SCIENCE INSIGHTS INTO OUR PLANET AND SOCIETY

No. 1 / 2020

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Future Earth is governed by the International Science Council (ISC), the Belmont Forum of funding agencies, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the United Nations University (UNU), the World Meteorological Organization (WMO), and the Science and Technology in Society (STS) forum.

Publication date
February 2020

Suggested citation
Future Earth. Our Future on Earth 2020.

www.futureearth.org/publications/our-future-on-earth

International Science Council

BELMONT FORUM

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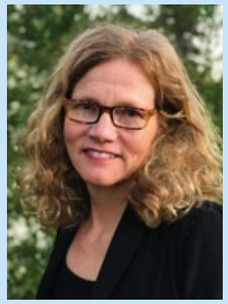

ABOUT THIS REPORT

Humanity is at a critical stage in the transition to a more sustainable planet and society. Our actions in the next decade will determine our collective future on earth. Making this planet a place where people can thrive in equity, prosperity, and peace is a task that falls to many hands.

Future Earth works to help build that common future. Formally established in 2015, Future Earth builds on more than three decades of global environmental change research that began with the International Geosphere-Biosphere Programme, Diversitas, and the International Human Dimensions Programme on Global Environmental Change. With offices in 20 countries and host to nearly 30 research-to-action networks, we collaborate with different societal groups to jointly develop knowledge that will accelerate transformations to global sustainability.

"Our Future on Earth" aims to tell the story of where we are on our collective journey by connecting the dots between what society is currently experiencing – from fires to food shortages to a rise in populism – with recent developments in the research community. Physical and social scientists have much to say about what is driving current events, and in this report science provides insight into how we might move in a more sustainable direction.

This inaugural report recounts how our future on earth is unfolding, while reminding us all that it is a future we are building together.

Amy Luers
Executive Director, Future Earth

OUR MOST URGENT TASK TODAY IS TO PERSUADE NATIONS OF THE NEED TO RETURN TO MULTILATERALISM

FOREWORD

Our world stands at a crossroads. We face existential threats that demand urgent action, from the climate crisis to the risk of nuclear war. In 2020, we need to make a bold, collective, and positive choice to work together to secure our common future, and not retreat into tired dogma, failed policies, or defeatism.

As someone who has worked on sustainable development and social justice for many decades, I firmly believe that a collaborative and inclusive approach is essential. As Minister of Environment in Norway in the 1970s, I became engaged in pursuing a pattern of development that could benefit everyone, protect our planet, and promote peace. I continued this agenda as Prime Minister in the 1980s, while I also chaired the UN's World Commission on Environment and Development.

I am glad to say that our 1987 report, "Our Common Future", became a landmark document that brought sustainable development to the attention of Presidents, Prime Ministers and Finance Ministers.

Today's world is immeasurably different from that of the 1980s. The Cold War is over, millions of people have been lifted out of poverty, and the internet has transformed how we communicate, opening up new conversations and breaking down barriers. But at the same time, deadly pandemics can spread at lightning speed in our interconnected, globalized societies; likewise, the scourge of terrorism respects no borders and does not adhere to the "rules of war" as codified under the Geneva Conventions.

The values and institutions of multilateralism are under attack, both from resurgent authoritarian rulers and cynical or weak politicians in established democracies. Faced with such a radical transformation of our economic and social paradigms, it is perhaps understandable that many people from everyday walks of life feel overwhelmed and seek solace in simplified narratives of a bygone "golden age" when they had a sense of being in control. What is profoundly irresponsible, however, is for politicians to collude in or deliberately stoke these illusions for their own aims of securing and sustaining power, in full knowledge that no one country, however powerful, will be able to meet these global challenges on its own.

The impressive array of articles in "Our Future on Earth" illustrates the extent of the challenge we face as global citizens, and also the inspiring and creative opportunities for transformational change, building on the activism of young people and those at the grassroots. When I look back at the words I wrote in the foreword of "Our Common Future" in 1987, I am struck by their continued relevance today:

"Our most urgent task today is to persuade nations of the need to return to multilateralism … the challenge of finding sustainable development paths ought to provide the impetus – indeed the imperative – for a renewed search for multilateral solutions and a restructured international economic system of co-operation."

As we face the future in 2020, I hope we can draw on the lessons from the past to strive ceaselessly for a better, fairer, cleaner, and more peaceful world for all.

Gro Harlem Brundtland
Founding member of The Elders,
Chair of the United Nations World Commission
on Environment and Development (1983–1987)
and former Prime Minister of Norway

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A network of fracking wells at the Oil and Gas Jonah field, Wyoming.

