
TRUE
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TRUE PLANET
Oxford research for a changing world

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Welcome

By Professor Patrick Grant

The world around us is changing, and Oxford researchers are at the forefront of trying to better understand the reasons for global temperature and sea level increases, extreme weather events, plastic waste proliferation and threats to biodiversity. With this understanding, our researchers are working with partners in industry, government, the third sector and at other universities to address these challenges and to propose innovative approaches and solutions.

In this publication you will hear from Oxford experts on the effects of human-induced climate change, the economic implications of environmental policies, the need to think carefully about our global food system, and how best to integrate renewable energy into our lives.

You will read about how Oxford researchers are helping to tackle the plastics crisis, preserve our marine ecosystems, identify climate-related security threats, and make the UK's water system more resilient.

From water to weather, fuel to food; from how we power our homes to how we protect the landscape around us, Oxford's cross-disciplinary research approach is helping to better understand the complexities and interactions of human activity and the sustainability of our environment.

Take part in the discussion, make informed decisions, collaborate on the next big breakthrough – and discover how Oxford research is making a positive impact on our changing world.

Join the conversation at **#TRUE**PLANET

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Join experts from the University of Oxford and beyond as they explore the latest debates around climate change on the FUTUREMAKERS podcast.

bit.ly/futuremakers2

Tackling the plastic problem

It's a distressing image. A sea turtle lies dead among plastic debris on a beach, seemingly a victim of our global pollution crisis.

If the pictures are stark, so are the figures. An estimated 10 million tonnes of plastic ends up in the oceans each year. Almost 5 billion tonnes has gone to landfill since the post-war boom in production. We get through 1 trillion plastic bags each year worldwide. It takes around 500 years for a plastic bottle to biodegrade. And less than 10% of plastic is recycled.

With marine life facing 'irreparable damage' according to the Director of UN-Oceans, and recent research emphasising the impact of land-based plastic pollution, solutions are urgently needed.

In 2017, one of those potential solutions was turned into a company spun out from Oxford research. Oxford Sustainable Fuels (OSF) is developing technology that can turn end-of-life plastic into high-quality transportation fuel, unlocking the potential of a substance known as pyrolysis oil.

Pyrolysis is the process of decomposing plastic at moderately high temperatures, in the absence of oxygen, to produce an oil-like substance. So far, this pyrolysis oil has found few uses – in part because of its instability. But the academics behind OSF have developed efficient ways of purifying and upgrading this viscous, highly reactive substance to produce gasoline, diesel and jet fuels. Significantly, the process is able to handle mixed plastics, negating the need for sorting and separation.

It's a novel use for plastics that would otherwise have found their way into landfill, our oceans or the atmosphere via incineration. And, as company co-founder Professor Peter Edwards notes, it's a quirk of science that Nobel Prize-winning research into the synthesis of polymers – the molecules that make up plastics – is essentially now being reversed.

'Proposed solutions to the plastic waste crisis, such as plastic-free aisles in supermarkets or the banning of all consumer-use, non-biodegradable plastics, are laudable,' says Professor Edwards, from Oxford's Department of Chemistry. 'However, it will take considerable time and effort to wean a global society off plastic.

'Given the extraordinary scale and rate of expansion of plastic waste, we urgently need complementary strategies. Catalytic chemical recycling techniques such as ours offer substantial environmental and economic benefits.'

OSF was spun out with the help of Oxford University Innovation – the University's research commercialisation arm – and attracted £1 million in seed funding before progressing to the scale-up phase. Currently based at the Begbroke Science Park in Oxfordshire, the company hopes to have opened a waste-to-fuel plant capable of handling 10,000–20,000 tonnes of plastic within the next two years, creating numerous jobs in the process. Past and present Oxford DPhil students have played key roles in the research advances that have brought the science and technology to this point – notably the company's chief technology officer, Dr Zhaoxi Zhang.

'There is often no money to be made in recycling something like a plastic bag', says Ben Williams, chief operating officer at OSF. 'Unfortunately, it can be cheaper simply to make new plastic, and much of the lower-quality waste will end up in landfill or an incinerator. Using our technology, which cleans up, stabilises and upgrades the pyrolysis oil, you can power just about anything – from road cars and haulage to marine engines.'

OSF co-founder Dr Tiancun Xiao, also of Oxford's Department of Chemistry, adds: 'Our aim is to become a key part of the circular economy by enabling the transformation of waste into valuable and needed products. To be a part of the solution in helping our global and local environment is a huge motivation for us. We believe our technology will be an important element in the fight against plastic waste ending up in the oceans.'

It's a novel use for plastics that would otherwise have found their way into landfill, our oceans or the atmosphere via incineration.

WASTE

Find out more: bit.ly/osfuels

Greenhouse gas removal: the key to a carbon-neutral UK?

It's been nearly four years since the majority of the world's nations met to draft what would become known as the Paris Agreement: a commitment, among other things, to limit global temperature increase to no more than 2°C above pre-industrial levels – aiming for 1.5°C.

How can the world's biggest economies meet this target? According to a major report chaired by an Oxford scientist, it will require not only extensive cuts to carbon emissions but the active removal and storage of greenhouse gases from the atmosphere.

Commissioned by the Department for Business, Energy and Industrial Strategy (BEIS) in response to the UK Clean Growth Stategy, the Royal Society and the Royal Academy of Engineering presented an ambitious plan detailing how the UK can lead the way in deploying greenhouse gas removal (GGR) technologies to achieve net-zero carbon emissions by 2050. Their recommendations ranged from well-known methods such as planting trees to more speculative techniques like capturing CO_2 directly from the air.

Professor Gideon Henderson, Professor of Earth Sciences at the University of Oxford and now Chief Scientific Adviser at Defra, chaired the report working group. He says: 'If the UK acts now on greenhouse gas removal, we can reach national emissions targets and show how a major industrialised economy can play a leading role in meeting the goals of the Paris Agreement.

'In this report we've identified the available GGR technologies, how they might be used together for maximum effect, and how their phased development and deployment could enable the urgent action required to avoid the devastating impact of climate change.

'We must absolutely continue to prioritise rapid cuts in greenhouse gas emissions, but we will also have to use these GGR methods to achieve international climate goals and steward the planet for future generations.'

'In this report we've identified the available GGR technologies, how they might be used together for maximum effect, and how their phased development and deployment could enable the urgent action required to avoid the devastating impact of climate change.'

The report, published in autumn 2018, assesses a range of GGR technologies for their real-world potential to help meet climate goals in the UK over the next 30 years and beyond.

Each technology is assessed on its readiness for deployment in the timescale required; its potential for scalability, its financial, environmental and social impacts, and how much of a dent it can make in removing excess carbon to meet the targets.

The report states that, while the UK's first priority must be to maintain efforts to rapidly cut greenhouse gas emissions, GGR technologies have a role to play in counteracting emissions from aviation and agriculture, where the scope to completely reduce emissions is limited. However, to meet climate targets significant action is essential – starting now. Bringing the UK to net-zero emissions by 2050 will require annual removal of large amounts of CO_2, even with stringent reductions in emissions.

The report also considers the global picture and outlines a scenario in which a portfolio of GGR technologies can be implemented together to achieve carbon removal across the world by 2100 to meet the goals of the Paris Agreement. Biological solutions like planting trees will become saturated by the end of the century, and other GGR technologies will need to be developed and used in the longer term.

The GGR report fed explicitly into thinking by the Committee for Climate Change, which suggested in its 2019 report that the UK government set a net-zero target for 2050. This suggestion has now been taken up and enshrined in UK law, making the UK the first major economy to commit to net-zero.

The UK 2050 net-zero scenario

GGR technologies suitable for the UK to use to meet net-zero emissions by 2050

- Ready-to-use GGR methods such as forestation, habitat restoration, soil carbon sequestration and building with wood or carbonated waste could provide just over a quarter of the target to reach net-zero emissions.
- Biochar (charcoal used as soil amendment), enhanced terrestrial weathering in agricultural soils, direct air capture (DACCS), and bioenergy with carbon capture and storage (BECCS) could contribute to the rest of the 2050 target.

What we need to do to achieve net-zero emissions in the UK

- Rapidly increase forestation to 5% of UK land, restore wetlands and salt marshes, and store more carbon in farmland.
- Establish an incentive or subsidy system to encourage farmers to use their land to store carbon.
- Encourage changes in building practice to use wood and cement manufactured with carbonated waste.
- Develop better ways of monitoring the effectiveness of GGR technologies.
- Pursue research into the potential of longer-term GGR technologies such as enhanced weathering, biochar, BECCS and DACCS.
- Capitalise on the UK's strengths in engineering and industry to establish the infrastructure required for the storage of CO_2.

How to meet the Paris Agreement using GGR technologies

- Continue and increase global efforts to reduce emissions of greenhouse gases.
- Implement a global portfolio of GGR technologies now to meet the goals of the Paris Agreement.
- Build carbon capture and storage infrastructure, essential to meeting the scale required for achieving climate goals.
- Encourage investment in the development and piloting of GGR projects to assess their real-world potential and understand any environmental and social impacts.
- Establish incentives, such as carbon pricing, to pay for removal of CO_2 and encourage businesses to use a wide portfolio of GGR technologies.
- Establish a framework to govern use of GGR technologies that addresses sustainability and engages the public.
- Build GGR into regulatory frameworks and carbon trading systems.
- Establish international science-based standards for monitoring the effectiveness of GGR technologies and their environmental impacts.

CLIMATE

Read the full report: bit.ly/greenhouse-gas-removal

Is the UK ready for an electric car revolution?

As the effects of climate change ramp up, the world's love affair with the internal combustion engine may be coming to an end. Transport is the largest energy-consuming sector in the UK, with cars, buses, lorries and motorbikes making up 73% of all transport-related pollution. Transitioning to electric vehicles would make a substantial difference to the UK's carbon emissions, as well as improving air quality in urban areas and delivering substantial savings in running costs and maintenance for consumers. But is the UK ready for an electric car revolution?

Political action will be necessary to encourage the public towards electric vehicles.

Barriers to entry

Despite the clear benefits of electric vehicles, adoption has not been widespread. 'We are still wedded to the internal combustion engine in a variety of ways,' says Professor Tim Schwanen, Director of the Transport Studies Unit (TSU) at Oxford's School of Geography and the Environment. 'For some segments of the vehicle market, few electric models are available – and those that are on the market are often considerably more expensive than their conventional counterparts. For heavy goods vehicles, electric versions are often not yet on the market.'

Infrastructure challenges

Even for those who can afford an electric car, infrastructure to support them is lagging behind. 'A charging infrastructure will in particular have to accommodate charging at home, because this is what potential users tend to prefer,' says Professor Schwanen. 'It is also unclear what "home" means – whether this refers to private parking, street parking in front of the house, or if people are willing to charge at safe overnight parking nearby.' Research will soon start at the TSU to understand more about charging preferences for people considering an electric car. The outcomes of this work will generate solid evidence that could potentially be used for policymakers considering the roll-out of electric car infrastructure.

'The biggest infrastructure challenges lie with the electricity grid, which is in no way equipped to accommodate massive adoption of electric vehicles,' explains Professor Schwanen. 'One issue is peak use, with large numbers of people charging their car at more or less the same time (for example, between 5pm and 11pm). This can be addressed with smart charging, whereby algorithms determine when is the most appropriate time for a car to be charged, and/or vehicle-to-grid technology, where stationary vehicles are functioning as storage devices or batteries and can support the grid. Another issue is that in many geographical locations the grid will have to be upgraded, because there is often insufficient power for fast and ultra-fast charging.'

