollution are better known: the economic costs for tourism, shipping and fishing alone have been estimated at around $13 billion a year. Overfishing and climate change potentially pose even greater threats to marine life, biodiversity and the health of the oceans. Hotter and more acidic oceans will result in the loss of coral reefs, which are a keystone species for many marine ecosystems. The Intergovernmental Panel on Climate Change (IPCC) places the overall cost of unabated human effects on ocean quality at $1.9 trillion a year by 2100.

When it comes to their root causes, there is a parallel between climate change and plastic pollution. Both our oceans and atmosphere are overused, and some of this is due to a lack of what economists call ‘property rights’. With no owners, there is no clear responsibility for protection. And in the absence of prices (which an owner could charge for their use), they end up as waste-sinks for plastics and greenhouse gas emissions, respectively.

Unlike greenhouse gases, where the rich world is still responsible for most emissions, marine plastic disproportionately originates from developing countries because of fewer possibilities for recycling and more common landfill leakages, as well as illegal dumping. Policies should be targeted towards helping these countries build the capacity to recycle their plastics or store them safely.

Dirty old river

Plastic waste by river, thousand tonnes, 2015



Source: Lebreton et al, 2017

Economics explains why relying on voluntary changes in consumer behaviour alone is not going to work for either the climate or plastic problem. Individuals are tempted to ‘free-ride’ on the action of others and do not take account of the full cost of their choices. Economists use the term ‘collective action problems’ to describe this type of dilemma, notably studied by Nobel laureate Elinor Ostrom.

In some instances, appealing to social norms or nudging households towards more sustainable behaviour can be helpful. This may be especially true for some forms of plastics consumption. Promoting the use of reusable plastic bottles or shopping bags is relatively unintrusive and plays into consumer psychology: it is an easy way to signal pro-environmental attitudes and adherence to social norms, as well as creating a feeling of making an immediate impact.

But for climate change, the fact that the damage caused by our actions is so hard to see is a problem. Our choices affect people living in the future or in distant countries, yet cutting our emissions or consumption requires costly lifestyle changes. Human traits that typically support cooperation in small groups—for example, a tendency to reciprocate the good behaviour of others or punish free-riders—are far harder to sustain when it comes to global environmental problems where those who cause the damage and those harmed never meet.

We lack information too. For emissions or plastic pollution, it is hard to grasp the total environmental impact of consumer choices. Without extra information, it is almost impossible to compare the relative climate costs of two different products. Carbon pricing is a potential solution: by introducing a global carbon price, carbon-intensive goods would become relatively more expensive. All customers need to do is something with which they are already familiar: compare the prices of different products.

Carbon pricing would help with plastic pollution too, by making plastics less attractive than more sustainable materials. Their production is relatively energy-intensive and, in its conventional form, requires fossil fuels as a raw material. Plastics production in 2015 accounted for roughly 4% of global emissions. The damage from plastic would be lower if bio-based plastics replaced conventional plastics, and recycling rates were higher. These goals are supported by higher carbon prices.

Innovative technologies that help to break the link between pollution and consumption are essential if we want to preserve current living standards while saving the planet. New types of plastics—for example, polylactic acids—use raw materials like starch, which are easily derived from renewable sources such as corn or potatoes. Not only do they share some of the valuable properties of existing plastics, but they are also biodegradable, reducing their impact on marine environments. But their production is currently more expensive and requires energy that should come from renewable sources to reduce their carbon footprint.

Pricing emissions can help to speed up this innovation. The EU’s Emissions Trading System may have increased low-carbon innovation by energy firms by 10%, a recent study shows. A more ambitious approach would be to provide additional funding for basic research. Technology transfers can also be used to help developing countries avoid marine plastic pollution.

Plastic pollution garners attention. Its effects resonate with the public in a world where images are so important: clips of dolphins playing with plastic bags and turtles trapped in beer holders have become central rallying calls in anti-pollution campaigns. Solving the problem may rely on a simple piece of economics that the public will have to get used to: plastic needs a higher price ●

The second best time is now.

Richard Davies talks to Dr Jane Goodall DBE, one of the world's leading environmentalists, founder of the Jane Goodall Institute (JGI) and a United Nations Messenger of Peace.

Vincent Calmel

RD: Your projects often rely on individuals taking action. But events like COP26 are about government policies and they can leave people feeling like their choices have little impact. What can we do to convince people?

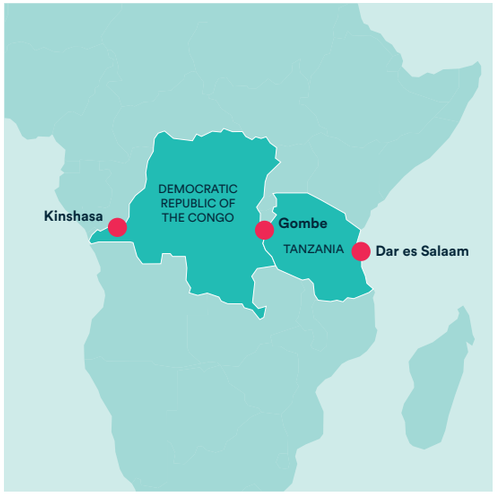
JG: Well, that is basically what I do all around the world. Of course, if it is just one individual, it makes no difference. But once you get millions of people making ethical choices about what they buy and what they wear, asking where it came from and whether it harmed the environment: that makes a difference. We work particularly with youth groups, like our organisation *Roots & Shoots*. They then influence their parents and grandparents.

And then there is consumer pressure. I was talking to the chief executive of a large company last week. They are taking major steps to go carbon neutral in two years' time. They see the writing on the wall: the natural resources that companies use won't go on forever. But it was also because of consumer pressure: when people demand that the product be made ethically, then companies either go under or they make the necessary changes.

RD: So businesses will react if you can convince shoppers. Is it better to appeal to empathy—concern about others, the environment and the animal kingdom, say—or self-interest?

JG: To change an individual's way of thinking, it is no good arguing. Yes, there are certain facts that you can present. On water, for example: levels are dropping and that is a fact, people should listen to this. But for the most part, you need to reach the heart.

I reach the heart by telling stories—stories of things that I have seen. This is the way that we create change. It is useless pointing your finger, shouting and getting angry. That either makes the person—if they are a high-up politician—pay lip service just to get rid of you; or they feel angry and think 'I'm not going to be dictated to'.



RD: You've spent a career in places where deforestation is a problem. This is often seen as both a cause of poverty and a consequence of it. What is the best solution?

JG: I realised in 1986 that chimpanzees and forests were disappearing across Africa. I flew over the tiny Gombe National Park in Tanzania—where our chimp research is in its 61st year. In the 1960s, it was part of this great equatorial forest belt, but by the 1980s, it was a tiny oasis of forest surrounded by bare hills. There were more people living there than the land could support; the land was over-farmed and infertile. They were cutting down the trees in order to survive, to grow more food to feed their families or to get some money from charcoal or timber.

So we began our 'Take Care' programme (TACARE) in the 12 villages around Gombe. It ranges from restoring and regenerating hills without the use of fertiliser, and with water management, to health and education, and family planning information. The people become partners in conservation, using smartphones to monitor the health of their forest reserves. But yes, an awful lot of deforestation is due to poverty.

RD: The area where you mention forest loss—equatorial Africa—is vast. And its countries have had a hugely diverse experience since 1960. Those in the east have grown, those in the west are among the worst performing economies on the planet. Do initiatives like yours require that the economy strengthens over time?

JG: We work in both Congos, Guinea, Senegal, Tanzania, South Africa and Uganda.

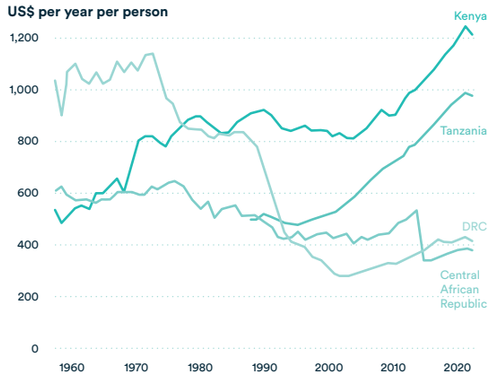
RD: Can I ask you about the Democratic Republic of the Congo (DRC) then? How does sustainability work in a country where GDP has declined so drastically? [GDP is down 60% since 1960.]

JG: We work in the very far east of the DRC. It is volatile due to the mineral wealth. But we run the same programme, and we find there isn't any difference. The people are the same on both sides of the lake. If you go to Dar es Salaam on the one hand and Kinshasa on the other, there is obviously a difference. But we are not working at the political level, we are trying to keep the illegal mining out of areas where we work. But the good news is that in both Tanzania and the DRC, we have had ministers of environment that have been part of *Roots & Shoots* as young people. They are tough, they have stood up.

Scan to find out more about the Jane Goodall Institute

East versus west

GDP per capita by country



Source: World Bank, OECD

RD: Political interest in the environment tends to ebb and flow. This autumn it is on everyone's agenda. How hopeful are you that this will lead to concrete action? Or are these big get-togethers just a photo opportunity?

JG: Unfortunately in the past, many of these big meetings have been 'talk, talk, talk' with little follow-up action. Like the Paris Agreement: it was wonderful to have everyone agreeing to a certain level of emissions control, but I don't think a single country lived up to its promise because there is no enforcement of these regulations.

But climate change is now hitting the wealthy countries, not just places like Bangladesh. The recent hurricanes and flooding in New York have been a wake-up call to everyone. The Western countries are waking up and taking notice. I am just praying that COP26 will find some way in which the commitments made by countries are followed through. It is encouraging that young people are so vocal. They are so much better informed now and are concerned about their future—and this concern rubs off.

RD: You are a COP26 Advocate. What is at the top of the list of your policy priorities? What should we see to hold politicians to account for?

JG: It is very difficult: there are so many things. We need to consider both the pandemic and the loss of biodiversity—and these are interrelated in that they are all due to our disrespect for the natural world and for animals. We caused these conditions that made it relatively easy for there to be a spillover from animals to humans, including in our factory farms.