INTRODUCTION

CHARTING THE FUTURE

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author of Adventures in the Anthropocene
(2014) and Transcendence (2019)

It's an interesting time for humanity: we are a vast global population facing unprecedented environmental challenges, yet we still have the time and the capability to prevent extreme outcomes, such as runaway climate change and wildlife extinctions. The future is in our hands – but, for now, unequally. Our ability to act and adapt depends on our position in society. The future needs to be not just more sustainable but also more resilient and more fair.

This report provides a snapshot of our world at the start of 2020, helping to make sense of the state of this unique biophysical-human ecosystem we inhabit as a planetary-changing species. It combines up-to-date research with the latest world events, including physical and social science perspectives to explore where we are now, where we hope to go, and how we might get there. It also includes a novel survey of scientists to rank their top concerns for global systemic risks in the coming years *(see "Global Risks").*

HUMANS ARE NOW THE MAIN DRIVER BEHIND PLANETARY CHANGE

Humans are now the main driver behind planetary change, and human systems must be targeted if we are to do something about it. That means addressing societal systems including populism, finance, and information transmission, alongside the practices and technologies that emit greenhouse gases, from fossil-fuel burning to food production.

This is a particularly exciting time to look at these issues: the past year has been one of extraordinary social awakening to the hazards of environmental change, and of demands for action towards a sustainable future. As 2019 unfolded, people began talking of "climate breakdown" and demanding their governments and institutions declare a "climate emergency" (Oxford Dictionaries chose "climate emergency" as its 2019 word of the year). At the same time, there were calls for action on air pollution and single-use plastics.

Historians will surely argue over what spearheaded this sudden public engagement – outrage, even. There was no single factor, rather a combination of events, backed by more than three decades of work by the Intergovernmental Panel on Climate Change (IPCC). It was perhaps heralded by the nonagenarian naturalist David Attenborough, in a powerful episode of the BBC's *Blue Planet II* oceanic wildlife series in 2017, which portrayed albatross parents feeding plastic to their chicks. This prompted more than 80% of viewers to make some change to their own behaviour, according to one survey,[1] and is widely credited with general consumer demands for reducing plastics in packaging.

Towards the end of 2018, an IPCC Special Report spelled out the lesser impacts of heating the planet to 1.5°C above preindustrial levels versus 2°C, which was the target of the 2015 Paris Agreement. The main takeaway from this report was that limiting warming to 1.5°C would be far better for ecosystems and communities, and this requires urgent and aggressive action to reduce carbon dioxide emissions and remove greenhouse gases from the atmosphere *(see "Climate").*

Soon after that report's publication, a grassroots organization called Extinction Rebellion blockaded five bridges across the River Thames in London, causing widespread disruption and huge media coverage, demanding government action on biodiversity loss and a reduction in greenhouse gas emissions to net zero by 2025. Then, just a few weeks later, at the December meeting of the United Nations Climate Change Conference in Poland, Greta Thunberg, a 15-year-old Swedish schoolgirl, delivered an extraordinarily blunt speech – more of a call to arms – to heads of state. Thunberg's own journey had begun months earlier, with daily, solitary protests outside the Swedish Parliament, holding a sign calling for action on climate change.

This has occurred against a backdrop of extreme weather and ongoing warming. At the time of writing, 2019 was on track to be the second or third warmest year on record. In 2019, wildfires blazed across the northern hemisphere and Australia. Summer heatwaves produced temperatures above 45°C in Europe – above 50°C in India, Pakistan, and Australia – breaking temperature records and killing hundreds of people. Meanwhile, Arctic sea ice melted to its second lowest extent in the 40-year satellite record, alongside alarming melting of Greenland's ice sheet. A crippling drought coupled with poor infrastructure in Chennai, India – home to 10 million people – caused water shortages so severe that there were street clashes. Meanwhile, the heaviest monsoon in 25 years produced catastrophic floods across 13 Indian states and the loss of at least 1,600 lives. In Kerala, over 100,000 people had to be evacuated. In September, Hurricane Lorenzo became the largest and most powerful hurricane to make it so far east in the Atlantic that it reached Ireland and the UK, just weeks after Category 5 Hurricane Dorian devastated the Bahamas.

All of this has inspired action on a global scale, engaging young and old, rich and poor, escalating the pressure on governments and corporations. Thunberg's school strikes have been carried out on Fridays in countries across the world, with some coordinated protests involving over 1 million children. Extinction Rebellion activists have closed streets and businesses globally in countries including the United Kingdom, the United States, and Australia, generally garnering public support for their cause despite the inconvenience. Meanwhile, in the United States, Democratic congresswoman Alexandria Ocasio-Cortez started the year introducing a proposed Green New Deal: legislation for drastic measures to cut carbon emissions across the economy, from electricity generation to transportation to agriculture. In the process, it aims to create jobs and boost the economy. Although it has stalled in the Senate, there remains public support for the idea.