Policy action

Political action will be necessary to encourage the public towards electric vehicles. 'The time for a gentle approach is now well and truly over, given transport's immense contribution to climate change and the slow pace with which ultra-low-emission vehicles have been adopted by private households and professional organisations,' says Professor Schwanen. 'A mix of policies will be needed. Current initiatives such as subsidised charging infrastructure and government grants for battery electric vehicles should be maintained. At the same time, we need more zero- or low-emission zones in cities and an increased tax on internal combustion engines. Freight and goods transport is disproportionately responsible for air pollution, so those industries need to be targeted for electrification.'

Lifestyle changes

Even if the UK were prepared for a transition to electric vehicles, ditching our conventional cars for greener versions would not be enough to combat global climate change. 'Electrification of vehicles is only a part of the solution,' says Professor Schwanen. 'A much more comprehensive change will be necessary, and this will inevitably involve changes to our behaviour. Replacing driving your own car with public transportation, walking, cycling and using a car club will be key elements of what is going to be required.'

Other transport networks will need to be addressed, too. 'Flying will need to be curtailed somehow, as this is the fastest-growing contributor to CO_2 emissions in the transport sector,' adds Professor Schwanen. 'The sort of change required to address climate change will not be popular – driving your own car and flying for business and pleasure have become a way of life for most of us. But, as Greta Thunberg shows, avoiding flying while still playing a prominent role in public life is entirely possible.'

ENERGY

Find out more: bit.ly/transport-studies

A critical moment for coral reef survival

Coral reefs are the backbone of ocean biodiversity, as well as industries that support over 500 million people worldwide.

They are, however, some of the most threatened habitats on earth. Vulnerable to temperature changes that destabilise their delicate ecosystems, some scientists estimate that up to 90% of the world's coral could be gone by 2050 owing to climate change. This would have devastating consequences for ocean plants and animals, as well as the millions of communities who rely on fishing for their sustenance and livelihoods.

'Global warming has caused unprecedented increases in sea surface temperatures, which kills coral,' says Dr Melita Samoilys, a research fellow at Oxford's Department of Zoology. 'Corals cannot survive even just a few degrees of temperature rise because of their remarkable symbiotic relationship with microscopic algae called zooxanthellae. These zooxanthellae feed the coral and enable them to form into reefs. Zooxanthellae can only survive in a narrow temperature range, so cannot cope with temperature increases caused by climate change. When the water gets too warm, the algae, which allow the coral to survive and give them their beautiful colours, desert the coral – hence "coral bleaching" occurs.'

Coral bleaching, so called because of the ghostly white colour taken on by dead coral, has increased rapidly over the last few years. Dr Samoilys says: 'Changes in weather patterns, such as El Niño and La Niña, have been connected to climate change and cause a rise in sea surface temperatures. Over the last few years, we have seen summer sea surface temperatures exceed corals' comfort zone almost every year.' Intense summer temperatures in 2016 and 2017 alone are blamed for the coral bleaching of nearly half of the Great Barrier Reef, a reef structure so large that it can be seen from outer space.

'Massive coral mortality, such as in the Great Barrier Reef, has a dramatic effect on marine life,' says Dr Samoilys. 'Coral reefs are one of the most biodiverse ecosystems on the planet, and their loss has a major impact on other invertebrates, vertebrates and plants. We are seeing a disappearance of fish species that are highly dependent on live coral for food and shelter. Reef sharks, too, are rapidly disappearing in developing countries such as Kenya and Tanzania, where they are at a critical level of depletion. Large predatory fish such as sharks are a critical component of a reef's food chain and their loss precipitates a cascade of disruption throughout reefs.'

Not only is ocean biodiversity under threat, but so are the coastal communities that rely on the ocean to survive. 'In the western Indian Ocean alone, we estimate there are 60 million people dependent on coral reefs for their livelihoods,' says Dr Samoilys. 'Local fisheries are vital to the economies of developing countries, for food as well as income. Reefs also create a barrier protecting coastlines, which is essential to defend

'The mass coral bleaching occurring on enormous scales globally is a startling and accurate indicator of how much our climate is changing.'

villages against ocean storms. They protect lagoons against seasonal weather like monsoons, which can last several months, allowing fishers to continue to fish in the lagoon. This is critical for their livelihoods.'

Despite this bleak picture for coral reef survival, researchers are continuing to look for ways to save and conserve reefs. 'When a reef dies, the reef structure is still there, in carbonate rock form. And there are usually a few isolated coral colonies still alive,' explains Dr Samoilys. 'What we are working on is trying to understand if it is possible for coral larvae to settle and grow when the reef is no longer functioning – if it has the potential to return.'

Going forward, the future of coral reefs is uncertain. Dr Samoilys says: 'Reefs' responses to elevated sea surface temperatures are highly variable and not always predictable; some species are very sensitive, while others are more tolerant. Thus, as we go forward into a future with warmer seas, the community of coral species on a reef will change.

'The response of reef fishes, too, is also highly variable. Some species that are highly dependent on live coral are likely to go locally extinct. Others may survive a changed ecosystem – these are often larger, more important species in fisheries, which is a good thing for people dependent on fishing. It also means, however, that these species' populations need to be safeguarded now so they survive into the future.

'The mass coral bleaching occurring on enormous scales globally is a startling and accurate indicator of how much our climate is changing.'

In light of the increasing damage wrought by climate change, controlling for other factors that affect reefs is becoming even more important. 'Maximising the resilience of reefs to hot water is a primary objective of conservationists,' says Dr Samoilys. 'There is strong evidence that the healthier the general state of the reef, in terms of its fish populations and the surrounding water, the more resilient it will be to climate change.' This means combating pollution and overfishing, in order to give reefs the healthy environments they need to bounce back.

'But ultimately the most important thing we can do to preserve coral reefs is to address climate change. Governments need to get serious about changing policies across all sectors to reduce greenhouse gas emissions. Emissions need to be central to all domestic policies; there is no "later" for climate change.'

BIODIVERSITY

Find out more: bit.ly/ocean-research

The future of cooling on a warming planet

By 2050, it is predicted that 68% of the world's populations will live in urban areas. Central to this shift will be developing countries, which will undergo the largest transitions to city living. While this change will create new socio-economic opportunities for many nations, it will also introduce many challenges to infrastructure and services. This will be compounded by another major shift which will affect poorer nations disproportionately: climate change.

'Cities – especially those in transition, where most of the world's population are projected to live – must find ways to manage the tension between development and environmental protection,' says Radhika Khosla, Research Director at the Oxford India Centre for Sustainable Development, and a Senior Researcher at the Smith School of Enterprise and the Environment. 'This is a crucial time for transitioning cities because, once large-scale infrastructure decisions are made, they are "locked in" for decades owing to the costs and difficulties in changing entrenched systems.'

A key player in the global migration to cities is India, one of the world's most populous nations. The country is already home to over 400 million city dwellers, a number expected to double by 2050. Cities in India already experience widespread issues meeting the basic needs of inhabitants: one in six urbanites live in slums, officially defined as accommodation that is 'unfit for human habitation'. Owing to the country's ongoing economic and social transitions, India is projected to account for a quarter of the rise in global energy use by 2040.

Climate change is also already hitting India hard. Heatwaves, drought, cyclones and other dangerous weather patterns directly threaten both lives and livelihoods, as well as creating the conditions for food and water supply crises, population displacement and higher incidences of disease. Developing nations such as India have few dedicated resources to manage climate change, and political focus is often on making immediate improvements to living conditions rather than preparing for future catastrophes.

However, Dr Khosla is more optimistic about the challenges facing India. 'In India, where urban infrastructure has not yet been developed in many areas, there is a golden opportunity to undertake large-scale climate-conscious planning that reduces energy uptake without compromising on city needs,' she says. 'This includes the choice of building types, how they expend energy to cool and heat, the amount of travel distance for residents and ways in which residents travel.'

In many ways, India is providing a template for other developing nations struggling to create improved living conditions while also addressing climate change. 'National policy and city initiatives are beginning to incorporate climate action into urban planning, driven by the synergies between city development and climate goals,' explains Dr Khosla. 'For example, urban planning that accounts for the interdependence between infrastructure, transport and buildings, as opposed to only pursuing options within the sectors individually, is significant in reducing energy use and global greenhouse gas emissions for the long term.'

One of the key places where energy is used – and therefore will need to be reduced – is in cooling homes, offices and other buildings. With temperatures routinely hitting the forties in major cities like Delhi and Mumbai, the demand for air conditioning, fans and other cooling appliances is predicted to grow exponentially as the city populations and income levels grow. Around the world, the energy needed for air conditioning is likely to triple by 2050, with ten new air conditioning units projected to be sold every second for the next 30 years.

'Shaping the future of cooling is potentially the most significant opportunity we have to moderate future energy demand,' says Dr Khosla. 'Cooling is necessary for the quality of life of billions of people living in developing countries and, increasingly, for those developed countries traditionally unprepared for ever more frequent heatwaves due to climate change.

'On the issue of cooling, it can result in a feedback loop with significant negative consequences. Heatwaves are made more likely by climate change, but the cooling required to mitigate them drives further energy consumption. This in turn causes more CO_2 emissions and contributes to further climate change.'

In order to tackle this issue, a new programme on the Future of Cooling at the Oxford Martin School will bring together expert researchers from across the University. Led by Dr Khosla and Professor Malcolm McCulloch (Department of Engineering Science), the programme's aim is to examine and help shape the unprecedented growth in cooling energy demand. This will include research into the social behaviours and health impacts of severe heat, as well as the environmental impacts of the global cooling industry and new sustainable technologies.

'Global research on this topic is lacking, and the University of Oxford is at the forefront of new social and technical solutions for sustainable cooling,' says Dr Khosla. 'We hope that, by 2050, sustainable cooling will be available to all.'

Find out more:
bit.ly/future-cooling

Around the world, the energy needed for air conditioning is likely to triple by 2050, with ten new air conditioning units projected to be sold every second for the next 30 years.

On a mission: tackling the world's ocean waste, one flip-flop at a time

Professor Lindsay Turnbull and DPhil student April Burt from the Department of Plant Sciences, led a major clean-up operation on the Seychellois island of Aldabra in March 2019. Back in Oxford they joined Ruth Abrahams, from the University's Research and Innovation Communications team, to discuss the challenging experience and share what stark realities confronted them about global plastic waste.

'The timescales on which we are able to respond are not commensurate with the magnitude and the urgency of the problem.'

RA: Where did the idea come from?

AB: Aldabra is a UNESCO World Heritage Site. It's the second-largest raised coral atoll in the world, and along its coastline are dotted 52 turtle nesting beaches. That adds up to the largest breeding population of endangered green turtles in the western Indian Ocean.

Plastic trash is now clogging these beaches and is having a massive impact on the turtles' ability to nest.

Lindsay is a trustee of the Seychelles Islands Foundation, and I worked on Aldabra for two years. She came up with the idea of organising a collaborative project involving young people in Oxford and Seychelles, so that they could tackle the problem together.

RA: Was this the main motivation?

LT: In the first instance, we wanted to remove as much of the rubbish as possible and make a significant dent in the problem, but we knew that any effort couldn't possibly remove everything that was there. So we also wanted to raise awareness of the general problem.

RA: How did you raise the money?

AB: It felt like a huge mountain. Aldabra is so isolated and logistically difficult. We had a target of £150,000; to raise the money we had several strategies and it was very challenging and took a lot of time.

RA: What were the larger issues at stake?

AB: The impact of plastic pollution, especially within small island nations, needs urgent attention – they don't have the resources to deal with this problem, so how can we manage the threat for the future?

LT: The plastic hasn't come from the people of Seychelles. It comes from all over the world. We certainly saw items from Indonesia, China, India: all countries that border the Indian Ocean, many of which don't have proper waste management. If you live in one of those countries and your shoes are worn out, what are you going to do with them if there's no waste disposal?