I would want to ban industrial farming. Because it is destroying the land, it is harming people, it is devastating for biodiversity and it is killing the soil, and we depend on the soil. The environmental impact is devastating—all the animals being fed, with fossil fuels used to get the grain to them, then the animals to the slaughter and the meat to the table. Water is wasted and in some countries, it is getting scarce. And the animals create a lot of methane, a bad greenhouse gas. We need smaller farms, permaculture and agro-forestry.

We have launched a new programme recently: *Trees for Jane*. It is about responsible planting of trees and protection of existing forests. You can donate to people planting trees or to the indigenous groups protecting forests. Everybody can get involved—everybody can plant a tree. It isn't the solution to climate change, but it is *a* solution. I love the Chinese proverb that says: the best time to plant a tree is 20 years ago, the second best time is now. Planting the right tree is the key and that is what the programme is emphasising.

RD: I saw what the locals called 'The Curse of Teak' when researching my book in Panama: the government subsidised tree planting but didn't specify what should be planted. [Teak is a non-native species and kills plants and insects around it due to acid in its leaves]. Below the teak trees is ghostly dead ground.

JG: : I've seen the degradation in Panama—it is terrible. And the same in Argentina from the cattle grazing. What was rainforest becomes forest, becomes scrubland, becomes desert. The cattle will eat the young trees. And goats are even worse: they will eat anything. I never say people must become vegan, but we should move towards a plant-based diet.

RD: Thank you for your time and I hope you now get a break from dreaded Zoom calls. At least it means people are not flying as much.

JG: Yes, but there is twice the work. There is no break. No Saturday, no Sunday, no Christmas, no birthday. It is relentless! But it does mean we can reach millions more people. We started JGI and *Roots & Shoots* in India during the pandemic, and in Turkey.

RD: So there is an upside to the change in our use of technology in the past couple of years?

JG: Yes. I couldn't have done all this, no way. More and more companies are switching to video calls. Some face-to-face meetings are important of course. You have fun and you have side conversations. In fact those side conversations are the only good thing about these big meetings I think. The people you meet, that is more important than all these boring lectures and pontificating politicians [laughs]. 'Pontificating politicians' that sounds quite good doesn't it?

Scan to find out more about *Roots & Shoots*

GETTING BUSINESS TO NET ZERO.

Corporate emissions disclosures may be essential for reaching climate targets, but they should be straightforward to measure, report and verify.

/ Patrick Bolton / Marcin Kacperczyk / Christian Leuz / Gaizka Ormazabal / Stefan Reichelstein / Dirk Schoenmaker /

The drive to reduce—and ultimately eliminate—greenhouse gas emissions begins with the mundane tasks of annual measuring and reporting. Yet the vast majority of publicly listed companies around the world still do not disclose their emissions. Even fewer privately held companies do so. What's more, current voluntary disclosures lack comparability and consistency across firms.

That's why economists are increasingly coming around to the idea that mandatory corporate carbon disclosures could make an elementary but essential contribution to the global drive towards net zero. Such mandates could deliver much of what policy-makers and asset managers need to manage carbon transition risk. More importantly, they might accelerate the pace of future emissions reductions.

For this to happen, carbon reporting mandates need to be simple and straightforward—and the information must be verifiable. A common methodology for measuring and reporting emissions has been established through the International Greenhouse Gas Protocol. This comprises a firm's direct emissions from its own operations, as well as indirect emissions, which include upstream emissions from the supply chain of its production inputs and downstream emissions attributed to use of its products.

Estimation of a firm's indirect emissions is complex by its nature and therefore the articulation of comprehensive reporting standards is a time-consuming process. So we recommend a mandate that pertains only to direct carbon dioxide equivalent emissions, with the weights attributed to different greenhouse gases calculated in accordance with IPCC guidelines.

Data providers such as the Carbon Disclosure Project or Trucost have developed significant expertise in estimating emissions. In multiple jurisdictions, firms in carbon-intensive industries already report their direct emissions as part of their compliance with carbon pricing regimes. It will therefore be possible to mandate reporting of these emissions without having to wait for more comprehensive standards that institutions like the International Sustainability Standards Board will set.

So what kind of corporate carbon disclosure mandate might governments adopt at COP26? An opening formulation of this kind could work: *publicly listed firms are to report their global greenhouse gas emissions for the past calendar year in their annual reports. Private firms beyond a certain minimum size are to report their global greenhouse gas emissions for the past calendar year to a national registry in the country in which the firm is headquartered.*

Such a carbon reporting mandate is unlikely to solve the climate crisis on its own, even if globally agreed. But there is research evidence that a mere reporting requirement on past emissions spurs companies to reduce their current emissions, as they fear adverse publicity and comparisons with their peers. To achieve these effects and avoid a shift of emissions to private companies, the mandate should cover both private and public firms.

Numerous global corporations—including AstraZeneca, Microsoft and Nestlé—have recently issued voluntary net-zero targets and specified milestones on their paths towards the ultimate objective. We expect some firms to supplement their mandatory reports of annual direct emissions with forward-looking voluntary disclosures. Over time, the combination of mandatory and voluntary disclosures should provide more transparency about a firm's actual achievement of earlier targets.

The Montreal Protocol, established in 1987 to regulate the substances that deplete the ozone layer, provides an illustration of how the international community can move quickly on an agreement to implement comprehensive mandatory emissions reporting. Under this protocol, 24 governments agreed to phase out chlorofluorocarbons by 2000, thereby initiating long-term recovery of the ozone layer. Something along these lines could start at COP26

Further details are in *Mandatory corporate carbon disclosures and the path to net zero*, a Policy Insight by the authors, published by the Centre for Economic Policy Research (CEPR).

It won't cost the earth.

The price of clean energy is tumbling. Along with the potential growth boost from investment in low-carbon technologies, tackling climate change may be far less costly than expected.

/ Dimitri Zenghelis /

The economy of the future will need to be low-carbon, less reliant on fossil fuels, and put less pressure on precious natural resources such as forests and fisheries. Yet it is not clear that reducing demand—'degrowth'—is politically feasible. The good news is that it may not be economically or technologically necessary. Innovation to increase resource productivity is proceeding at pace.

Start with the challenge: a clean growth model rests on leaving some resources unused. To limit temperature rises to 2°C above pre-industrial times, a third of global oil reserves, half of gas reserves and 80% of current coal reserves will have to remain in the ground. If they are burned, any emissions will have to be captured and stored if the target is to be met.

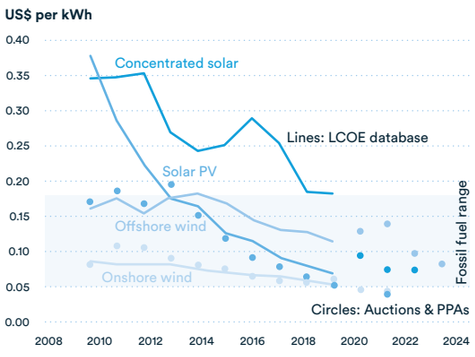
This means a transition to clean sources of energy that will inevitably affect everyone. Since the Industrial Revolution, the global economy has been powered by fossil fuels. But the costs of this structural transition could be manageable, and there are already signs that efforts to avert climate catastrophe are driving innovation.

CLEAN INNOVATION

Ten years ago, renewables and electric vehicles were seen as expensive luxuries. Since then, the price of solar photovoltaic energy has plummeted—falling by 83% since 2010. The cost of wind energy has fallen by 40%. The sun doesn't always shine and the wind doesn't always blow, but here too the news is good: the cost of lithium-ion batteries, which provide storage capacity when energy sources are intermittent, has also fallen eight-fold over this period.

Clean and cheap

Evolution of global average levelised costs of electricity (LCOE) renewable energy technologies

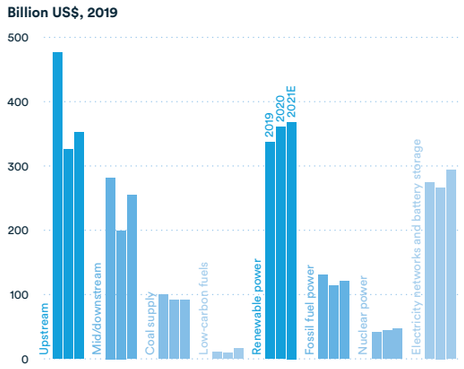


Source: Climate Change Committee (CCC), based on International Renewable Energy Agency (IRENA) data

Increasingly, these technologies are producing electricity that is cheaper than most gas- or coal-fired power plants. The world now invests more in renewable power generation (excluding nuclear and hydro) than in oil, gas and coal generation combined.

Backing green

Global energy supply investment by sector



Source: International Energy Agency (IEA)

Renewables are set to overtake coal to become the largest source of electricity generation worldwide in 2025, according to the International Energy Agency (IEA). In the vehicle sector, manufacturers have switched research and development (R&D) spending away from combustion engines. The gains ripple out. Using data on one million patents and three million citations, one study finds that productivity-enhancing spillovers to other sectors (such as information technology, robotics, healthcare and aerospace) from low-carbon innovation are over 40% greater than from conventional technologies.

International competition will matter too. As the world shifts to low-carbon, resource-efficient markets, those that fall behind on policies and investments may find that high productivity activity may move elsewhere. Research shows that it is easier for countries to become competitive in new green products that require similar production capabilities and know-how to existing sectors. This demonstrates the advantage of acting first: countries that invest in green capabilities early on have greater success in diversifying into future green product markets.

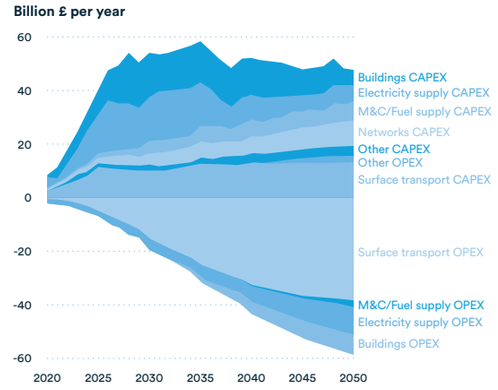
Countries should play to their strengths, research shows. Studies analysing 'revealed technological advantage' indicate where opportunities for sustainable growth and recovery might reside. For example, by comparing broad categories of technologies, the UK is relatively specialised in ocean and wind energy. A complementary study shows how returns to public investments in these technologies are also high.