You'll dump them somewhere and they'll end up in a river, and that river will flow into the ocean. Plastic shoes are so light that they could easily be caught in currents and travel thousands of miles, but eventually they will be washed up somewhere. Remote islands which stand in the middle of these currents are one of the places that they end up.

But part of the travesty is that we don't recycle our own rubbish properly here either. We ship lots of it overseas to countries who have no ability to recycle that rubbish. There have been some shocking reports about what is happening to our recycling, so I think it's a problem that we are not taking responsibility for. It's much easier to blame people somewhere else.

RA: What were some of the biggest challenges of the clean-up operation?

AB: Just how long it took to clear the beaches. When you went back the next day the turtles would have been up nesting and they would have churned up a lot of old trash. So there was a lot that was hidden really deep under the sand.


© Aldabra Clean-Up

RA: How much did you collect?

AB: We ended up with more than 25 tonnes of trash that only just fitted on the ship we had chartered. The Oxford team and the Seychellois team were just astonished by the number of flip-flops. We collected about 60,000 individual flip-flops.

Sadly, we estimate there are still half a million to a million flip-flops there. Another big source of rubbish was fishing gear. How can Seychelles manage that kind of problem? What are they supposed to do with it all?

LT: What people don't understand about plastic is that it never goes away. You can move it from here to there, but until you put it into a process that will actually turn it back into something useful, it will remain.

AB: That's been one of the most difficult challenges: what to do with it. Everything led to a dead end because Seychelles is so isolated and doesn't have solutions yet for that kind of waste. But, off the back of this project, all sorts of things are being put in motion.

The President of Seychelles took photos from the project to the G7 summit and showed them to world leaders. Several countries have pledged money to a fund that aims to improve waste management in small island states, like Seychelles. At the recent World Ocean Summit in Ireland the President was talking about the project and we created a report that he handed to the UN Secretary General. So we have shone a light on the issue, and Aldabra is now being used as an example of how bad the problem has become.

LT: One of the hardest things about a project like this is that you're suddenly confronted with the madness of modern society – like making things that are used for five minutes out of a material that can endure for thousands of years. The timescales on which we are able to respond are not commensurate with the magnitude and the urgency of the problem.

RA: What do you hope the impact will be of this project?

AB: We'd love to see changes implemented in Seychelles. We've also tried to do as much education and outreach as possible. We're trying to help to create awareness.

RA: Has it helped to inform future directions or priorities of research?

LT: I feel that any research I do in the future should have a significant and positive short-term impact, so I'm trying to reprioritise what I put my energy into. I'm involved in the Ridgeway Project which is trying to support biodiversity in the British countryside. Biodiversity needs help here too. It can feel daunting, but you have to do things where you already have connections or networks. My advice would be: look at what you've got already and ask yourself – if I've only got so much time and energy, what am I going to do that would make the biggest difference?

AB: I think that's a good message for Oxford.

Find out more:
bit.ly/aldabra-project

'We collected about 60,000 individual flip-flops.'

Individual actions in a time of climate emergency

By Dr Tina Fawcett

We are living in an age of increasing concern about climate change. Driven by the science, governments are setting more ambitious greenhouse gas reduction targets. In June 2019, the UK announced a target of reaching net-zero emissions by 2050.

Over 70% of British citizens live in local areas which have declared a climate emergency. At the same time, civil society movements including Extinction Rebellion and Youth Strike for Climate, inspired by Greta Thunberg, are mobilising many, particularly young people.

Concern reaches beyond activists; a recent poll showed that the proportion of people in the UK who are 'very concerned' about climate change has jumped to a record 52%, up from just 18% five years ago. But what can individuals do? Indeed, is individual action worthwhile, given the planetary scale of climate change?

Prominent academics and activists have engaged in debates about the relative merits of 'system change' versus 'individual change'. Most conclude that both are needed, and that these changes are interdependent: since only individuals can change the system, and without system change most individuals cannot live low- or zero-carbon lives. The more important focus is on what actions individuals should prioritise in everyday life, and how best to contribute to larger-scale change.

On average, travel, home energy use and food consumption are the three biggest contributors to an individual's carbon footprint, with other goods and services making up the rest, although everyone's footprint is different. Nevertheless, some general guidance applies (see box below).

Many of these changes will save money and have benefits for health, comfort and local air quality, beyond 'just' reducing carbon emissions.

To influence the wider social and political system, there are many local and national organisations to join which are working for change. You can email or write to your MP or local politicians. You can join a march. You can talk to friends, classmates and work colleagues about climate change.

Given that society-wide and individual change are needed, how can we connect these very different scales? The University of Oxford, and others, are developing thinking on sufficiency, and specifically energy sufficiency, to explore how individual needs can be met, fairly, within environmental limits. The idea of sufficiency – something which is enough for a particular purpose – goes beyond efficiency, traditionally key to energy demand policy. Sufficiency links to individual values and ideas of the good life. Turning this concept into workable and publicly acceptable policies is work in progress.

Another innovative Oxford idea is 'personal carbon allowances', where each individual receives an equal carbon allowance to cover household energy and travel, which reduces over time to meet national targets. Allowances would be tradeable, so that those with lower carbon lifestyles could sell their surplus to others. This too makes an explicit link between individual actions and national and global targets.

Oxford is also leading a new multi-university research centre – the Centre for Research into Energy Demand Solutions (CREDS), which aims to help achieve the goal of becoming a low-carbon society.

There is much to do. Some changes are within individuals' power to make right now, such as choosing not to fly abroad on holiday. Others will take longer and need infrastructure change, such as better public transport and cycling options. The transformation to a low-carbon society is vital to avoid catastrophic climate change. New thinking and policy ideas can help deliver change in a just and positive way. We are all part of the solution.

Find out more at bit.ly/creds-energy

Individual actions:

1. **Understand your consumption patterns. How much energy do you use? What for? How many miles do you travel by car? Why?**
2. **Reduce waste – particularly of energy and food. Nobody means to waste, but nearly all of us do. Action can range from switching off lights to low-energy home refurbishment.**
3. **Increase your active travel – walking and cycling. Drive less. Reduce or avoid air travel.**
4. **Eat more plant-based meals, and less meat and dairy.**
5. **Make plans for a low-carbon future. How could you become less car-dependent? How might you heat your home without fossil fuels?**

Tina Fawcett
Senior Researcher and Acting Deputy Leader in the Energy Programme at the Environmental Change Institute and Co-Director of the Centre for Research into Energy Demand Solutions (CREDS)

'The transformation to a low-carbon society is vital to avoid catastrophic climate change. New thinking and policy ideas can help deliver change in a just and positive way.'

© John Cairns

Reversing the decline of pollinators

Bees are important pollinators for many wildflowers and crops and are essential for both a healthy environment and a healthy economy.

'Over the past 50 years we've seen a dramatic decline in all insect numbers, but particularly bees and other wild pollinators,' explains Prince of Wales's Charitable Foundation Fellow Dr Matthias Becher. 'One of the main reasons for this is changing agriculture, but the use of pesticides, as well as pests and diseases, are also factors.'

Dr Becher builds complex computer models to better understand the way in which these factors influence colony growth and survival. Developed in collaboration with researchers around the world, the BEEHAVE models are fed with experimental data and expert knowledge in order to simulate real biological processes, such as nectar- and pollen-foraging behaviour in different landscapes. They are user friendly, and freely available to download online.

'The models enable us to look at how different factors act together, such as pesticides and food availability,' explains Dr Becher, who took up his post at Oxford in 2018. 'A colony has a foraging range of several kilometres, so to study these things in the field would actually be very difficult, time-consuming and expensive. Using a model means we can identify interesting factors or scenarios before committing to the actual experimental work.'

As well as serving as valuable tools for other researchers, Dr Becher's models also contribute to the protection and enhancement of pollinator communities in agricultural landscapes. BEE-STEWARD – a recent addition to the BEEHAVE suite – allows farmers to see how pollinator-friendly land management could affect bee survival and pollination rates. The aim is to help farmers make the most of their land, both for bees and for business.

Having already produced models for honeybees and bumblebees, Dr Becher is now turning his attention to solitary bees. It's work that 2018–19 John Oldacre Scholar Sabrina Dietz is keen to support. 'I'd like to think that we could feed his model with the data I gathered, which will help to make it even better at predicting outcomes for solitary bees,' she says.

While at Oxford, Sabrina investigated both the effectiveness of pollinators and the quality and quantity of nectar and pollen provided by the plant in return. Her research will assist in predicting the stability and resilience of plant–pollinator networks, as well as the way in which interactions within these networks would rewire if, for example, a particular species of plant or bee were to disappear.

Like Dr Becher, Sabrina hopes that her work – and that of future John Oldacre Scholars – will help to inform land management and conservation practices in the future. 'If the data shows that certain pollinators prefer flowers with a specific protein and sugar content, we can say to farmers: these are the types of plants you should have in your fields in order to improve the availability of nutrients,' she explains. 'Of course it may turn out that bees don't have specific preferences and that they actually love a wide range of nectar and pollen nutrients – we'll see!'

'If the data shows that certain pollinators prefer flowers with a specific protein and sugar content, we can say to farmers: these are the types of plants you should have in your fields in order to improve the availability of nutrients.'

BIODIVERSITY

Find out more:
bit.ly/oxford-plan-bee

The security threats of climate change

When we think about climate change, plenty of direct consequences spring to mind: rising temperatures, extreme weather, melting ice caps, shrinking habitats for wildlife. Some effects, however, are not so obvious.

Kate Guy is a DPhil candidate in Oxford's Department of Politics and International Relations, researching the links between climate change and threats to national and international security. If international efforts to address global temperature rises have thus far largely been about negotiation and cooperation between states, what happens if the effects of environmental change threaten to derail that cooperation? Will scarcer resources lead to increased conflict and competition between and within nations? And how can governance be maintained against a backdrop of increased environmental and economic 'shock'?

A research fellow with the Washington DC-based Center for Climate and Security, and previously an expert working on the negotiation of the UN's Sustainable Development Goals, Guy is looking at the security risks associated with climate change across a variety of warming scenarios.

'It's a topic of growing importance as the impacts of climate change become more pronounced,' says Guy, who also works as a research assistant to the Dean of the Blavatnik School of Government at Oxford. 'In the US, the Pentagon and intelligence communities have been giving climate risks increased attention. The UN Security Council has also started to look at climate change as part of its most high-profile security deliberations.'

Through her background in politics and policymaking, Guy has witnessed first-hand the international efforts to 'negotiate our way out of climate change'. But she has also seen the opposite taking place.

'Having come from the world of international institutions and diplomacy, I became interested in how climate change could begin to have a detrimental impact on cooperation,' she says. 'My research considers how states might shift their alliances and security relationships in the face of widespread climate change, and which climate risks are most threatening to the current global order.'

According to Guy, the effects of climate change – direct and indirect – that are likely to have an impact on national and global security include extreme weather events, pressure on resources and crop yields, sea level rise, the spread of disease, economic instability, population migration and radicalisation, and even potential mitigation efforts such as the use of geoengineering and nuclear technologies.

'The security community classifies all of these climate impacts as "threat multipliers",' says Guy. 'It's often difficult to demonstrate direct causality between climate change and shocks, and they may not be severe threats in and of themselves, but in combination they could have serious consequences on the ground. There are also threats of what we call "fat-tail risks", which are high-impact but low-probability events – like the potential collapse of the West Antarctic ice sheet, which would lead to catastrophic levels of sea level rise globally.'

The most pressing and useful task for researchers, she adds, is scenario planning – in particular, looking at those regions and areas facing the biggest overlap of climate risks and considering their security implications. 'For example, in an extreme scenario of 4°C temperature rise, which our current emissions put us on track to reach, we're likely to see widespread drought and crop failure, which could lead to political instability in states whose governance is already fragile,' says Guy. 'One of the saddest things about climate change is that the places

'What's really interesting in terms of projecting the security implications of climate change is that we are able to use sophisticated climate prediction models to look into the future – including lots of fantastic work being produced right here in Oxford.'

likely to be most vulnerable to shocks are often the places that are less economically developed and therefore less able to adapt to environmental change. In the Sahel region of Africa, for example, we're already seeing increased violence and fighting over scarce resources in the context of prolonged drought and food insecurity.'

An increase in the fragility of states is a common prediction among those who study the effects of rising temperatures. 'It's been suggested that a 0.5°C increase in temperature leads to a 10% to 20% increase in intergroup conflict,' says Guy. 'We're already living with some of the consequences of climate change: we've experienced about a 1°C rise in temperatures from pre-industrial levels, and it's estimated that climate and natural disasters in 2018 alone pushed another 29 million people around the world into food insecurity. We need to mitigate this immediately and keep ourselves under the threshold of 1.5°C, because if we allow climate change to spiral out of control then the effects on the ground will quickly spiral out of control as well.

'I don't believe we have the global institutions in place at the moment to deal with a climate-changed world, and nor do I think our existing treaties and alliances will be applicable in a world in which resources are highly constrained and shocks are frequent.'

State rivalry is already on the rise, says Guy, citing the example of the Arctic Council. An innovative intergovernmental forum, the Arctic Council was set up to discuss the issues affecting the Arctic region, with representation from indigenous groups and observer states at the table. 'What we're seeing now – and what I'm predicting is likely to happen around the world – is a breakdown in cooperation among the Arctic Council members as the region's sea ice rapidly melts, resulting in shipping routes and access to drilling becoming open for longer periods each year. Countries are not necessarily coming to international fora in good faith anymore, because the push and pull of self-interest takes precedence.'

There are, however, some reasons for optimism. Guy says: 'One bright spot is that there is evidence that these risks and shocks could, if we handle them correctly, lead to the creation of new and improved spaces for international cooperation. Take the 2014 international response to Ebola, for example. It was a terrible global shock with enormous loss of life, but the international community came together relatively quickly to contain the virus and create innovative new solutions. That could be a model for similar future shocks.'

She adds: 'What's really interesting in terms of projecting the security implications of climate change is that we are able to use sophisticated climate prediction models to look into the future, including lots of fantastic work being produced right here in Oxford. What we haven't done well is link this research into an understanding of climate change's second-, third- and fourth-order effects. For example, what would a one-foot sea level rise mean for the governance and security of the affected regions? We haven't yet collaborated enough across the hard and social science disciplines to answer these questions, but there's a great opportunity there – particularly in a place like Oxford.'

CLIMATE

Find out more at bit.ly/oxford-politics

Under threat: on the trail of the African golden wolf

For Liz Campbell, Oxford is just a base. Her home for most of the year is 1,350 miles due south in the Atlas Mountains of Morocco.

Liz Campbell lives in a remote town called Azrou from where she is studying a newly discovered species, the African golden wolf. Until 2015 this species was unknown and had been considered to be a kind of jackal; in actual fact the two species have been separate for 1.2 million years.

The African golden wolf – as it is now correctly identified – is top predator in this region since the Barbary lions, leopards and hyenas have disappeared, mostly from human persecution and loss of habitat and loss of prey. But even these golden, misidentified survivors are under threat.

They are seen as a menace by local shepherds. Campbell, a DPhil student who leads the Atlas Golden Wolf Project, says, 'One of the things that the shepherds really dislike is that a wolf won't just kill one sheep. It might kill ten and only eat one, so in the shepherds' view they think the wolves are vengeful and spiteful, but that isn't the animals' motivation at all.'

This sounds devastating, but Campbell says, 'What I'm seeing from my data is that they don't attack sheep that often, so only 15% of shepherds have had any kind of attack in the last year.'

But if the wolves are, in some ways, harmful to a group of people scratching a living from their land, does it matter whether the wolves survive or go the way of the lions, leopards and hyenas?

In simple terms: yes, it does. 'You need predators in an ecosystem to balance prey,' Campbell explains. 'In the Atlas Mountains there are a lot of wild boar and if you have nothing to eat the wild boar, the numbers increase. They reproduce really quickly and they root up the ground, destroying vegetation. It's the same with other herbivores: if you don't have a predator to control those populations there are too many and they destroy vegetation.'

This is a pattern of predator-eradication that has occurred across the world. Wolves became almost extinct throughout North America and Europe because of human influence. They're now recovering and returning to a lot of places they were extirpated from. In Yellowstone National Park they reintroduced wolves and it has had 'massive cascading effects', says Campbell.

Eventually the consequences of predator loss becomes damaging for humans but, as Campbell says: 'There's also the argument of biodiversity having its own intrinsic value. There is the argument that the wolves have a right to be alive, and who are humans to come in and decide that these wolves are bad for their livestock and wipe out a whole branch of evolution because of that?

'They have a place in nature. We don't even understand all the intricacies, and in the end it would affect us, but even without that fact they have a right to exist as well.' Professor Rob Salguero-Gomez, at the University's Department of Zoology, researches the delicate balance of ecosystems and biodiversity. He says: 'We have a big responsibility to document everything we have – total global biodiversity – to develop methods to prevent species from going extinct. To that end, we need to assess the relative vulnerability and resilience of as many species as possible: how likely they are to become extinct and how likely they are to recover from a disturbance, such as a hurricane or a fire. Acquiring this knowledge will be critical for the development of priority management plans in the future.

'We are now in an era where humans are the main affecters of biodiversity through climate change and we know that biodiversity is a buffer against our actions. From a human-centric point of view, the benefits of biodiversity can be understood through natural resources to support us, our infrastructures, our food sources, our physical and mental health. Biodiversity offers what we call ecosystem services. As you eliminate species the benefits of eco-services diminish.

'We are collaborating with other demographers around the globe to create an informed world map to show which areas need to be protected and which areas are most vulnerable. We need global solutions.'

Professor Nathalie Seddon leads the Nature-based Solutions Initiative at Oxford – a research group that develops ways of working with nature to solve the global challenge of climate change, working with nature to address societal challenges, with a focus on climate change, says: 'The last 12 months have seen the publication of several major reports on the state of the biosphere and climate. It has become clear that not only are we failing to stabilise the climate and stem the tide of biodiversity loss, but that this is having and will increasingly have severe impacts on humanity. It is against this backdrop that we are seeing the rise of nature-based solutions – ie working with and enhancing nature – as integrated approaches to addressing the causes and consequences of climate change, protecting biodiversity and enabling sustainable development.

'We have to steer investments in nature away from single species plantations and towards protecting what we've got (ie biodiverse, intact ecosystems) and restoring what we've damaged. That's what the Nature-based Solutions Initiative is focused on achieving. In particular, we apply leading-edge thinking from across multiple disciplines to shore up the scholarship around the socioeconomic and ecological effectiveness of nature-based solutions in a warming world, and to bring about a step change in how these are financed and governed, for the benefit of people and planet.'

The African golden wolves, which are key to maintaining biodiversity in the Atlas Mountains, are secretive animals and of no harm to humans. In years of studying them Campbell has only actually seen them twice. Her observations come through cameras and tracking.

After learning the basic essentials of this new species, the next stage of Campbell's research is to develop strategies to make sure that the humans aren't losing livestock and to protect the predators themselves.

'Strategies are probably going to be focused on husbandry practices, for example the common problem of losing your sheep in the forest.' she says. 'You can fairly easily improve this issue by having guard dogs and having the sheep locked up better at night, but there are indirect costs as farmers (or shepherds) would have to pay for dogs and put up fences.

'We need more research to understand the animals and what role they play in the ecosystem; understanding why they're attacking livestock and how we can prevent that.'

Campbell's work involves outreach events with local communities and educational events with children to teach them about the value of predators and the balance of nature. She also trains students in Morocco to increase capacity of conservation within the country.

The Atlas Golden Wolf project is part of the WildCRU – Wildlife Conservation Research Unit – suite of projects based at the University of Oxford. Catapulted into the spotlight in 2015 when one of their study lions, Cecil, was shot dead by a trophy hunter, the research group has roots stretching back to the early, pioneering days of environmental conservation. Founded in 1986 by David Macdonald, WildCRU was the first university-based conservation research unit in Europe. It has grown to be one of the largest conservation research institutes in the world.

One of Campbell's WildCRU colleagues, Dr Tan, whose work has affected positive change for the clouded leopard in the previously unprotected Ulu Muda forest in Malaysia, also talks about the importance of working with local communities.

'Ulu Muda is a water catchment area which provides four million people with drinking water and supplies water to the rice fields of four states,' he says. 'But there was unmanaged logging and poaching going on. We found out last November that logging is now banned and this result has come about because of a combination of research, engaging the public and a petition.'

Four of Dr Tan's projects are funded through Oxford University seed funding.

'Oxford is a great place to try out new ways of doing things,' he says. 'The University is open to innovative teaching methods. I'm proud to be training the new generation of conservation educators by helping early-career conservationists learn to be teachers themselves, so as to improve training of conservation biologists working on high biodiversity hotspot areas.'

Professor Salguero-Gomez points out: 'We can't manage what we don't understand. A key question in our understanding of biodiversity, before even talking about how much of it is being lost due to human actions and climate change, is to quantify our knowledge of species across the tree of life, from bacteria to humans and anything in between.'

Dr Tan believes that some of the main challenges we face are that people are very pessimistic or lack awareness around climate change. Part of his research and practice is about empowering people to believe that they can make a difference.

'We think we're one small person and that we can't make a difference,' he says. 'But I strongly believe in changing mindsets and understanding through education.

'We all want to achieve comfort and provide for our families, but I believe that people can make a difference through small changes in their behaviour. Ideally, in the future, everyone would be aware of how their behaviour and actions impact wildlife and they would make small positive changes. But there would also be a top-down approach from policy-makers.'

What about a worst-case scenario? 'In a worst-case scenario we will accelerate temperature increase, population increase will run out of control and every living thing will eventually become extinct. We as humans will be ignorant of our actions and this will be the cause of our own detriment.'

By holding this worst case in mind and working towards an evidence-based best-case scenario, Cedric Tan, Liz Campbell, Rob Salguero-Gomez, Nathalie Seddon and many more conservation biologists at Oxford are collaborating around the world to create solutions which respect the balance of human need, the right to life on earth and the intrinsic value of biodiversity.

BIODIVERSITY

Find out more:
bit.ly/wildcru-golden-wolf

'We are now in an era where humans are the main affecters of biodiversity through climate change and we know that biodiversity is a buffer against our actions.'

Shaping the energy systems of the future

With energy supply responsible for 65% of global greenhouse gas emissions, the transition to renewable energy sources is a critical part of the fight against climate change. We have the resources and the technology – the challenge is creating a reliable supply of power, both for developed countries used to having electricity at the flick of a switch, and for developing nations for which a stable, affordable power supply is an essential foundation for economic growth.

Exactly how we go about transforming the energy landscape is the question that the Oxford Martin Programme on Integrating Renewable Energy, established in 2015, has set out to answer. Its ambition, broadly, is to build an understanding of how to integrate renewables while at the same time retaining a secure energy system, an issue which – above cost or availability – is now regarded as the main barrier to large-scale adoption of renewable sources. The challenges and uncertainties are both intrinsic – namely generation, distribution, storage and end use – and extrinsic, such as new technologies, business models and finance, social acceptability, and governance and regulation. The team, which includes economists, social scientists, materials scientists and engineers, set out to look at how all these factors influence and interact with each other, and what opportunities, synergies and constraints these interactions might present.

'The central question is, "How are our systems going to have to adapt and change to enable far more clean technologies to provide energy for society?" ' says Professor Malcolm McCulloch, who, with Professor Nick Eyre from Oxford's Environmental Change Institute, leads the programme.