CLEAN AND PRODUCTIVE

Making the transition to net zero will not be cheap. It will require substantial upfront capital expenditure in transport, energy and buildings. But before long, operational costs in most sectors are likely to fall (if they have not already) below those of fossil fuel generation.

The path to zero

Capital and investment costs and operating cost savings in the balanced net-zero pathway



Source: CCC, Sixth Carbon Budget 2021

Efficiency, by definition, saves money, and innovation boosts productivity. But there are also numerous near-term opportunities associated with tackling local air pollution (which costs 6.2% of global economic output), congestion, ill health, biodiversity loss and waste.

The IEA estimates that economic growth will be around 0.5% higher in a 1.5°C scenario compared with under present-day policies. The International Monetary Fund argues that an additional £1 in public borrowing to invest in highly productive and greener activities would generate an additional £2.70 of additional output. This investment does not prohibit growth: it will encourage it.

In line with this evidence, expectations are shifting, as indicated in a recent survey of 231 experts from G20 central banks, businesses and finance ministries. The respondents clearly stated that fiscal recovery packages focusing on sustainable infrastructure were the most likely to deliver growth. In particular, they highlighted spending on clean R&D, clean energy infrastructure, connectivity infrastructure, building upgrades, energy efficiency and investment in green spaces. There is a growing appreciation that growth is not only compatible with sustainability, but requires it—and that sustainable growth may be cheaper than many people expect

Low-hanging fruit.

As the world's second-largest emitter of greenhouse gases, the United States will inevitably play a key role in global efforts to achieve net zero. The fundamental shift in climate policy under the Biden administration is cause for optimism.

/ Lint Barrage /

Climate policy has long been politically challenging in the United States. While survey evidence suggests that public awareness of climate change has been increasing, misinformation remains widespread. According to the Yale Program on Climate Change Communication, only 57% of Americans believe that global warming is caused by human activities.

Nonetheless, there is now an unprecedented opportunity for US climate policy. According to the Pew Research Center, the share of survey respondents viewing climate change as a major threat increased from 40% in 2014 to 59% in 2018. In June 2021, a newly formed Conservative Climate Caucus in the House of Representatives acknowledged the reality of anthropogenic climate change. And many major US corporations—ranging from AT&T to IBM and Proctor & Gamble—are supporting proposals such as the bipartisan Climate Leadership Council's Carbon Dividend Plan.

Within days of taking office in early 2021, President Biden issued an Executive Order outlining broad climate policy goals. From the perspective of economics, the tried and true market-based approach yields clear 'no brainer' policy recommendations: first, a national price on carbon; second, large-scale increases in public support for clean innovation; and third, climate risk disclosure requirements. If designed properly, such a policy package could yield substantial benefits for the US economy.

One of the core advantages of a uniform national price on carbon is that it automatically provides appropriate incentives for emissions reductions across all relevant margins. But given the political challenges of implementing a carbon price, a suite of policies targeting different sectors may be required to achieve equivalent reductions. There is a growing body of research evidence on the potential (cost)-effectiveness of a range of such 'second-best' climate policies.

Some are attractive. For example, a federal clean energy standard for electricity generation can potentially achieve emissions reductions at a comparable cost to a sectoral carbon price, depending on design features such as whether natural gas receives appropriate credits. Given that the electricity sector is the most important and cost-effective decarbonisation opportunity in the country, a national clean energy standard may thus be a highly valuable option.

Current policy proposals also include several market-based instruments. For example, methane emissions fees imposed on oil and gas producers could increase economic efficiency if designed appropriately. Addressing methane leakage is especially important, as the United States has become the world's largest producer of both oil and natural gas.

The country also maintains some tax provisions favouring fossil fuel producers. On efficiency grounds, removing fossil fuel subsidies is a no brainer, and President Biden has called for their elimination via Executive Order. Other recent price-based proposals include carbon border taxes and climate royalty surcharges on fossil fuel extraction on federal lands.

Some policies may be less effective than previously thought: for example, the US Weatherization Assistance Program, the country's largest residential energy efficiency programme, fails to achieve the energy savings predicted by engineering models by a factor of 2.5. And some policies under discussion, such as bans on US natural gas production or export, might even be counter-productive.

In sum, while it will be difficult to replicate the full economic and environmental benefits of a uniform national carbon price, there are undoubtedly climate policy options that can yield substantial net benefits to society.

The challenge ahead remains large. In 1962, President Kennedy motivated the US space programme and efforts to reach the moon by noting that: 'Our leadership in science and in industry, our hopes for peace and security, our obligations to ourselves as well as others, all require us to make this effort.' If the United States can channel this sentiment into the climate challenge, it can no doubt reach extraordinary achievements

Further details are in the author's contribution to *No brainers and low-hanging fruit in national climate policy: Country-specific insights for implementing achievable and efficient climate change policies*, published by the Centre for Economic Policy Research (CEPR).

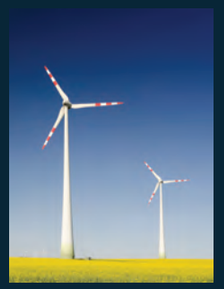
What to do next.

Twelve ways to decarbonise the UK economy

/ David Hendry / Jennifer Castle /

1. RENEWABLE ENERGY

Falling costs and increased efficiency of renewable energy from onshore and offshore wind turbines and solar cells could rapidly reduce oil and gas use in electricity production.



2. NUCLEAR POWER

Safe small modular nuclear reactors —based on the engines of nuclear submarines —can reduce reliance on fossil fuels. Their size limits many of the financial and safety risks associated with large plants and would allow them to be used in countries with smaller grids.

Canadian Nuclear Laboratories/Flickr

3. GRAPHENE NANOTUBES (GNTS)

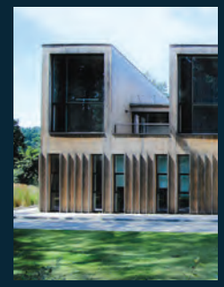
Graphene—which can be generated from food waste or plastic—may enable rapid charging for cars, trains and even planes. Fitted to an electric car, GNTs may allow the vehicle itself to become the battery.

4. A CONNECTED INTELLIGENT GRID

Plugging electric vehicles into an intelligent network would enable a vast electric storage system with cars acting as part of the National Grid's storage.

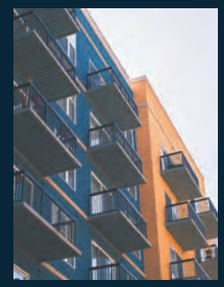
5. SUSTAINABLE HOUSING

Subsidies would encourage installation of solar panels and air or hybrid heat pumps. Higher taxes on natural gas and oil use—such as higher VAT on household fuel, which could be redistributed to families facing fuel poverty —would also change behaviour.



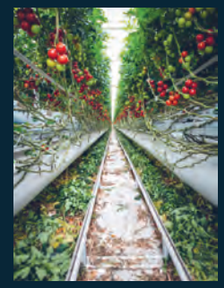
6. ENVIRONMENTAL CONSTRUCTION

Prefabrication of highly insulated dwellings using less greenhouse gas-intensive building materials must be a priority. Retrofitting insulation to 25-30 million homes would be expensive but is less crucial if renewable power is used.



7. GREEN CITIES

Inner-city underground and vertical farms economise on water, fertiliser and energy —partly from transport reductions—and are increasingly viable given cost reductions for LED lighting. Additional tree planting can also help to reduce carbon and pollution in the atmosphere.



8. REDUCE, REUSE, RECYCLE

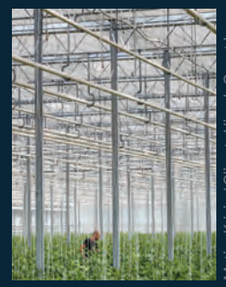
Promoting environmental behaviour—including expanding recycling, switching to more plant-based diets and reducing landfill—is essential.

9. ECO-FARMING

Altering farm-mammal diets—such as adding dietary fumaric acid (from plants like lichen and Iceland moss) —can reduce methane emissions. Replacing artificial fertiliser with biochar and basalt dust will also boost carbon sequestration.

10. CARBON CAPTURE AND STORAGE (CCS)

CCS, possibly combined with atmospheric carbon extraction methods, must remove remaining greenhouse gas emissions. Major technological change—involving development of artificial photosynthesis and removing or reusing existing carbon as a fuel or chemical feedstock —will be required.



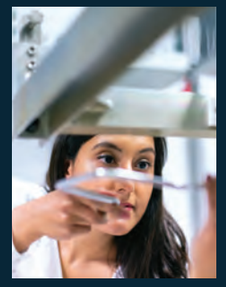
Matjaz Krivic / Climate Visuals Countdown

11. TRACKING EMISSIONS

Imposing border carbon taxes can improve the performance of both exporters and importers. Targeting production rather than consumption emissions incentivises emitting industries or exporting countries to improve their performance.

12. FINANCING AND JOBS

All these initiatives require public funding for research and prizes to galvanise innovation. Investments —for example, in a fast intelligent grid—will lead to cheaper power. While minimising stranded assets, attention must be paid to the costs of lost jobs and mitigating inequality.



Time for a new model?

Carbon efficiency is improving, but far too slowly to offset climate change. One option is to consider lower rates of economic growth.

/ Tim Jackson /

Aulia Erlangga

When the Club of Rome published *Limits to Growth* in 1972, the economist Kenneth Boulding remarked to the US Congress that 'anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist'. At first, it seems like a disparaging reflection on his own profession. But beneath Boulding's irony lies an important insight into what Greta Thunberg more recently called the 'fairytales of eternal economic growth'.

As global leaders gather in Glasgow to work out how to meet the commitments of the 2015 Paris Agreement, the underlying growth-based economic model has come under renewed scrutiny. Many will push back on this, but the raw numbers of climate change show why we need engagement at the highest level on post-growth economics.