'The impact of human activity is now making a substantial difference to the planet's ability to provide us with the services we depend on: fresh water, oxygen, stable temperatures, biodiversity – provisions that allow us to do everything from breathing through to making a mobile phone. We need to transform that environmental capital far more effectively, at much lower cost, and reverse some of those environment-to-society flows.'

Fossil fuel sources have been successful for many reasons. Key in this context is the relative simplicity they present for the energy system as a whole. 'The amount of land that a coal-fired power station takes up is very small and focused, whereas renewables tend to be distributed over much larger areas,' says Professor McCulloch, who is based at Oxford's Department of Engineering Science. 'Going from point-based resources to decentralised, distributed resources has strengths and weaknesses. You need far more power sources, but these sources can be located far closer to customers, be those individuals, businesses or even electric vehicle charging facilities. You'll also have a much wider range of people owning assets as the costs to start a solar "power station" are much smaller.'

All this is good, he says, but it means the system as a whole becomes much more complex and difficult to control. The ability to digitise information means it's no longer prohibitively expensive to create a smarter distribution system, but organisations face a big challenge in how they adapt to dealing with all that data.

Enter Project LEO (Local Energy Oxfordshire), whose underpinning basis was developed by the Oxford Martin programme. Announced in early 2019, the £40 million initiative was one of only four energy projects to win funding from the UK government's Industrial Strategy Challenge Fund. Led by distribution company SSEN, it will use Oxfordshire as a test bed to explore how local energy demand can be balanced with local supply, and will include renewable energy sources, electric vehicles, battery storage and vehicle-to-grid technology. LEO and the three other 'demonstrator' projects are designed to show how local systems approaches can deliver cleaner and cheaper energy, producing better outcomes for consumers and contributing to economic growth for the UK.

It's widely acknowledged that what's going to be required over the coming years is a fundamental change from our current distribution network operator model (DNO) to a distribution system operator model (DSO). A DNO can be thought of as the owner of the wires and the transformers, whereas the DSO would actively control the system, telling people whether energy needs to be put in or taken out, and what power sources need to be wound down.

'You can think of the DNOs as members of the orchestra, and of a DSO as the conductor,' says Professor McCulloch. 'Previously there was only a very simple piece of music being played, and the only decision to be made was whether another person could join the orchestra. But with the piece now getting more complex, the timing between the instruments gets more important.'

Exactly what the shape of the conductor's role will be, and who might fulfil it, are issues that have been worked through by Professor McCulloch and his colleagues on the Integrating Renewable Energy programme. They're now being tested in the real world with the LEO project.

The programme team's expertise is also helping to drive a number of other major energy initiatives, both in the UK and overseas. These include the Centre for Research into Energy Demand Solutions (CREDS), led by Professor Eyre, the Faraday Battery Challenge, the Energy Revolution Research Consortium (EnergyREV), and RELCON (Robust Extra Low Cost Nano-grids), a Global Challenges Research Fund project investigating radical approaches to new energy systems in Africa, which is being led by Professor McCulloch.

The push for change to UK energy systems is coming from both business and government, he says. 'Of course it's going to require a lot of investment. But you're balancing out the cost of the conductor with the cost of having assets that are uncoordinated. This way you are able to unleash a whole lot of capacity in the network that currently isn't available, because no-one is conducting the orchestra at the moment. The additional value created far outweighs the money spent.'

Find out more: bit.ly/integrating-renewable-energy

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Improving health around the world

There have been tremendous advances in improving human health over the past century, from the advent of antibiotics to the eradication of diseases like smallpox. However, rising populations, climate change and the emergence of drug-resistant diseases are increasing the health burdens of many countries and are likely to place an increasing strain on resources.

The annual WHO ranking of the top ten causes of death reflects the increase in lifespans globally, with ischaemic heart disease, stroke and COPD taking the top three places. But the presence of diarrhoeal diseases and tuberculosis in ninth and tenth place highlights the disparities.

Despite technological advances worldwide, access to basic necessities such as healthcare and sanitation remains a serious problem for many.

Professor Rob Hope, of Oxford's School of Geography and the Environment and the Smith School of Enterprise and the Environment, has been leading work in Africa and Asia to design and test performance-based models to improve the reliability and financial sustainability of rural water infrastructure for communities, schools and health clinics.

Rural water infrastructure breaks regularly and takes weeks or months to repair. Professional maintenance service models have improved repair times from weeks to days with water users paying a share of the costs. User payments are providing a platform to design new funding models to reward service delivery monitored over time rather than increasing access by building new infrastructure.

'Progress to achieve and maintain drinking water for everyone, every day requires rethinking the design and funding of current policy and practice,' Professor Hope said. 'We have evidence that professional maintenance models can unlock user payments at scale and attract matched funding. However, progress on reliable and affordable water must be complemented by ensuring water quality too.'

In response, collaboration with Professor Katrina Charles, also of Oxford's School of Geography and the Environment, is allowing measurement of the quality of the water, to ensure these systems are providing reliable and safe water.

'Communities have access to a range of water sources – from hand pumps, dams and rain,' says Professor Charles. 'They choose their water based on taste, affordability, availability and convenience. Our research will identify the health risks from these different sources and ways to ensure communities have useful access to safe water.'

The Malaria Atlas Project (MAP) at the University of Oxford's Big Data Institute has created the most comprehensive picture to date of the burden of *Plasmodium vivax* and *Plasmodium falciparum* parasites, which cause the majority of the world's malaria cases. Crucially, their work charts the change in distribution of the parasites over time from 2000 to 2017, revealing areas of progress and regions where the burden of malaria is still high or increasing.

Dr Katherine Battle, Director of Malaria Mapping for Elimination at MAP, said: 'Despite the global health burden of *P. vivax* malaria there has been little work to quantify it. Our research aimed to produce robust measures of burden with associated uncertainty, and generate maps at a fine local geographic scale to allow decision-makers to target interventions where the need is greatest.

'Challenges with both the diagnosis and treatment of *P. vivax* malaria make it a difficult parasite to target, so up-to-date assessments of trends and the global distribution of burden are essential to optimise control and elimination strategies.'

MAP's latest research showed that *P. vivax* dropped from 24.5 million cases in 2000 to 14.3 million cases in 2017, a drop of around 42%, confirming that current strategies to combat the disease are working successfully. But the study also revealed that in some places progress has plateaued or gone into reverse in recent years.

Some big data studies have revealed less encouraging news about diseases that, while less lethal than in the past, still place an enormous strain on healthcare systems.

Researchers at Oxford have compiled one of the most comprehensive studies of HIV around the world to create a map of the spread of subtypes of the virus across the world. The study, which included 400,000 samples from 116 countries over 26 years, showed which strains are dominant in which country and region, and where new strains are emerging.

Dr Joris Hemelaar of the University of Oxford's Nuffield Department of Women's & Reproductive Health, who led the research, said: 'It is unlikely that we will be able to end the HIV pandemic without a vaccine, but one of the challenges is the huge global genetic diversity of HIV-1 [the most common type of HIV in humans globally].

'Different HIV strains can differ by around 25%, whereas the yearly change in influenza is only a few percent, but necessitates a new flu vaccine every year.

'HIV vaccine immunogen sequences have to match, as closely as possible, the viral sequences circulating in the target population, which is why as much information as possible on the regional spreads of each subtype is vital for vaccine researchers.

'The analysis showed that subtype C causes the greatest number of global HIV infections (46.6%) and that subtype C is the dominant strain of HIV in southern Africa, where HIV prevalence is highest. A trial with a subtype C-specific HIV vaccine is currently under way in

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South Africa, the country with the largest HIV epidemic, offering hope of protecting people from HIV.'

As with malaria, the researchers stress the importance of keeping HIV tests up to date to ensure that when the virus changes new strains don't slip under the radar and go undetected in blood donor screening, surveillance, and clinical diagnosis and management. 'Early diagnosis and treatment are key to stopping the spread of HIV and being able to offer effective treatment,' Hemelaar adds.

Early and accurate detection is likely to play an increasing role in combating disease in the future, especially if we are to be able to stay ahead of the curve when spotting fast-spreading outbreaks of diseases such as Ebola and Zika.

In 2018 a new clinical research and response network for epidemic infections was launched in sub-Saharan Africa.

The African coaLition for Epidemic Research, Response and Training (ALERRT) aims to reduce the health and socioeconomic impact of disease outbreaks in sub-Saharan Africa.

ALERRT involves 21 leading African and European partner organisations, and has established a network of centres and clinics stretching across sub-Saharan Africa to conduct research on epidemic-prone infectious diseases which will respond quickly to outbreaks.

Professor Peter Horby, from Oxford's Centre for Tropical Medicine and Global Health, whose team coordinates the network, said: 'People who are suffering from epidemic infectious disease deserve to benefit from the fruits of clinical research as much as any other patient, and the broader benefits of such clinical research are even greater in the context of outbreaks.

'We want to deliver the evidence that is needed to improve patient care, including the evaluation of new diagnostics and treatment, but also the evidence to improve the control of outbreaks.

'Through ALERRT, we will see the creation of a sustainable clinical and laboratory research network, with the operational readiness to rapidly implement clinical and laboratory research in support of outbreak control efforts.'

A second way to tackle the issue of epidemic infectious diseases is to work on prevention. Vaccines are a powerful weapon against many diseases, and are especially effective once enough of the population has received them to create herd immunity.

Despite being rare in Western countries, typhoid is still a major cause of fever in children in low- and middle-income countries and is responsible for nearly 11 million cases and more than 116,000 deaths a year worldwide.

The Typhoid Vaccine Acceleration Consortium (TyVAC), which is co-led by researchers from the University of Oxford, has been carrying out a large field study in Nepal of a new vaccine against typhoid, involving 20,000 children and infants.

Andrew Pollard, Professor of Paediatric Infection and Immunity at Oxford University's Department of Paediatrics, who has been leading the trial in Nepal, said: 'Vaccination will play an important part in helping to control this serious disease.

'This vaccine has the potential to significantly reduce the burden of typhoid in high-risk populations that lack clean water and proper sanitation.'

CLIMATE

Find out more:
bit.ly/tropical-medicine

'Early and accurate detection is likely to play an increasing role in combating disease in the future, especially if we are to be able to stay ahead of the curve when spotting fast-spreading outbreaks of diseases such as Ebola and Zika.'

Economic growth and a healthier planet: are they compatible?

Think of life on Earth as a doughnut. In the middle are the foundations of a just and equitable human society: access to food, water, healthcare, education and so on. Around the outside are the delicate biophysical systems and growing environmental pressures inextricably tied to our planet's prosperity: climate change, biodiversity, ocean acidification, ozone depletion, nitrogen and phosphorus cycles. The ring is the 'sweet spot'– an appropriate term within this confectionery metaphor – in which humanity can thrive without endangering its environment.

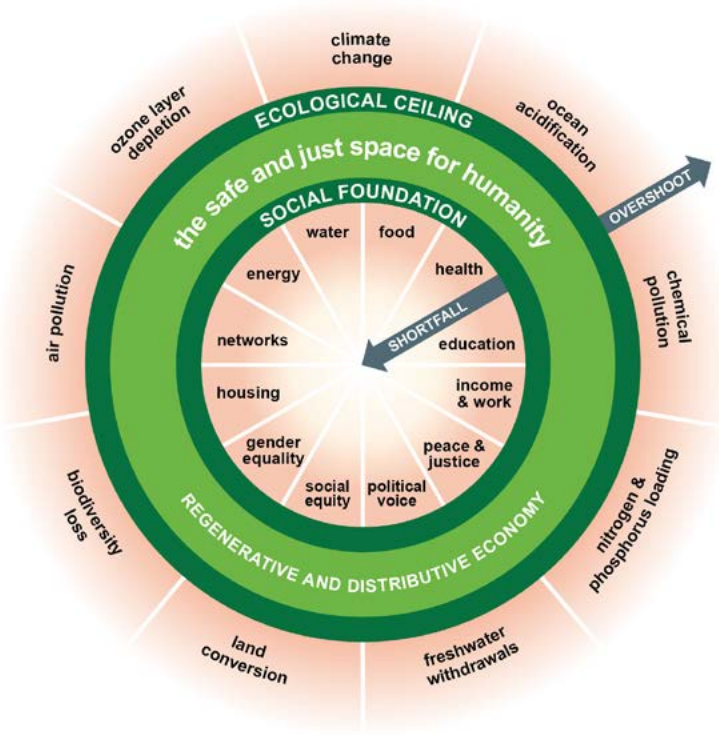
The idea of 'doughnut economics' is the brainchild of Kate Raworth, a senior visiting research associate and lecturer at Oxford University's Environmental Change Institute. Raworth proposed the framework in 2012, while working for Oxfam, to stimulate discussion around whether our constant desire for economic growth was pushing the world towards deepening inequality and ecological collapse. The goal, argued Raworth, should be 'meeting the needs of all, within the means of the planet'.

The intersection between the economy and the environment is clearly a complex one. For Cameron Hepburn, Professor of Environmental Economics and Director of Oxford's Smith School of Enterprise and the Environment, growth is not something to be shunned – but we need to find new ways of ensuring economic growth and planetary health are not mutually exclusive.

'Economic growth can and must be achieved alongside climate mitigation,' says Professor Hepburn. 'Stopping economic growth is unnecessary, undesirable and indeed probably impossible. But we need a new economic model that enables humanity to prosper within planetary boundaries.'

Professor Rick van der Ploeg, of Oxford's Department of Economics, agrees. 'Pessimists about technical change and the excessive consumption patterns in modern society argue that the only way to limit emissions and curb global warming is to shrink the economy. I think this view is overly pessimistic and starts from the premise that it is not possible to substitute clean for dirty production patterns and that it is not possible to move the direction of technical progress from dirty to clean research and development.

'A better policy is to jump-start the green transformation by subsidising green R&D and making sure those sectors of the economy that use renewable energy grow, and other sectors that rely on fossil fuels shrink. It is thus possible to curb global warming without lowering the overall growth rate of the economy.'



The doughnut economics model identifies a 'sweet spot' in which humanity can thrive without endangering the environment.

Clean growth – increasing national income while cutting greenhouse gas emissions – is one of the four pillars of the UK government's industrial strategy. Achieving continued growth is desirable, says Professor Hepburn, because 10% of the world's population still lives in extreme poverty. And while the transition to clean growth in a post-carbon world won't be easy for many sectors, the outlook for business is perhaps counterintuitively promising: a Smith School report on the connection between corporate social responsibility and profitability found that, in the vast majority of cases, sound environmental and sustainability standards lowered companies' capital costs and improved stock performance.

There is historical precedent, too, suggesting that economic growth and green policies can go hand in hand. Ryan Rafaty, a postdoctoral researcher on climate policy and energy transformation based at Nuffield College, Oxford, points to the 1973 oil crisis, when Arab states introduced an embargo on the exporting of oil to countries deemed to be in support of Israel during the Yom Kippur War.

He says: 'Sweden and Denmark today provide dramatic evidence that the curve of growth can go up while the use of carbon-intensive energy goes down. Denmark also provides a strong historical example. During the oil embargo in the early 1970s by the Organization of Arab Petroleum Exporting Countries, the price of oil quadrupled within a year for many Western countries. Responses to this crisis varied greatly: France and Sweden began stepping up their nuclear energy

'We need a new economic model that enables humanity to prosper within planetary boundaries.'

programmes, while in the US there was a tension between the rationing of oil and the instinct for growth and deregulation.

'In Denmark, though, there was a major political realignment. Being a small country dependent on oil imports, they were particularly affected by the shock and went into severe recession. But through a programme of Keynesian stimulus spending on an alternative energy sector, they were out of recession within a few years and had founded the Danish Energy Agency, which introduced a nationwide wind energy strategy. This state-led industrial policy, which included grants to farmers, cooperative ownership models and the first feed-in tariff, produced a domestic manufacturing industry that thrives today: Denmark still controls a large proportion of the global wind market. Crises bring about change, and the nature of that change depends on the character of a country at the time.'

He adds: 'It is possible to reduce emissions while increasing GDP per capita, as the UK has done, but there are a number of complicating factors: how do we deal with or compensate the declining industries? Are we being honest about our dependence on carbon-intensive imports? Is economic growth too much of a cherished dogma? Do we actually know what we mean by "clean growth"?'

According to Professor van der Ploeg, who is also Research Director at the Oxford Centre for the Analysis of Resource-Rich Economies (OxCarre), a range of policies will be required alongside the much-discussed subsidies for green R&D. He says: 'First, the IMF has calculated that the world subsidises fossil fuels to the extent of 6% of GDP. It is a no-brainer to scrap these subsidies immediately. This would include the exemption of carbon taxes for kerosene use by airlines, and for diesel use in shipping.

'Second, there should be an immediate moratorium on the use of coal – including coal-fired power stations. Third, there should be a gradually rising tax on carbon to encourage industry and households to make the move to clean growth. If those policies are implemented, there is a reasonable chance of keeping temperatures below the internationally agreed ceiling of 2°C or 1.5° C.'

Subsidies for green technologies are an example of what Professor Hepburn and colleagues working on the Oxford Martin School's Programme on the Post-Carbon Transition would call 'sensitive intervention points'. 'When it comes to stopping the climate crisis, the stakes are high and time is running out,' says Professor Hepburn. 'We can't afford to chase down every seemingly promising idea or persist with standard approaches that are not working. Instead, we need a smart, strategic approach that identifies a portfolio of interventions to generate effective and outsized impacts. We call these sensitive intervention points, or SIPs: social, political and economic situations where a small action can trigger rapid or dramatic change.

'Examples of SIPs include subsidies for renewable energy, which have enabled the real cost of solar photovoltaics to drop by around 10% a year since the 1990s, or one Swedish teenager kick-starting international protests. Changes to financial disclosure could be another SIP: most companies don't currently properly account for climate change risk. If they were required to do so, this could cause a substantial repricing of fossil assets, reducing emissions and transforming the energy industry.'

Professor Hepburn and colleagues at the Oxford Martin Net-Zero Carbon Investment Initiative have proposed a series of principles to help companies and investors address the moral and ethical questions they face in the context of rapid environmental change. Professor Hepburn says: 'The Oxford Martin Principles for Climate-Conscious Investment answer an urgent ethical question: should investors continue to fund fossil fuels or should they divest, sending a signal about the perceived illegitimacy of particular business models in a changing climate? The involvement of the commercial sector is essential to mitigate climate change. Divestment alone is not the answer, and indeed is potentially counterproductive – by definition if you sell, someone else buys, and the buyer is likely to care even less about climate than the seller. Instead, the principles provide climate-conscious investors with a science-backed framework to engage with firms and assess whether their investments are compatible with the transition to net-zero emissions.'

To comply with the principles, companies need to commit to reaching net-zero emissions, identify a plausible and profitable business model in a net-zero world, and produce quantitative mid-term targets compatible with their net-zero goals. Meanwhile, another Smith School concept – that of 'stranded assets' – is helping the business community get to grips with why environmental issues matter to the bottom line. With assets such as coal-burning power plants at risk of becoming devalued amid the move towards reduced carbon emissions, Oxford research is changing the way investors think about climate risk and helping shift capital flows away from environmentally unsustainable – and unprofitable – investments.

And when it comes to achieving those ambitious goals of clean growth, Professor Hepburn is optimistic: 'The transition to a post-carbon world will necessarily involve structural transformation in many economic sectors, but this means huge opportunities as well as challenges. Increased investment in clean technology has a significant role to play, as does clear regulation on net-zero carbon emissions and the reallocation of capital away from fossil fuels. Over the coming decades a shift to sustainable economics will accommodate the growth of human prosperity alongside environmental protection.'

Find out more at bit.ly/post-carbon-transition

'We not only drink water, but we swim in water, we sail or row on water, we walk along rivers, canals and lakes. We cherish water in various ways, but often neglect its social and cultural value at the same time.'

What is the value of water?

By Dr Kevin Grecksch

Whenever I start a presentation about water governance, I ask the audience if they know what the price of a litre of tap water is. Usually the room goes quiet, shoulders shrug and only a few make a guess, usually an overestimation. My next question is about the price of a litre of petrol. Within a split second, I get the right answer from the audience.

Water is indispensable, not only for humans, but for all living things. Yet our relationship with water is out of touch. In developed countries, drinking water is readily available everywhere: from the tap, the supermarket and the corner shop. Most of us take water for granted; many do not realise just how important water really is and what we use it for. Besides drinking water, water is used in production processes, both industrial and in the food and drinks sector. We trade water in reality and virtually, we regulate water, we divert water, we pollute water, we fight over water, we rely on water to cool thermal power plants and, most importantly, water will be the medium through which climate change impacts are felt and experienced. Water can also be a threat. Floods and droughts endanger and destroy livelihoods, kill people and animals, and contribute to the spread of vector-borne diseases.

Water is an important issue, if not the most important, yet at the same time it cannot be singled out as it is part of the wider environmental story. That story tells us about the interdependencies and links between water and other sectors, such as agriculture, energy, forestry, manufacturing and waste disposal. For example, a simple daily routine such as a hot shower involves not only the public water supply, but also relies on electricity or gas to heat up the water. Furthermore, water is a highly social issue. It is humans who make decisions about water, and who gets it and how much.

Sustainable water governance is therefore a precondition for successful climate change adaptation. Water governance describes the steering, coordination and decision-making processes of actors to govern water. This includes laws, regulations, public participation and education. A diversity of actors – policymakers, regulators, water companies, non-governmental organisations and consumers – have a role in this process. This differs from jurisdiction to jurisdiction and legacies play a major role in how public water supply is institutionalised in a country.

Water governance faces challenges such as population growth, rapid urbanisation and land use changes. Climate change and its projected effects will exacerbate this. Some regions will have more water, and others less. Increasing populations will lead to questions about access and allocation. A key issue is uncertainty: we simply do not know if and when the projected effects of climate change will happen, and to what extent.

In the context of climate change, the term 'adaptive water governance' is frequently used. What this means is that water governance needs to be flexible in order to adapt to uncertainties. Legislation and policies should not be set in stone, but reviewed at regular intervals to account for the latest research results or practical experiences. In some cases we need to be able to overcome current water policies and opt for new approaches. Cape Town's threat of a 'day zero' in 2018, where all taps would be turned off, led to drastic policy changes, which subsequently led to massive reductions in daily water consumption by the general public and businesses.

Flexibility also means catering for the different projected impacts of climate change across the world. This includes taking into account geographical, regional, social and cultural characteristics, and should result in tailor-made adaptation strategies. Public participation from the very beginning of a process, and not just to legitimise the outcome, should be an inherent part of adaptive water governance. Unfortunately, this is also one of the greatest challenges. Who are the stakeholders that should take part? Do they have enough staff and financial resources at their disposal?

Another key issue to overcome is the silo mentality we still find in environmental governance. While the scientific consensus is clear about the need to look at an issue like water in an integrated way, in reality we often find a silo mentality. This refers to non-collaboration across policy sectors, for instance among water, urban planning, agriculture and energy. Even within water governance, we often find that flooding and drought policy teams operate separately from each other and are not looking at the issue from an integrated perspective.