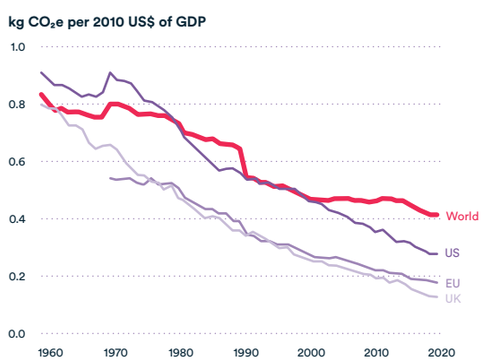
First off, it's worth noting that when economists contend that growth can go on forever, it's because their preferred measure of growth—gross domestic product or GDP—is often measured in monetary rather than in material terms. Carbon emissions and economic growth are separable, on this view. By 'decoupling' one from the other, we ought to be able to escape the finite limits that nature seems to impose.

It is vital to distinguish here between relative and absolute decoupling. The former refers to a decline in the carbon intensity of economic output. The latter to an absolute fall in carbon emissions that continues even when output rises. Put simply, relative decoupling is about doing things more efficiently. And since efficiency is one of the things that capitalism is supposed to be good at, decoupling has a familiar logic and a clear appeal to those hoping growth can continue indefinitely.

It's easy to find evidence for relative decoupling, even at the global level. For instance, the carbon intensity of the global economy fell from about 760 grams of carbon dioxide per dollar ($gCO_2/\$$) in 1965 to less than 500 $gCO_2/\$$ today, a decline of 35% in little over half a century.

Greener growth

Emissions intensity of GDP



Source: World Bank Development Indicators

But relative decoupling is barely half the story. For efficiency to lead to an absolute fall in emissions, the carbon intensity of the economy must decline faster than economic output rises. What's more, if the economy continues to grow forever, then efficiency must outpace growth indefinitely. And it must do so fast enough to reach net zero before time runs out to keep global temperatures below 1.5°C or even 2°C above the pre-industrial average.

The evidence for that possibility isn't compelling. The fastest efficiency gains the advanced economies ever made was an average decline in carbon intensity of around 3%. That happened in the years immediately following the oil crises of the 1970s. Today, the rate of decline is barely 1% each year. This is far below the 14% that is needed to avoid runaway climate change.

In the meantime, global carbon emissions are more than three times higher today than they were in 1965 despite the efficiency improvements since then. Efficiency moved on. But scale outran it. And now we find ourselves running out of time to ensure a liveable climate for our children.

A recently leaked draft report from Working Group III of the IPCC's sixth assessment supports this view. The paper acknowledges that there is little or no room for further economic growth and even suggests that we need to move away from the current capitalist model of economics.

There's no doubt that's a scary proposition. Only a few economists—and even fewer politicians—have challenged the primacy of economic growth. Fewer still have begun to think about how a post-growth economics would work. We've been so convinced that growth can go on forever that we've built almost all of our financial and political institutions around that assumption.

But being frightened to scare the horses is no way to win the race against climate change. Einstein had a different definition of madness from Boulding. Insanity, he said, was doing the same thing over and over and expecting a different outcome. So perhaps it's time to put post-growth economics at the heart of the COP26 negotiations ●

Scan to read other ECO articles on energy and climate change

PROMISES KEPT?

Most countries have signed up to at least one of the three big international climate change agreements to date, but adherence to targets has been mixed. Greater ambition and stricter compliance will be essential.

/ Silvana Tenreyro / Tiloka de Silva /

In response to the threat from rising emissions of greenhouse gases, there have so far been three international agreements promising countervailing action: the Kyoto Protocol of 1997; the Copenhagen Accord of 2009; and the Paris Agreement of 2015. What climate targets were pledged? Have any been met? And which of the wide variety of measures adopted are proving most effective for cutting emissions?

The pledges in each of the treaties differ in the coverage, timelines and targets set by the various signatories. Moreover, in working towards their targets, countries have resorted to different policies and laws over time. And each comes from its unique history of previous contributions to the more than doubling of total global emissions over the past half-century.

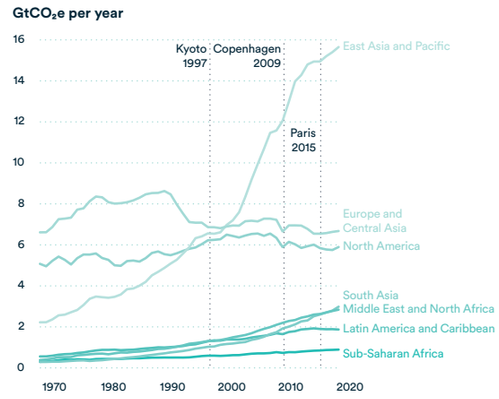
Trends in emissions are tightly associated with economic activity and population growth. In absolute levels, the top emitters since the 1970s have been China, the United States, Russia, Japan, Germany and Canada, with Saudi Arabia, South Korea, India and Iran joining the list more recently. Among these, six are also in the top-ten list of oil-producing nations. Other oil producers also record very high per capita emissions, but make smaller contributions to total emissions.

Emissions from North America and Europe, which were the largest emitting regions until the 1990s, seem to have stabilised in the following decade and a half, and are gradually declining, albeit from high levels. Emissions from elsewhere in the world have been increasing, particularly in East Asia and notably China. Sub-Saharan Africa remains the region with the lowest total emissions. Emissions from the Middle East (the largest oil-producing region in the world) remain at a lower level than in the West or in East Asia.

But per capita emissions remain highest by far in North America, followed by Europe and Central Asia. These regions show a gradual decline since the 2000s. In contrast, East Asia and the Middle East seem to be converging upwards to the European level.

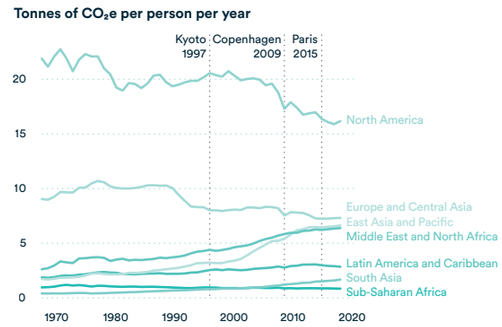
Passing the baton

CO_2 emissions by region



Source: Tenreyro and de Silva, 2021

CO_2 emissions per capita by region



Source: Tenreyro and de Silva, 2021

Since the first international agreement on climate change, compliance with emissions-reduction targets has been mixed, with many countries undershooting what they have promised to achieve. Relatively few countries overshot targets to reduce emissions. Nevertheless, signing the Kyoto Protocol or the Copenhagen Accord has led to significant reductions in emissions, when compared with those countries that did not sign the treaties. In contrast, signing the Paris Agreement does not appear to have led to any significant reduction in emissions yet.

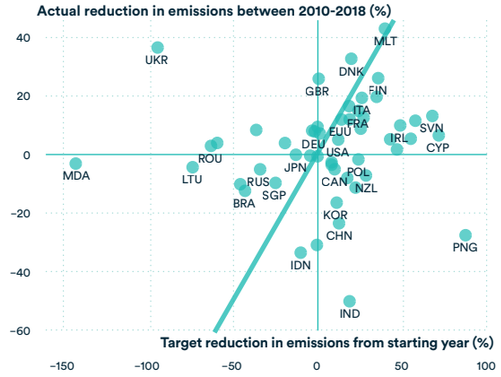
When examining success by country, there is wide variation in both the ambition and achievement of targets. For example, with the Copenhagen Accord, which specified targets for 2020, 21 of the countries in the chart had reached or exceeded the targeted reduction (those to the left of the 45 degree line) by 2018, while 35 had not (although countries close to the 45 degree line are those that were reasonably close to achieving their targets).

The vast majority of countries that had already achieved their targets by 2018 were those that specified an increase in emissions from the starting year of 2010 (in the official pledges, many countries continued to specify their baseline year as 1990 under the Copenhagen Accord), with only a few countries, such as Denmark and Malta, having achieved more ambitious targets.

Germany, Japan and Russia were the only countries among the top-ten emitters that had already achieved their target level of emissions as of 2018. It is conceivable that with the pandemic and the implied reduction in emissions caused by lower activity, many more countries would have met the targets.

The best laid plans

Planned and actual reductions in emissions



Source: Tenreyro and de Silva, 2021
Note: Negative values represent an emissions increase

Having quantifiable objectives certainly seems to have helped in reducing emissions. And of all climate-related measures enacted, two stand out as having had a material impact on emissions reduction: the introduction of carbon taxes and emissions-trading schemes.

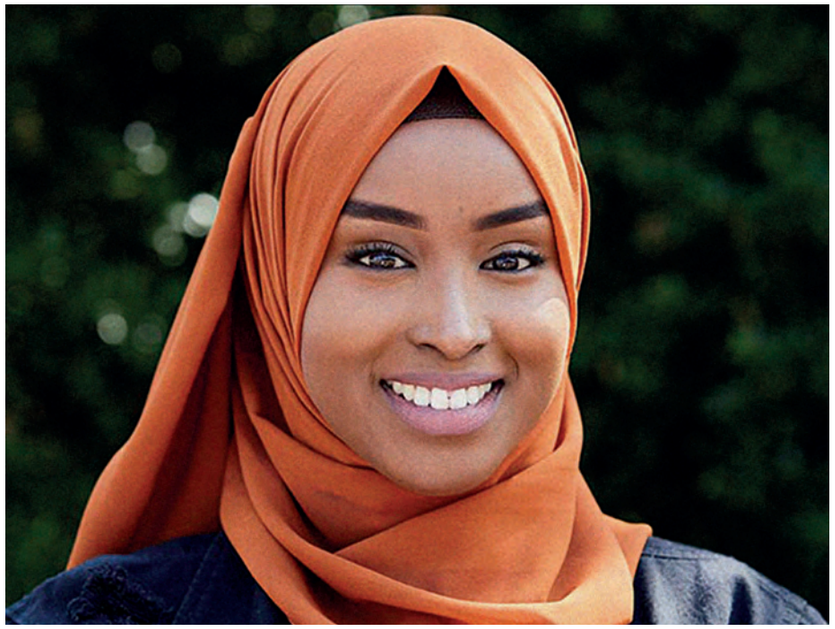
A few other specific climate-related laws or policies appear to have quantitatively small effects on emissions. But the number of climate-related laws is associated with significant reductions in greenhouse gas emissions. The effects on GDP growth and inflation from these measures are largely insignificant.

Overall, it is clear that much more ambitious targets and stricter compliance will be needed to offset the large impact of economic and population growth on the flow of emissions and to contain a damaging further expansion in the stock of greenhouse gases

Scan to read other ECO articles on energy and climate change

Sustainability and social justice.