Water governance is a challenging task, but there are many positive and promising examples, policies and approaches available. Some great examples are catchment-based approaches, which look at a river catchment as a whole, or the Netherlands' 'water squares', public places shaped like a bath tub that function both as a playground and as a retention area for overflow water after a heavy rain event. It is those co-benefits, being good for climate change adaptation as well as fulfilling another function such as recreation, creating jobs or restoring wildlife, that are key.

We not only drink water, but we swim in water, we sail or row on water, we walk along rivers, canals and lakes. We cherish water in various ways, but often neglect its social and cultural value at the same time. Tackling this is a key challenge for water governance in the future.

Find out more:
bit.ly/oxford-water

Kevin Grecksch
British Academy Postdoctoral Fellow at the Centre for Socio-Legal Studies in the Faculty of Law

Heating up: extreme weather and climate change

As Earth's temperature rises, extreme weather events that were once a rarity are now becoming common occurrences around the world. Incidences of dangerous heatwaves, major hurricanes, floods and other natural disasters are on the rise, influenced by record temperatures and their effect on global weather patterns.

A key question for scientists is understanding the connection between extreme weather and climate change. It will inform our expectations of the weather we are experiencing today – and what dangers may lie ahead in the future.

'There is very solid evidence that heat extremes are occurring more often than they used to,' says Dr Karsten Haustein, a researcher in the World Weather Attribution team at Oxford's Environmental Change Institute (ECI). 'Temperature extremes, which could be defined as hot days – over 30°C in northern Europe – are increasing. This is the root cause for heatwaves, with knock-on effects for the water systems responsible for droughts and flooding.'

Dr Friederike Otto, acting director of ECI and leader of the World Weather Attribution team, has been working to analyse the effects of climate change on weather for almost a decade in order to find out how much of the increase in extreme weather can be attributed to climate change. 'We use weather observations and climate models: the same models used to do the weather forecast,' explains Dr Otto. 'By running two scenarios, one that includes the current amount of greenhouse gases in the atmosphere, and one with the human-caused fraction of the greenhouse gases removed, we can see what the world might have been like without man-made climate change.'

This process makes it clear how much our weather is affected by climate change. 'For example, we looked at the UK heatwave in July 2019, which would have been a once-in-40-years event,' says Dr Otto. 'However, with the current level of greenhouse gases in our atmosphere, we are looking at a one-in-eight likelihood. This means that climate change made the July heatwave five times more likely.'

While some people may enjoy the increasingly hot summers in the UK, it is not only northern Europe that is experiencing rising temperatures. 'The duration and severity of heatwaves are expected to get worse almost everywhere in Europe, North America, Russia, Australia, Southern Africa and parts of South America,' says Dr Haustein. 'Unfortunately, for tropical regions, this also means that the hot and moist conditions are exacerbated, with poorer – mostly Central African – countries bearing the brunt of climate change with very limited resources to adapt.'

While heatwaves are a danger in themselves, they also play a role in increasing the likelihood of other extreme weather events like flooding and droughts. 'Climate models and theoretical underpinning suggests an increase in both flood and drought risk, in many cases – counterintuitively – at the same time,' says Dr Haustein. 'Since warmer air has a higher capacity to hold water, it takes longer before it rains. If it eventually does rain, the rainfall has the tendency to be more torrential than it would have been without human-induced climate change.'

This effect will not be spread evenly around the world, however. 'Another way rainfall pattern can be influenced is by altered atmospheric circulation – basically, where and how weather systems develop. In contrast to the rising temperatures observed everywhere, this effect is very uneven from place to place and season to season,' explains Dr Otto.

Unpredictable weather systems present a danger of their own. 'We need to think about vulnerability and exposure,' says Dr Otto. 'Droughts in East Africa are a good example. Climate change is not playing a big role there yet, but the region is affected by a strong natural variability in rainfall year to year and a highly vulnerable population. Many regions in the world today are already struggling to adapt to the present climate; thus small additional changes can have dramatic consequences. Whether an extreme weather event turns into a disaster depends on how well prepared we are. And in every society, it is the most vulnerable that pay the price of a changing climate.'

So how can rising temperatures be stopped? 'Even if we decrease emissions, climate change will continue to occur, including the trend for more extreme weather events,' says Dr Haustein. 'This is due to the greenhouse gases already in the atmosphere. That said, every avoided tonne of carbon is reducing warming and therefore counts. The more and the faster we decrease global emissions, the fewer additional instances of extreme weather we are going to have in the future.'

Find out more at bit.ly/world-weather-attribution

'The duration and severity of heatwaves are expected to get worse almost everywhere in Europe, North America, Russia, Australia, Southern Africa and parts of South America.'

Securing the future of our global food system

By Professor Sir Charles Godfray

Charles Godfray
Professor of Population Biology and Director of the Martin School and the Oxford Martin Programme on the Future of Food

After a period of relative stability, global food prices suddenly rose in 2008 and 2010, leading to widespread instances of civil unrest and the fall of several governments.

Food security rose rapidly up political agendas, prompting a renewed focus on the question the demographer Thomas Malthus first asked at the end of the 18th century: can food production keep pace with an expanding global population?

The good news is that the rate of population growth is declining nearly everywhere, and we know what to do to encourage this: bring people out of poverty, provide access to reproductive healthcare, and provide education, especially for girls. Less good news is that better-off people demand diets that have a greater environmental footprint. Food production also faces increased competition for land and water, and will be negatively affected by climate change in ways that are not yet clear.

We are also experiencing an epidemic in diseases associated with overconsumption and obesity, not just in high-income countries but increasingly in middle- and low-income countries. More positively, scientific progress is constantly providing new tools to increase yields and to produce food more efficiently, with fewer negative effects on the environment.

The production, processing and consumption of food is a dynamically complex and interrelated whole that we call the food system. Policies can have unexpected consequences as their effects ripple through the food system: for example, subsidies to maize farmers led to cheap corn syrup, which has contributed to unhealthy diets and obesity.

There are also complex interactions between what is often called the food-water-energy nexus. For example, the poor choice of crops for biofuels can increase competition for water and land, and raise food prices.

Oxford University has always been active in many areas of research in food (and water and energy), but over the last decade it has made a major effort to bring together everyone interested in food to be better able to take an interdisciplinary and system-level approach to the challenges ahead. Supported by the Oxford Martin School, the Future of Food Programme lists nearly 100 academics with interests in food – roughly a third each from the medical, natural and social sciences, plus a smaller number from the humanities.

The programme is embedded within the Oxford Networks for the Environment (ONE), which facilitate 'nexus approaches' linking food researchers with those working on water, energy, climate change and biodiversity.

An example of an interdisciplinary project that arose from linking together food researchers from throughout the University is the Livestock, Environment and People (LEAP) project funded by a £5.5 million award from the Wellcome Trust's 'Our Planet, Our Health' programme. The project seeks to look at the multiple ways that the globally increasing consumption of meat and dairy is affecting the environment, our health and the economy.

A novel modelling approach combining economic, environmental and health modules allows the effects of policy change to be evaluated at national and global levels.

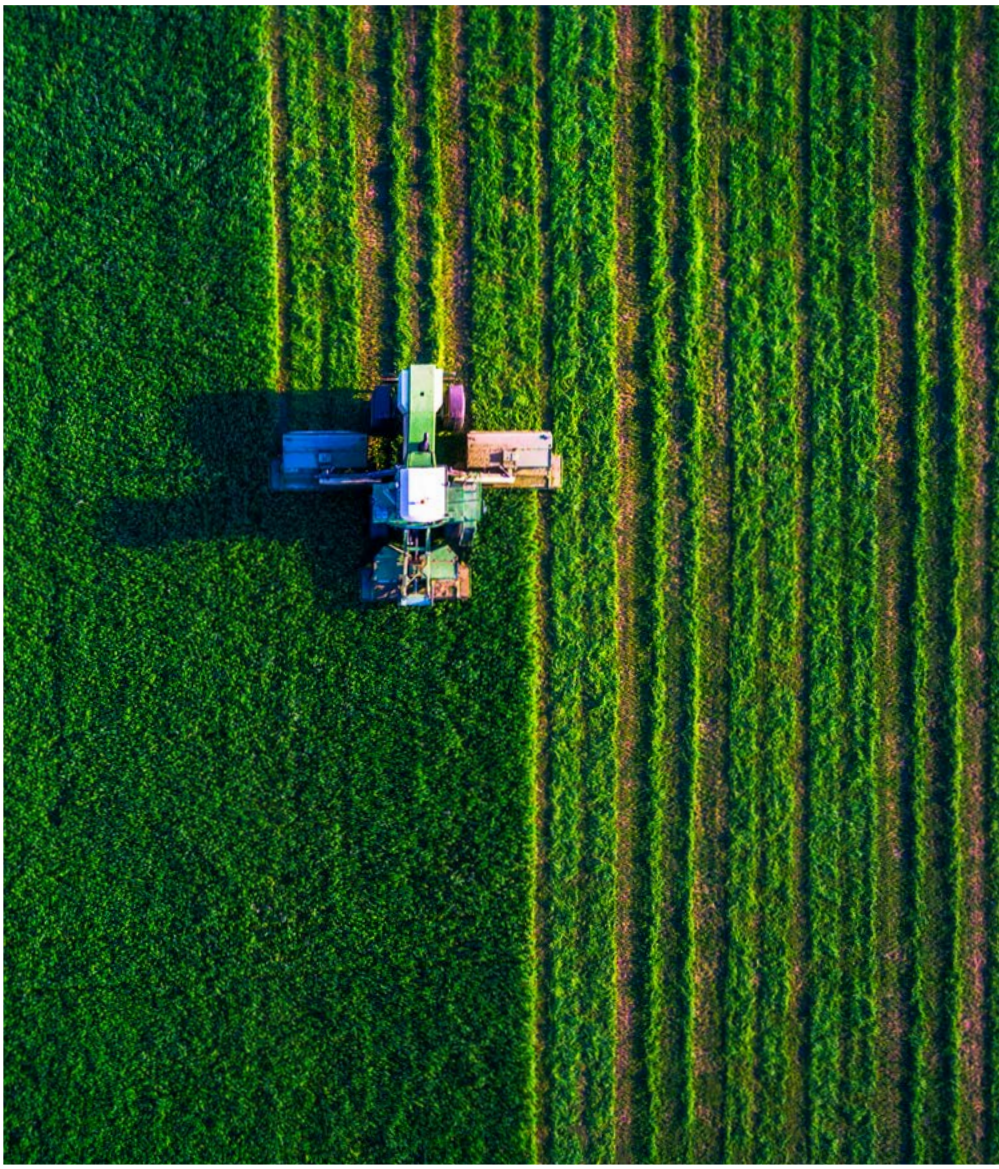
'The production, processing and consumption of food is a dynamically complex and interrelated whole that we call the food system.'

New analyses of large cohort studies are revealing unexpected links between meat and dairy consumption and health, both negative and positive. Using cutting-edge quantitative social science methodologies, researchers are tracking changing narratives about consumption and non-consumption of meat, and evolving attitudes to meat substitutes.

Working with other ONE groups, LEAP is developing new metrics for assessing the effects of livestock production on climate change, and looking to better understand how meat production affects competition for water and water quality, and how to mitigate its negative effects on biodiversity. Finally, nutritionists and behavioural scientists are using systematic reviews and experimental studies to work out what might encourage people to choose healthier and more environmentally sustainable diets.

With global population growth rates decelerating, it is now possible to conceive of a time when humanity's demands on the planet for food will plateau or fall. The next few decades will show whether there will be a soft landing, or whether Malthus was right after all.

Research at Oxford will, we hope, help to make the former more likely.



FOOD

Find out more:
bit.ly/food-futures

'Using cutting-edge quantitative social science methodologies, researchers are tracking changing narratives about consumption and non-consumption of meat, and evolving attitudes to meat substitutes.'

Harvest for the world: how do you feed a global population set to reach nearly 10 billion by 2050?