Ashley Lait talks to Zamzam Ibrahim, a vice-president of the European Students' Union and co-founder of Students Organising for Sustainability UK.



AL: How has your experience as a student informed your work on the environment?
ZI: I first got involved during my time working for the National Union of Students, as sustainability fell under my remit. I remember feeling like the way that sustainability was spoken about didn't translate to me as a young black girl from a low socio-economic background.

Environmental campaigning was presented to me as something that privileged individuals do. But I had a conversation with a friend who said: 'if you can't relate to how sustainability is currently framed, reframe it and make it relatable'. That's when I started thinking about it differently and wondering what I could do to address the concerns that I have and how they intersect with the climate crisis.

A lot of environmental work is presented as a feel-good campaign and something we engage with out of guilt or self-importance. But we have a role in reframing the way it's spoken about.

It's not all about polar bears or saving trees: it's also about saving lives and livelihoods. When I saw it through the lens of human rights, I realised that it does affect me and that there was a lot I could do.

AL: The climate crisis is also a socio-economic and racial justice issue. Do you think one can be addressed without the others?
ZI: To share a personal story: I've experienced racism and watched my parents struggle to be able to provide and give me opportunities, like going to university. I didn't feel safe walking down my street to college. My everyday reality as a young person is living in crisis.

If you're just trying to get by, donating your time to a green organisation or to plant a tree is a privilege. I felt like I had bigger worries, so many of the campaigns around greening the environment didn't translate to my life. Even the knowledge and the political language that's used—like net zero or carbon footprint—isn't often accessible. I didn't have a clue what those terms meant when I was at school. Political education and being able to express yourself in this area is a privilege in itself.

One of the first Black Lives Matter protests in the UK that I remember hearing about was when they occupied London City Airport to counter its expansion. This highlighted the direct impacts of the climate crisis here in the UK, and how it's affecting people who look like me and have the same experience as me in the neighbourhoods near the airport. It brought it a lot closer to home.

There are other examples of how the climate crisis and systemic racism are quite literally intertwined. When we say we have ten years before places are underwater, in reality what that means is ten years until it hits the Global North. But it will be much sooner in places like Bangladesh.

People in the Global South have had the least impact on the situation we find ourselves in today but are seen as less valuable. It's a colonial mindset that many still follow, and it's our role to hold them accountable and make sure it's recognised as a global crisis that needs global solutions. I think a lot of climate activists, especially younger ones, have a better understanding of these racial inequalities.

AL: Young people have been at the forefront of campaigning on environmental issues. What is your hope for your organisation and student campaigning?
ZI: I think young people have a much more critical view than their parents or environmentalists that came before them. To give an example, the UK climate strikers at the peak of organising were campaigning every Friday and then the announcement came about the UK's new points-based immigration system. Immediately, the campaign message changed to focus on migrants and the link to climate migrants.

It's a real understanding of how all these issues are intertwined and the role we play in advocating for change. *Fridays for Future* was about campaigning on the climate crisis, but shifted to migration as those involved understood the links.

AL: There are often difficult balances to strike between lower growth and jobs around the world. How has your experience as a student campaigner shaped how you think about policy?
ZI: There is always nuance around the right way to do things. I've come to understand and respect different viewpoints. But to me, it's always clear that we have to be prepared to take the hard route if we're serious about addressing injustices. Making small changes won't make an impact. If we're not putting people over profit, we're going to remain on the bad path we're on.

In the short term, making changes does have an impact on economies but it can even out over the long term. That is how change is implemented. As humans, we're creatures of habit: we continue how things are even if it disadvantages us because we can't see anything different.

For example, in the space of just a few years, students went from paying no tuition fees to £9,000. Now if you talk to students, they can't imagine *not* paying for university. But it wasn't always like that. If something is normalised, it's just the way you've known it.

It will take brave people facing resistance to be able to make changes, knowing that in the long term there is going to be a better outcome.

AL: You've spoken about the need for young people to develop transferable skills so that they can be agile in their approach to work. How might that be achieved?
ZI: What work looks like today will be very different in a couple of years. But our education system hasn't changed sufficiently, which is a problem. We need systems that are agile. The ability to unlearn and relearn different knowledge and skills as we move through our working lives is important.

As a society, the way we come out of crises is by retraining people. Some jobs will be obsolete so people will need to relearn to provide for themselves and serve society. Building this into education is essential.

AL: Finally, if you could implement one policy to turn the tide on climate change, what would you choose?
ZI: It wouldn't be one policy. I would reallocate the budget to focus on environmental issues: to create green jobs, invest in individuals and communities to enable them to reform and subsidise access to renewable energy. I would invest heavily in green initiatives ●

Scan to find out more about SOS-UK

East side story.

Emissions released centuries ago explain why parts of cities like London, Paris and New York remain deprived today. The history of pollution offers important lessons for modern policy-making.

/ Stephan Heblich /

Classic accounts of poverty and hardship come from the east side of the metropolitan and industrialised cities of London, Paris and New York. Many have recently become the focus of media attention as a result of rapid gentrification. But why were eastern neighbourhoods poorer, and why did some gentrify while others didn't? The explanation lies in the air pollution emitted by the coal-burning factories of the industrial era.

THE RISE OF POLLUTION

Economic development and per capita growth took off with the Industrial Revolution as production moved from homes to factories, and new energy sources—first water, then coal—were powering the engines of growth day and night.

During this time, large industrial towns such as Manchester experienced unprecedented levels of growth, which sadly came with equally high social costs.

Workers were forced to live and work under terrible conditions, and cities experienced a steep rise in air pollution from the ever-growing number of coal-fired factories and furnaces.

In Manchester, the number of factory chimneys increased from 500 in the 1840s to around 2,000 at the end of the century. In line with this, there was a steep rise in total coal consumption during the 19th century. Charles Dickens captured it in his 1852 serial, *Bleak House*: **'Smoke lowering down from chimney-pots, making a soft black drizzle, with flakes of soot in it as big as full-grown snowflakes—gone into mourning, one might imagine, for the death of the sun.'**

These conditions were bad for health. It's estimated that industrial coal use in Britain over the decade 1851-60 explains about one-third of a phenomenon called the 'urban mortality penalty'—the extent to which city dwellers die earlier in life than those in the countryside. Children under the age of five were the most affected.

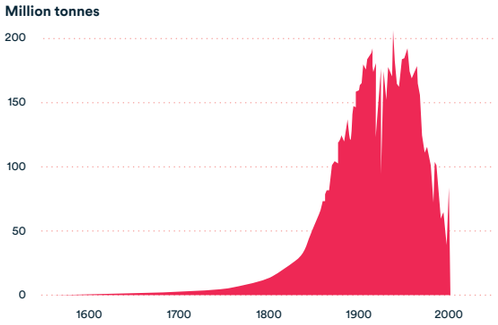
Today the risks are understood. But in the early days of industrialisation, chimneys that were not smoking caused more fear: closed factories would bring hunger and starvation. 'What cannot be cured must be endured, without grumbling, for it is the lesser evil than putting out the furnaces and fires', was the pragmatic conclusion drawn by William Nicholson, Chief Smoke Inspector in Sheffield.

THE FALL OF POLLUTION

With time and growing incomes, the willingness to accept skies darkened by coal smoke declined. When yet another London fog event trapped coal smoke in the city in 1952, killing nearly 4,000, it accelerated the introduction of limits on air pollution, with the UK's first Clean Air Act introduced in 1956—banning coal-fired plants from city centres—supported by a second Act in 1968.

The rise and fall

Coal consumption, 1750-2000



Source: Heblich, based on Warde, 2007

Since this time, many other countries have adopted clean air laws. Initially, most sought to reduce airborne particulates and other pollutants, including ozone and sulphur dioxide. As a side effect, these regulations—the banning of coal-burning plants, for example—have helped hold back the growth of greenhouse gas emissions.

Still, atmospheric carbon dioxide has shot up: from 280 parts per million (ppm) in the mid-1700s to 410ppm in 2019, a 40% increase. This is the result of 1.5 trillion tonnes of emissions, nearly half of which has been from the United States (25%) and Europe (22%).

THE LONG SHADOWS OF HISTORICAL POLLUTION

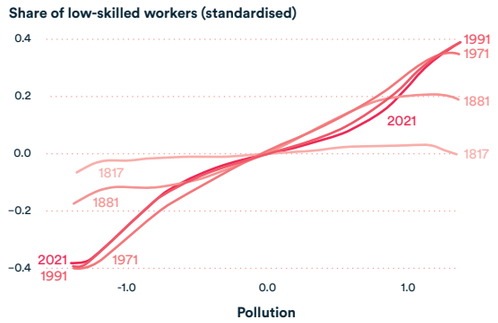
The chimneys of Victorian England were short and the coal was burned at a lower temperature. As a result, pollution was local and unevenly spread. The prevailing winds—the 'westerlies', which blow from west to east—influenced where people lived. The eastern Mancunian neighbourhood of Ancoats was far more polluted than contemporary Beijing, while others like Davyhulme were below modern pollution limits.

Neighbourhoods sorted along income lines, with rich and skilled people moving to the less polluted west side of cities and poorer low-skilled workers living in the eastern parts. The impact can be seen more than a century later: the share of low-skilled workers in eastern and western city districts in 2011 are comparable to those at the end of the 19th century.

The persistence of this segregation is puzzling. One explanation is an idea known as 'tipping dynamics'. Past a certain threshold, a poor neighbourhood repels richer residents even when the original negative characteristics—for example, pollution—have long waned. Problems including lack of work opportunities, poor schools, higher crime rates and low-quality housing exacerbate this phenomenon. In some cities—Chicago is an example—these effects may literally be cemented by highways that impose a physical barrier between eastern and western parts.

Clean house, dirty house

Pollution and shares of low-skilled workers across neighbourhoods and time



Source: Heblich et al, 2021

WHAT IMPLICATIONS DO THESE FINDINGS HOLD FOR URBAN POLICIES TODAY?

History offers lessons for both developing and developed countries. In countries like China and India, air pollution presents a major challenge. The experience of Britain's industrialisation echoes today and offers a warning to policy-makers in Beijing and New Delhi.

Many developed nations use urban planning to support deprived areas, via new housing and business investment. England illustrates the remarkable stickiness of history, and shows why plans—the development of East London for the 2012 Olympic Games is one example—need to be bold and well-funded in order to succeed●

Making green growth fair.

Environmental policies like carbon taxes can hurt poor households and small businesses. Careful policy design can transform a trade-off into a double dividend.

/ Cristina Peñasco / Laura Diaz Anadon / Elena Verdolini /

Unabated climate change will not only damage our natural world, but also have a significant effect on the global economy. Inaction is therefore not an option. But will inequality grow because of decarbonisation policies? And if so, can the negative effects somehow be offset?

TRADE-OFFS

Inequality poses a real risk. If decarbonisation policies are perceived to be unfair or lead to job losses, they will lose public support. This could delay action, which scientific evidence suggests we cannot afford.

Inequality can take many forms. A policy may have different effects on individuals or families with different income levels or across regions. Studies have explored the impact on consumers (their spending on energy as a percentage of total expenditure) and the differences in the ability of large and small firms (including renewable energy producers of various sizes) to thrive under a range of policies. Age too is an important yardstick: policies may affect intergenerational equity. Internationally, energy transition may affect countries at different levels of development.

This body of research suggests that decarbonisation policies can push up inequality in the short and medium term. In particular, policies—including carbon taxes—that support the deployment of renewable energy can result in higher energy prices. This puts a disproportionate burden on poorer households.

Offsetting the downsides, these policies stimulate innovation, allowing firms to gain experience and exploit economies of scale. This has led to big cost efficiencies that now make renewable electricity the cheapest option in most places.

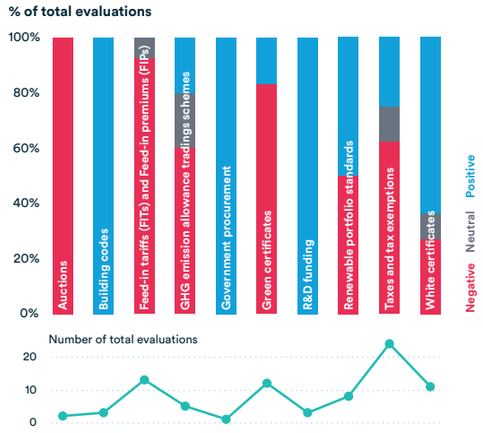
Ten examples include:

- **Building codes:** Mandatory standards or obligations for building energy efficiency.
- **Procurement:** Purchase of green and sustainable goods or services by government and the wider public sector.
- **Taxes:** Carbon or energy taxes that increase the price of fossil-based energy.
- **Certificates:** White certificates indicating energy savings, which can be traded between regulated firms to achieve government-set energy saving obligations.
- **Quotas:** Renewable energy quotas that energy suppliers are required to have by national, regional or local governments.
- **Auctions:** Competitive energy markets in which developers bid for the installation or generation of electricity using a specific technology.
- **Trading schemes:** A cap on emissions that regulated industries can either meet directly or cover through the purchase of permits from more efficient firms.
- **Investment:** Public funding for research and development (R&D) that supports innovation in low-carbon technologies.
- **Subsidies:** Guaranteeing the price for the purchase of electricity (usually above the market price) from renewable energy sources for a specific period —for example, feed-in tariffs.
- **Green certificates:** Certificates that represent the generation of one unit of renewable energy and which firms can use to meet the obligations.

The implications for inequality vary by policy. Tradable green certificates (TGCs), taxes and feed-in tariffs are most consistently associated with increased inequality —they all lead to higher retail electricity prices.

Who bears the cost?

Percentage of impacts on distributional outcomes by policy instrument type

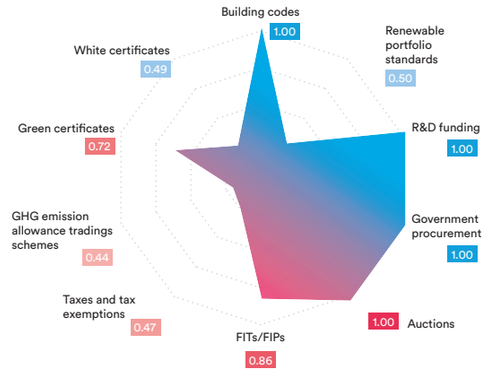


Source: Peñasco et al, 2021
Note: Positive impact (blue), no impact (grey), negative impact (red)

The evidence for consumers shows why it is important to track both the results of studies, and the degree of certainty among researchers. The body of evidence varies by policy (turquoise line): for some levers, there is a rich evidence base, while for others it is sparse. The level of agreement between researchers also varies. For some areas, policy evaluations yield consistent results; in others, results are mixed or inconclusive. The higher the value, the more consistent the evidence of either negative distributional impacts (red) or positive distributional impacts (blue).

Incomplete agreement

Agreement indicator and distributional impacts of ten policy instruments



Source: Peñasco et al, 2021
Note: Blue indicates primarily positive impacts and red primarily negative impacts. The boxes indicate the level of agreement, with 0.33 referring to full disagreement across the studies (half of the studies report positive impacts and the other half negative impacts) and 1.00 full agreement (all studies report impacts in the same direction).

Energy producers of different sizes can be helped or hampered by green policies. TGCs and auctions can also negatively affect small and new energy producers, including wind or solar farm project developers or local utilities. Evidence on renewable portfolio standards is inconclusive. Several analyses find that independent developers are disadvantaged compared with large vertically integrated companies.

Geography matters too. Environmental taxes can have greater negative effects in rural areas where travel distances and lack of public transport mean higher fuel bills. Some studies show that local air pollution taxes—for example, on nitrogen dioxide and sulphur dioxide, both by-products of burning fossil fuels—are fairer than carbon taxes.

Building regulations emerge as equitable policies. This is because poorer households have not disproportionately borne the cost of capital projects or, if they do, they have been compensated through other channels. White certificate schemes have been similar, with the cost burden distributed across society, including energy companies and governments.

There are important gaps in our knowledge. First, the evidence on procurement and R&D is too limited to draw strong conclusions. Second, most research focuses on OECD countries and some large emerging economies (mainly China and Brazil). Third, studies do not consider all the possible impacts of decarbonisation policies—for example, the health costs of air pollution and the damage associated with biodiversity losses are often missing. Fourth, much research focuses on whether certain vulnerable groups have, on some metric, been made worse off. Ultimately, a full analysis across all groups is needed.

Taken together, the evidence shows that some decarbonisation policies can raise prices for consumers and have uneven effects on firms of different sizes. Public opposition to such taxes is a possibility, and will be stronger when the measures are seen as a way to increase government revenues rather than to fight climate change.

To avoid this perception and offset inequality concerns, revenues can be recycled: used to provide social benefits or in-work tax credits for low-income households. The result then would be to stimulate employment and reduce emissions. Careful policy design can transform a problematic trade-off between the environment and inequality into a double dividend ●

Scan to read other ECO articles on inequality and poverty

DIRTY WORK.

High temperatures and increased air pollution affect workers' ability to do their jobs and can limit the hours they work. Productivity will take a further hit if these events become more frequent with climate change.

/ Matthew Neidell /

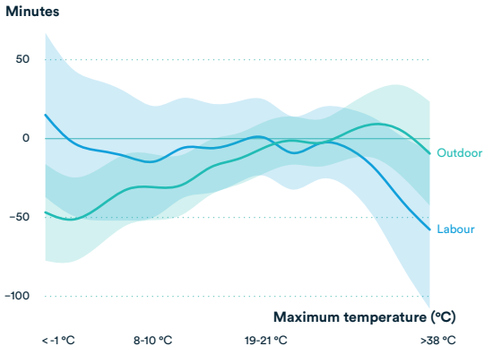
Among the vast number of detrimental effects a warmer planet may have, one that has received less attention is the impact on worker productivity. But the link is important: exposure to hotter temperatures has negative effects on human health, resulting in an unhealthy workforce.

The impact may be strong enough that people don't turn up to work. In other cases, workers may show up but—akin to heading into the office with a cold—will be less productive than when they feel well.

Workers in industries that are regularly exposed to the heat—examples include agriculture, landscaping and construction—reduce the number of hours they work when daily maximum temperatures exceed 32°C. This decrease largely comes from workers going home early. Poor air quality also tends to impair worker productivity.

Heat and time

Hours worked at different temperatures, high-risk industries



Source: Zivin and Neidell, 2021

There are many knock-on effects. Productivity increases are a pre-requisite for higher wages (although they don't guarantee them). By contrast, lower productivity may harm firms' profitability: costs rise as air conditioners are installed; those unable to pay find it hard to hire workers. The costs of operating a business rise, leading to lower growth and higher inflation.

Understanding this is an important corrective. Many argue against climate change policies because they fear that any regulations will be a drag on the economy. While there is certainly some truth to the notion that intervening may slow the rate of growth, so too will doing nothing. Climate change, if left unchecked, will be a drag on the economy as well

INCLUSIVE ACTION.

Low-income countries and their communities are disproportionately affected by climate change. Amplifying their voices is vital to ensure a just and equal transition to a low-carbon economy.

/ Mya-Rose Craig /

Climate change and inequality are linked. People in low-income countries are around five times more likely than people in high-income countries to be displaced by weather disasters—and gender, racial and economic inequalities mean that marginalised communities are most affected by the climate crisis.

As a British-Bangladeshi woman, climate breakdown is not some vague future concept, but something real and dangerous happening today. My family in Bangladesh are living in a country that is already facing the worst effects of it, with millions of climate refugees in Dhaka. Our village, Bashia Kowri, near Pataria, Sunamganj, has had terrible storms causing early flooding that wiped out rice crops. As well as flooding, the country is affected by non-seasonal droughts and increased typhoons.

By 2060, it is predicted there will be up to one billion climate refugees worldwide. The majority of these will be from low-income countries with few resources to support the internally displaced. This disproportionate impact highlights the importance of preventing the offshoring of emissions to less well-off countries.

I have been campaigning about environmental issues and climate change since the age of 11, with the belief that people must be at the centre of our approach to climate action. While climate change has become the issue of a generation, environmentalists of colour and indigenous people are often left out of the narrative despite their communities being disproportionately affected by the climate catastrophe.