In October 2011, the world's population hit the milestone of 7 billion. Despite growth rates slowing down, this upward trend is predicted by the United Nations to increase by 2 billion persons in the next 30 years, from 7.7 billion currently to 9.7 billion in 2050.

As the planet's population continues to grow, so too will demand for food and space to produce it. Oxford University researchers are looking at ways of helping us to meet this demand, while also factoring in predicted changes in the climate and reducing the impact farming has on our environment.

Despite the size of the world's population, the bulk of our diet centres on a relatively small range of staple crops. 3 billion people depend on rice for survival, one of the staple crops of Asia.

Land that provided enough rice to feed 27 people in 2010 will need to support 43 by 2050, meaning yield increases of over 50% are required over the 2010 baseline.

Researchers from Oxford are leading on an international research consortium called the C_4 Rice Project, which aims to 'supercharge' rice to the level of more efficient crops such as maize.

Plants use sunlight, water and carbon dioxide to produce the carbohydrates that we need for food, through the process of photosynthesis. There are three different processes through which different species do this, which leads to their classification as C_3, C_4 or CAM plants.

Rice uses the C_3 photosynthetic pathway, which in hot, dry environments is much less efficient than the C_4 pathway used by other plants such as maize and sorghum. If rice could be 'switched' to use C_4 photosynthesis, it could theoretically increase productivity by 50% and would furthermore improve nitrogen use efficacy and drought tolerance.

Jane Langdale, Professor of Plant Development in the Department of Plant Sciences at Oxford University and Principal Investigator on this phase of the C_4 Rice Project, said: 'Rice yields need to increase substantially over the coming decades if they are to keep up with demand. Given that yield increases in traditional breeding programmes have essentially plateaued, this is not a trivial endeavour.'

Professor Langdale's team have recreated the first step of the likely three-step evolutionary process that transitioned C_3 plants to the C_4 pathway.

Professor Langdale says: 'The challenge now is to find the right genes to tweak to complete the remaining steps in the process.'

Wheat is another of the world's most important staple food crops, and is also a target of Oxford research into improving crop yields.

Researchers from Oxford's Department of Chemistry have created a synthetic molecule that, when applied to crops, has been shown to increase the size and starch content of wheat grains in the lab by up to 20%.

The method is based on using synthetic precursors of the sugar trehalose 6-phosphate (T6P) – a first-of-its-kind strategy that used chemistry to modify how sugars are used by plants. Professor Ben Davis, of the Department of Chemistry, says: 'The green revolution in the 20th century was a period where more resilient, high-yield wheat varieties were created, an innovation that is claimed to have helped save one billion lives. By developing new chemical methods based on an understanding of biology, we can secure our food sources and add to this legacy. That way we can make sure as many people as possible have access to enough food and that the less fortunate can be rescued from unexpected hardship.

'The tests we conducted in the lab show real promise for a technique that, in the future, could radically alter how we farm not just wheat but many different crops.'

The method has the potential to increase yields across a wide number of crops, as T6P is present and performs the same function in all plants and crops. It could also enhance plants' ability to recover from drought, which could ultimately help farmers to overcome difficult seasons more easily in the future.

'A vegan diet is probably the single biggest way to reduce your impact on planet Earth: not just greenhouse gases, but global acidification, eutrophication, land use and water use. It is far bigger than cutting down on your flights or buying an electric car.'

Another approach being investigated is finding ways to use less fertiliser for growing crops. Aside from the cost of applying fertiliser to crops, excessive use can cause pollution of watercourses around farmland.

Legumes are used in arable farming crop rotation to replace nitrogen in the soil that has been used by other crops, because their roots possess small nodules that contain bacteria which are able to fix nitrogen into the soil.

Researchers from Oxford have been engineering a synthetic plant-microbe signalling pathway that could be used to help other plants, such as cereals, to mimic this ability.

Philip Poole, Professor of Plant Microbiology at Oxford's Department of Plant Sciences, said: 'Plants influence the environment of the soil surrounding their roots by sending out chemical signals that attract or suppress specific microbes.

'Engineering cereal plants to produce a signal to communicate with and control the bacteria on their roots could potentially enable them to take advantage of the growth-promoting services of those bacteria, including nitrogen fixation.

'We have been using a group of compounds, called rhizopines, which are normally produced by bacteria in legume nodules. We have been able to transfer the synthetic signalling pathway to a number of plants, including cereals, and engineer a response by rhizosphere bacteria to rhizopine.'

Enhancing the root microbiota has enormous potential for improving crop yields in nutrient-poor soils and reducing chemical fertiliser use.

Professor Paul Jarvis, also of Oxford's Department of Plant Sciences, has been working to improve our understanding of how chloroplasts – the tools plants use to convert sunlight into usable energy – function and develop. 'When you investigate processes that are as fundamentally important as this, it can lead you into areas such as food security,' Professor Jarvis says. 'There seems to be a realisation in government that we need to explore all possibilities when it comes to food security. Although there are still significant public perception and acceptance issues in relation to GM technology that need to be overcome, there is a sense that we're shifting in the right direction.'

As the site of photosynthesis in plants, chloroplasts are of fundamental importance as the basis for all agricultural production, which is why Professor Jarvis' team believes that fully understanding the mechanisms that underpin their development and functions will be crucial to developing more stress-tolerant plants.

'Although our starting point was to understand the molecular mechanisms governing chloroplasts, when you make such discoveries you realise that there are implications – potential practical applications.

'Now our research priorities are to further characterise the CHLORAD system, and in parallel with that to explore how the system can be used in crops to improve their performance. The SP1 gene and the broader CHLORAD system act by regulating the amounts of the 1000s of different proteins that make up each chloroplast, and thereby control chloroplast functions including photosynthesis'.

Professor Jarvis believes that the most promising angle for this research is in improving plants' tolerance to environmental stresses such as salinity and drought.

'Everyone realises there is a food security issue,' he explains. 'Genetic modification is one of the tools that can be used to address that problem and we have to be open to it.'

Aside from the necessity of feeding a growing population, it is also important to assess just how much of an impact the food that we eat has on the environment.

One of the largest and most extensive studies to date was led by Joseph Poore from Oxford's Department of Zoology and the School of Geography and Environment.

Working with the Swiss agricultural research institute Agroscope, he assessed the environmental impacts of nearly 40,000 farms, and 1,600 processors, packaging types and retailers, to enable them to assess how different production practices and geographies lead to different environmental impacts for 40 major foods.

They found large differences in environmental impact between producers of the same product. High-impact beef producers create 105kg of CO_2 equivalents and use 370m² of land per 100 grams of protein, a huge 12 and 50 times greater than low-impact beef producers. Low-impact beans, peas, and other plant-based proteins can create just 0.3kg of CO_2 equivalents (including all processing, packaging, and transport), and use just 1m² of land per 100 grams of protein.

'Agriculture is characterised by millions of diverse producers,' says Joseph Poore. 'This diversity creates the variation in environmental impact. It also makes finding solutions to these environmental issues challenging. An approach to reduce environmental impacts or enhance productivity that is effective for one producer can be ineffective or create trade-offs for another. This is a sector where we require many different solutions delivered to many millions of different producers.'

Despite the complexity of the issue, the research identifies some simple ways in which individuals can reduce their impact on the environment, such as reducing the amount of meat and dairy in their diet.

Joseph Poore says: 'A vegan diet is probably the single biggest way to reduce your impact on planet Earth: not just greenhouse gases, but global acidification, eutrophication, land use and water use. It is far bigger than cutting down on your flights or buying an electric car.'

Find out more:
bit.ly/food-futures

Climate change and the humanities

By Professor Fiona Stafford

Scientists are measuring air pollution, monitoring ice floes and modelling global temperatures. Engineers are designing low-carbon transport, deflecting solar radiation and developing sustainable-energy power plants. Zoologists and plant scientists are analysing the effects of rising temperatures and receding habitats on the earth's flora and fauna.

And what are their colleagues in the humanities doing to combat the climate crisis? Quite a lot, actually.

Historians, philosophers, classicists, linguists and literary scholars may not be providing the physical evidence for global warming, nor the practical measures to mitigate the worst of its effects, but their insights into the complexity of human interactions may be just as important. Climate change is now widely recognised as an all-encompassing aspect of the human condition, with implications for almost every area of research in the humanities.

The last decade has seen the rapid growth of scholarship on historical and literary ecology, land use, nature writing, marine studies, botany, forestry, air, animal rights, natural disaster, travel and exploration, and climate catastrophe. Some are obvious responses to the prospect of global warming, focusing on futuristic dystopias starved of food, fuel and water, or on self-sustaining robots taking charge and seeing off humankind. Some are more concerned with shedding light on maritime history, migration, colonial expansion or industrial development – but everywhere, the relationship between humans and their environment is crucial to fuller understanding.

Even when research interests seem very remote from climate change, consciousness of the pressing questions of the 21st century can open new avenues of investigation, and new questions to debate. History, classics, literature, theology and anthropology all offer rich seams of materials relating to floods, fire, drought, famine and extinction – and vital evidence of how earlier generations and other societies have coped (or not). Individual and communal survival (and failure): these are the stuff of stories and histories. Older narratives and theories of human nature have much to tell us about human responses to fear and perennial ways of dealing with impending disaster.

It is not just the methods of resisting or adapting to challenging circumstances that matter, but also the way human beings relate to each other when confronted with a shared crisis. Byron's vision of a world gradually cooling after the death of the sun conjures up the very opposite of global warming and yet the real horror of his poem 'Darkness' lies in the imagined reactions of the diminishing human beings.

A charge commonly levelled in discussions of climate change is that so much work in the humanities is underpinned by anthropocentric assumptions. Arguments for the preservation of rainforests, green spaces, clean water, declining insect populations or endangered species often rest on their benefits to human beings – from air quality and food security to aesthetic pleasure, good health, or mental and spiritual wellbeing. This is unsurprising, given the centrality of the human to the humanities. But if climate change results from human mismanagement, narrow focus and short-term goals, then reversing climate change is a human responsibility, demanding long-term, lateral and inclusive thinking – and here the humanities can make important contributions to debate and dissemination.

Climate change is a global challenge: international understanding, which entails language, culture and law, is essential to mitigating its causes and countering catastrophe. A good story well told can distil truths in ways that speak to huge audiences far beyond the reach of the research centre. Three minutes' footage of a seabird feeding plastic to its chicks can be more affecting – and more effective on policy change – than hundreds of peer-reviewed papers on oceanic pollution. It's not that one form of truth is better or worse, but that different audiences respond to different media.

Climate change can be presented as a prospect so overwhelming and inevitable that it induces despair or denial rather than action. Of course, we need to recognise the scale of the threat and we need brilliant, practical ways of resisting climate catastrophe, but what's also needed in the face of this international crisis is deeper understanding of the psychological, imaginative, emotional, intellectual and political challenges – and belief in human capacity to change things for the better.

CLIMATE

Find out more: bit.ly/environmental-hums

***Darkness* (extract)**
By Lord Byron

I had a dream, which was not all a dream.
The bright sun was extinguish'd, and the stars
Did wander darkling in the eternal space,
Rayless, and pathless, and the icy earth
Swung blind and blackening in the moonless air;
Morn came and went – and came, and brought no day,
And men forgot their passions in the dread
Of this their desolation; and all hearts
Were chill'd into a selfish prayer for light:
And they did live by watchfires – and the thrones,
The palaces of crowned kings – the huts,
The habitations of all things which dwell,
Were burnt for beacons; cities were consum'd,
And men were gather'd round their blazing homes
To look once more into each other's face...

Fiona Stafford
Professor of English Language and Literature, Faculty of English

'Climate change is a global challenge: international understanding, which entails language, culture and law, is essential to mitigating its causes and countering catastrophe.'

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