Oliver Edwards Photography

After speaking to 30 young campaigners from indigenous communities and communities of colour experiencing the stark reality of our changing planet for my book, *We Have a Dream*, it was evident how climate change is affecting them in their daily lives. They have to fight for clean drinking water. They have to stand up to oil companies trying to take their land. They have been aware of these issues and have been fighting for them since they were young children. This means that they are the first and most directly affected by shifts in the natural order—and should be at the forefront of the decision-making process.

Indigenous communities have also long had sustainable lifestyles and as a result are often the most engaged with our ecosystems. As global leaders gather in Glasgow for COP26, they should learn from these communities and pursue nature-positive policies that go 'high nature and low carbon'. This may offer a credible path to tackle the twin crises of biodiversity and climate change together.

Stopping climate change is an essential part of reducing injustice and inequality in our world, but achieving a just transition requires that we include all people who are affected

KING COAL.

Coal played a key role in the Industrial Revolution, but the air pollution it created eventually acted as a drag on economic growth. There are lessons for the energy transition we seek to achieve today.

/ John Turner /

Coalbrookdale by Night, Philip de Loutherberg, 1801

Coalbrookedale, a small village in Shropshire, has been called the cradle of the Industrial Revolution. It was here in 1709 that Abraham Darby discovered how to smelt iron ore using coke, a purified form of coal that burns hotter and cleaner.

The discovery transformed the making of iron, with annual production in Britain growing from 2,500 tonnes a year in the 1700s to 28,000 by the 1750s, 180,000 in 1800 and 2.5 million by 1850. This scale of production would not have been possible without coal. Crucially, iron enabled the building of bridges, the country's extensive rail network and the machinery that would power cotton factories, steamships and locomotives.

As well as its metallurgical uses, coal was increasingly used during the Industrial Revolution as a source of power. The heat energy it created was transformed into mechanical energy thanks to the development of the steam engine.

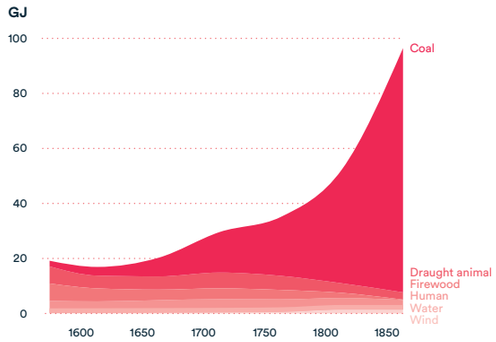
Somewhat ironically, the first steam engine, which was developed by Thomas Newcomen in 1712, was made to pump water from coal mines. Flooding meant that mines could not go below 50 metres, but the development of the Newcomen steam engine allowed mine shafts to be a lot deeper and thus substantially increased the supply of coal.

Steam engines were eventually developed for other purposes, most famously by James Watt in 1763. Although the technology was relatively slow to diffuse across other industries, by 1870, steam power was providing 90% of the horsepower for British industry. The famous French engineer Émile Levassor estimated that one horsepower provided by a steam engine was equivalent to that delivered by 21 manual workers. This means that by 1870, steam was delivering the equivalent power of 43 million people.

As a result, coal rose as an energy source relative to other sources. By 1700, it was a major source of energy for the country, but over the next 150 years it became the dominant one. Coal's dominance lasted until the 1950s, when oil and natural gas began to replace it. By 2000, coal supplied only 19% of the country's energy, with oil and natural gas supplying around 31% and 40% respectively.

The rise of the king

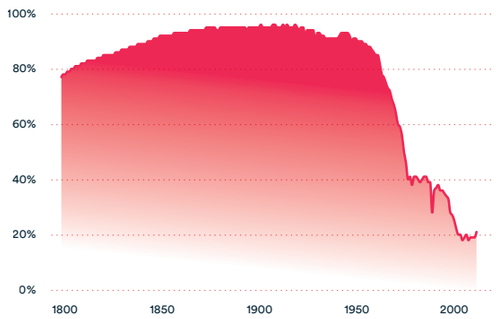
Annual energy consumption per head in England and Wales, 1561-1859



Source: Wrigley, 2013

Switching off coal

Coal's share of energy consumption in England and Wales, 1800-2006



Source: Warde, 2007

POLLUTION AND GROWTH

Coal smoke has long been considered detrimental to health. For example, John Evelyn, a diarist, published a pamphlet in 1661 entitled *Fumifugium,* which is considered one of the first works on air pollution. By the 1830s, social reformers were increasingly concerned about the conditions in which the urban working classes had to live—squalor, over-crowding and pollution from the burning of coal.

Air pollution had major negative consequences for infant mortality and child development. Analysis of data on the heights of soldiers who enlisted during the First World War and who had been born in England and Wales during the 1890s reveals the extent of the detrimental effect on children's growth.

Another study suggests that the effects of coal pollution on quality of life were trivial. This argument is based on the fact that people voted with their feet and moved into these urban areas, and that workers did not need much of a premium to move into a polluted urban setting for work. In this sense, the costs of regulatory attempts to tackle the negative effects of coal use during the Industrial Revolution would have fallen disproportionately on the working classes.

But research has also explored how air pollution from coal affected long-run city growth between 1851 and 1911. Exploiting the facts that air pollution was high and highly variable across Britain, this research finds that industrial use of coal had a major negative effect on employment growth in cities.

The effect may have come through two channels. First, pollution makes a city less attractive to live in and thus affects the supply of workers. Second, pollution makes workers less productive, thus affecting the demand for them.

LESSONS FOR TODAY

Coal played a role in the transformation of the British and European economies during the Industrial Revolution. This transformation ushered in economic growth and a substantial rise in living standards. But the air pollution that accompanied this revolution affected both mortality and health, and eventually slowed down growth.

As countries around the world seek to decarbonise, there are at least two lessons from the energy and industrial revolutions that coal underpinned. First, there needs to be recognition that fossil fuels both transformed economies and improved people's living standards. This implies that as developing economies seek to catch up with the rich world, fossil fuels will continue to play a central role unless there is a great leap forward in renewable technologies.

Second, the knock-on effects associated with the burning of coal placed a restraint on growth. Climate change will do the same.

The British government acted late in the day to deal with coal pollution because of its adherence to laissez-faire ideology. But even a more pragmatic government would have struggled to prevent the working classes from bearing the costs of regulation. As countries move away from fossil fuels, care needs to be taken that such costs are not disproportionately borne by the poor●

The public purse under pressure.

Beating global warming will require significant public investment, but climate change makes this harder by pushing up countries' borrowing costs.

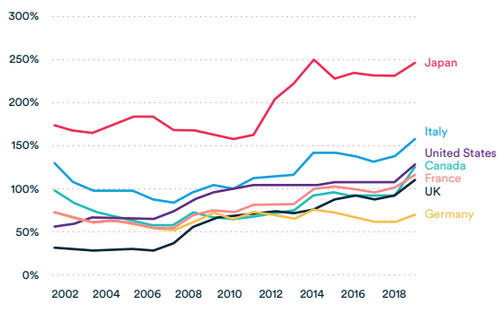
/ Matthew Agarwala / Patrycja Klusak /

Climate change will affect every element of the global financial system. With Covid-19 pushing global public debt to record levels, a key concern is how climate change will affect the state's fiscal options—the balance of spending, taxes and borrowing—and how this will affect nations' ability to respond to future crises.

Issuing bonds is the primary way that central governments borrow money. This public debt has been used extensively to deal with economic shocks including the global financial crisis of 2007-09 and the pandemic. Globally, public debt is expected to reach $92 trillion by the end of 2021.

A rising tide

G7 government debt, percentage of GDP



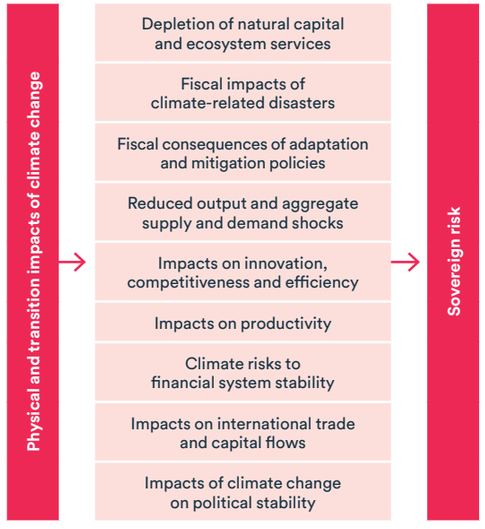
Source: IMF World Economic Outlook 2021

Sound public debt is a foundation of growth and macroeconomic performance. It is the mechanism through which countries invest. Government borrowing fuelled Roosevelt's New Deal, financed the UK through world wars and, if deployed strategically, will be a key tool in the drive to decarbonise. It is also the safe ground to which investors flee in a time of turmoil.

But public debt is not a free lunch. Investors expect to be compensated for trusting the government with their money. That compensation takes the form of interest rates, which are determined by a range of factors, but are higher when the government (or 'sovereign') in question is deemed to be a high credit risk.

Sovereign credit ratings serve as independent assessments of the creditworthiness of nations—their ability to repay debt. Establishing the link between climate risk and a country's borrowing costs is hard. In part this is because there are so many channels through which climate change can affect the public finances and sovereign risk.

Climate risk to sovereign risk



Source: Agarwala et al, 2021; adapted from Volz et al, 2020

The most obvious path from climate change to fiscal risk is through environmental degradation. In addition to extreme weather events, research reveals complex interactions between the climate and other elements of nature, demonstrating that expanding protected areas and restoring sensitive ecosystems can be a cost-effective way of addressing multiple environmental goals. For example, restoring coastal mangroves will help store more carbon while also providing habitat for fish and bird species, as well as dampening storm surges.

The transition can also create risks and opportunities in the management of natural resources. For example, phasing out fossil fuels will phase out the tax revenues that they generate. In the short term, the shortfall can be filled using carbon taxes. But in a net-zero economy, carbon taxes will not generate much revenue.

Putting these kinds of factors together, early research shows that climate change has increased the cost of public borrowing for 25 of the most climate-vulnerable countries—including Bangladesh, Costa Rica, the Maldives, the Philippines and Vietnam—by over one percentage point. When debt stocks are so high, this has a big impact. It has added over $40 billion to the debt interest paid by the 40 most vulnerable nations between 2007 and 2016.

Further increases in financing costs could be on the way. A recent study shows that 63 sovereigns may see their credit ratings downgraded by 2030 due to climate change, which could add over $200 billion to the annual interest payments on public debt in the G7 plus China by 2100.

These downgrades can be expected to increase the cost of public borrowing, making it harder and more expensive to make decarbonising investments in the future. They can also be expected to spill over into other asset classes, increasing the cost of borrowing for corporations and financial institutions.

LOOKING AHEAD

The potential effects of climate change on sovereign risk—and therefore countries' ability to respond to crises—are substantial. Climate economics can offer important insights into how this translates into sovereign creditworthiness and the cost of public and private debt.

Existing metrics have not factored climate risk adequately. Research shows that climate change is beginning to affect debt costs for some countries. Forward-looking climate risk assessments, bringing together the best climate and economic modelling, are needed. It is the difference between getting a diagnosis from the doctor beforehand or a verdict from the coroner afterwards

Scan to read other ECO articles on public spending, taxes and debt

TOO LITTLE, TOO LATE.

The poorest people in the world live close to the equator and rely on small family farms. For them, any promises made at COP26 may come too late.

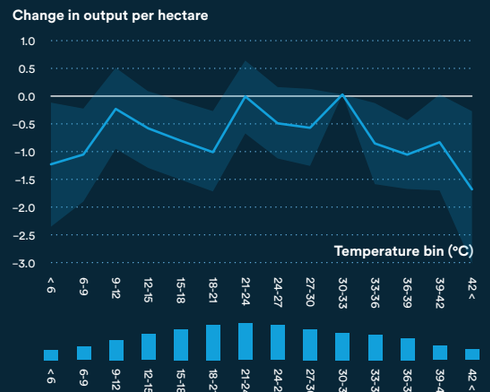
/ Juan Pablo Rud /

Poverty is mostly a rural phenomenon. According to the World Bank, nearly three-quarters of the 650 million people around the world living in extreme poverty are outside towns and cities. The majority are in countries located within a 2,000-mile band around the equator, between the tropics of Cancer and Capricorn, where two-thirds of the population rely on low-productivity small-scale farming. For these households, weather has a big impact—and abrupt changes in climate make them even more vulnerable.

Climate change is increasing the regularity and severity of extreme weather events, such as cyclones, droughts, wildfires and floods. These ruin crops, harming the rural poor. Fluctuations in heat are also harmful. High temperatures affect crops—getting above 30°C, for example, will damage corn. Global warming means more frequent and longer heatwaves: data from small farms in Peru and wheat fields in South Africa show that this is likely to lower agricultural productivity. The impact will not be limited to the poor. There is evidence of the damaging effect of heat on productivity in middle- and high-income countries too.

Too hot to work

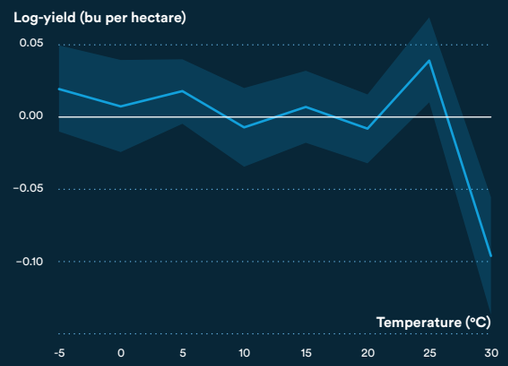
Change at different temperatures



Source: Aragón et al, 2021

Wilting in the heat

Effects of temperature on wheat yields

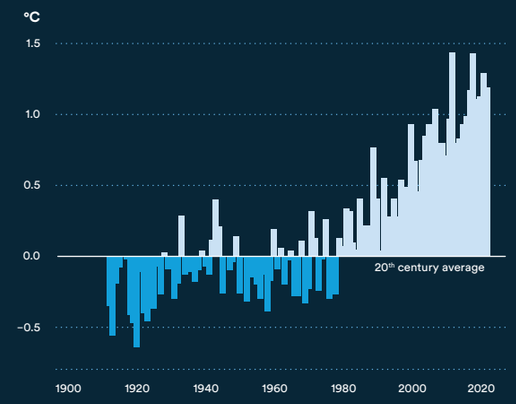


Source: Shew et al, 2020
Note: Data from South Africa

The scientific consensus is that countries between the tropics, where most rural poor reside, will experience the largest rise in temperatures. While international efforts aim to limit the rise to 1.5°C by the end of the century, this objective already looks beyond reach in many places. Every year between 2015 and 2020, average temperatures in Africa exceeded historical averages by more than one degree.

Getting hotter

January-December temperatures in Africa compared with the 20th century average

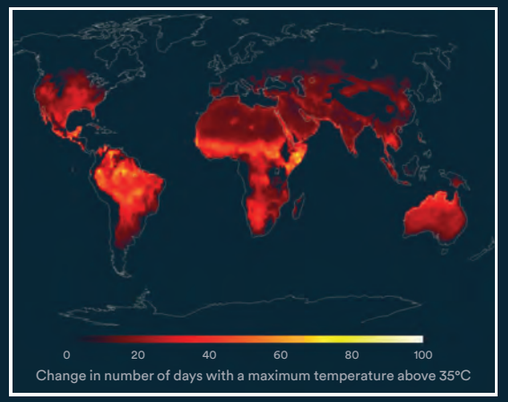


Source: National Oceanic and Atmospheric Administration (NOAA)

COP26 includes aims that would help: moving from fossil fuels to cleaner sources of power would reduce the greenhouse gas emissions that drive global warming. Yet even if these goals are achieved, some regions are still expected to experience up to 70 additional days of extremely hot weather each year by the end of the century. For these people, already poor, the change will have come too late.

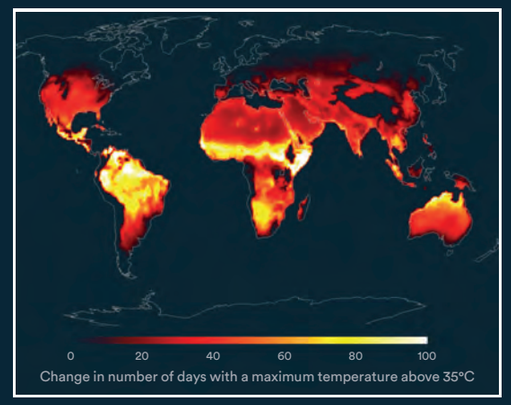
Scorched earth

Change in number of hot days under RCP2.6



Source: CMIP5
Note: Representative Concentration Pathway (RCP) 2.6 corresponds to a radiative forcing of 2.6W/m², equivalent to a warming of 1.5-2°C

Change in number of hot days under RCP4.5



Source: CMIP5
Note: Representative Concentration Pathway (RCP) 4.5 corresponds to a radiative forcing of 4.5W/m², equivalent to a 2-3°C warming

Farmers, particularly those in low-income countries, are responding by switching crops or even moving away from agriculture entirely. But this is harder where markets function poorly, financing is hard to secure and crop insurance is unavailable. Institutions are vital too. In many places, farmers' lives are insecure due to a lack of property rights: either because there is no formal ownership record or because land is communal. For example, in Uganda, around 80% of the land is under customary arrangements, rather than formal titles. In these cases, farmers may not be able to sell the land and move elsewhere. Further, even if they could move, they may struggle to find employment as in some countries—even large ones like Nigeria or Ethiopia—fewer than 20% of workers work for a wage.

There may be some winners in a warmer or wetter climate. For example, evidence from Peru shows that farmers on the coast (a dry and warm region) would suffer from projected changes in temperatures, while farmers in the highlands (which are cold and wet) would benefit from a few more hot days during the growing season. Despite these rare bright spots, overall agricultural output is likely to drop with the kind of climate change experts forecast.

In response, it is important to build resilience among farmers to manage and reduce risk exposure. Concrete proposals include insurance that is linked to weather effects, improving access to finance and technical assistance—advice and training from rich-world universities and scientists—on how to use new technologies including heat- or flood-resistant crops and irrigation

Reaching net zero.

This second edition of ECO goes to print as world leaders meet in Glasgow for the 26th UN Climate Change Conference of the Parties (COP26).

Few doubt that climate change represents the single most significant threat to our economic prosperity, and indeed to humankind itself.

Rising global temperatures threaten environmental damage on a scale not seen before, with implications for productivity, growth and inequality. We have all witnessed the intensity and frequency of extreme weather events around the world in recent years. The latest report issued in August 2021 by the IPCC highlights that scientists are now observing changes in every region of the earth and in our whole climate system.

This existential threat requires a comparable response. Redesigning our economy to be 'net zero' will require huge investment from government, businesses and households, and fundamental changes to many of our day-to-day activities.

Business models across all parts of our economy will be required to adapt. The way we heat our homes, grow our food, travel to and from our work—all will have to evolve.

The UK is leading the way in many aspects, setting bold targets to be net zero by 2050. Holding COP26 in Glasgow represents a further opportunity for the country to demonstrate global leadership.

COP26 also provides a platform for economists to inform debates about the changes that are needed to reach net zero.

Economics not only helps us to understand the costs of climate change, but also has a key role to play in identifying and designing solutions.

How can we create incentives for greater investment in renewable technologies and green jobs? How should we discourage economic activities that drive up emissions? And to what extent can market mechanisms and government regulation and co-ordination activities be used to manage these incentives?

Economics can also offer crucial insights about how we can best manage the 'costs' of transition and who, both in the UK and internationally, will face the greatest barriers to adapt to a net-zero world.

As economists, we each need to be thinking about how best to answer these questions.

I am delighted to see the progress that the Economics Observatory has made since its launch in informing public debate in a huge range of areas.

I am excited about its plans to contribute to strengthening our understanding of the economics of climate change and the transition to net zero over the coming years

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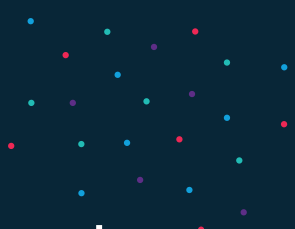

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