"Green deals" have been proposed by several nations, and if passed into legislation they could prove transformative. Most are at an early stage and there is no guarantee of mainstream support. The future, as always, is uncertain.

The most reliable projections about our future are demographic: we can predict roughly how many people will be alive in 2050 (9.7 billion). Towards the end of the century, however, even predictions about numbers of people become hazier: estimates range from 9–12 billion. Global population may well peak before 2100 and decline. We simply don't know.[2] It depends on a range of factors, such as the education of women and girls, which tends to reduce national reproduction rates. Crucially, it is not simply the number of people that is important, but where and how these people live. Currently, just a small, wealthy percentage of the global population is having by far the greatest influence on our planet.

Happily, the present is much more knowable and we have never had so many tools to help us. We can now see the changes we are making in real time, as we make them, from a planetary perspective: airborne surveys can spot the amount of photosynthesis in the Amazon, just as satellite images reveal the path of a churning hurricane as it approaches the islands of the Caribbean. Satellites chart the hourly change in temperature of the planet's surface, while clues from ice cores and leaf waxes reveal details of past climates.

Science now provides an important view of our planet from the macro to micro scales and across deep time, giving us new insight into the Anthropocene. But how will this knowledge be harnessed and used? Will we use it to make our future more or less equitable? More or less wild?

Into the Anthropocene

We are not the first generation to change our environment. Ever since humans first emerged onto the wild savannah, we have modified our home – burning our way through forests, hunting to vanishment the biggest animals, cutting terraces of rice into mountains, shifting rivers, and digging rock and mud to build our cities. But the changes humans have made in recent decades have been on such a scale that they have altered our world beyond anything it has experienced in its 4.5 billion-year history. Our influence is so profound it is pushing the planet into a new age that geologists are calling the Anthropocene: the Age of Humans.

Millions of years from now, a stripe in the accumulated layers of rock on earth's surface will reveal our human fingerprint just as we can see evidence of dinosaurs in rocks of the Jurassic, or the explosion of life that marks the Cambrian. Our influence will show up as changes in the chemistry of the oceans, the loss of forests and the growth of deserts, the damming of rivers, and the retreat of glaciers. The fossil records will show the

Congresswoman Alexandria Ocasio-Cortez introduced legislation for drastic measures to cut carbon emissions across the US economy.

extinctions of various animals (currently happening at 1,000 times the historic rate[3]), the chemical fingerprint of materials like plastic carrier bags, and the physical footprint of projects like the oil sands mines of Alberta, Canada, which annually move twice as much earth than flows down all the rivers in the world in a given year.

In the Anthropocene, humanity has become a geophysical force on a par with the earth-shattering asteroids and planet-cloaking volcanoes that defined past eras. Earth is now a human planet. We are now the most numerous big animal on earth, and the next in line are the animals we have created through breeding in order to feed and serve us. Four-tenths of the planet's land surface is used to grow our food. Three-quarters of the world's fresh water is controlled by us. Some 75% of the globe's terrestrial ecology has been significantly modified by humans.[4]

In changing the earth we have been able to live longer and healthier, in greater numbers than ever before. There are now nearly 8 billion of us. A 72-year-old man today has the same chances of dying as a 30-year-old caveman.[5] The chance of a child dying before the age of five has declined five-fold since 1950, and the number of women dying in childbirth has almost halved globally since 1990.[6] The world is becoming a safer place for a human to live and grow up in, largely due to modern medicine and affordable, plentiful food.

We have improved the planet for our survival in a number of ways, but we have also made it worse: using up its resources, killing off its biodiversity, polluting it with waste, and straining its capacity to support us. Some of those negative consequences we can overcome through technological advances, migration, or other adaptations. Others we will need to reverse. Some others we will need to learn to live with.

Humans are no longer just another animal: we have specifically human rights that are expected to be achieved through development, including access to sanitation and electricity – even the internet. Delivering social justice and protecting the environment are closely linked.

In 2015, the UN member states all agreed 17 Sustainable Development Goals (SDGs) for the year 2030, as a universal plan to achieve a better future for all, recognizing that all of our needs are intertwined with each other's and with our environment. The SDGs seek to address the global challenges we face, including those related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. We are one-third of the way through the timeframe to 2030, and despite progress in a number of areas, on some of the goals progress has been too slow or has even reversed. For instance, even though extreme poverty has reached its lowest point since monitoring began, we are still not on track to end it by 2030.

THE PAST YEAR HAS BEEN ONE OF EXTRAORDINARY SOCIAL AWAKENING TO THE HAZARDS OF ENVIRONMENTAL CHANGE

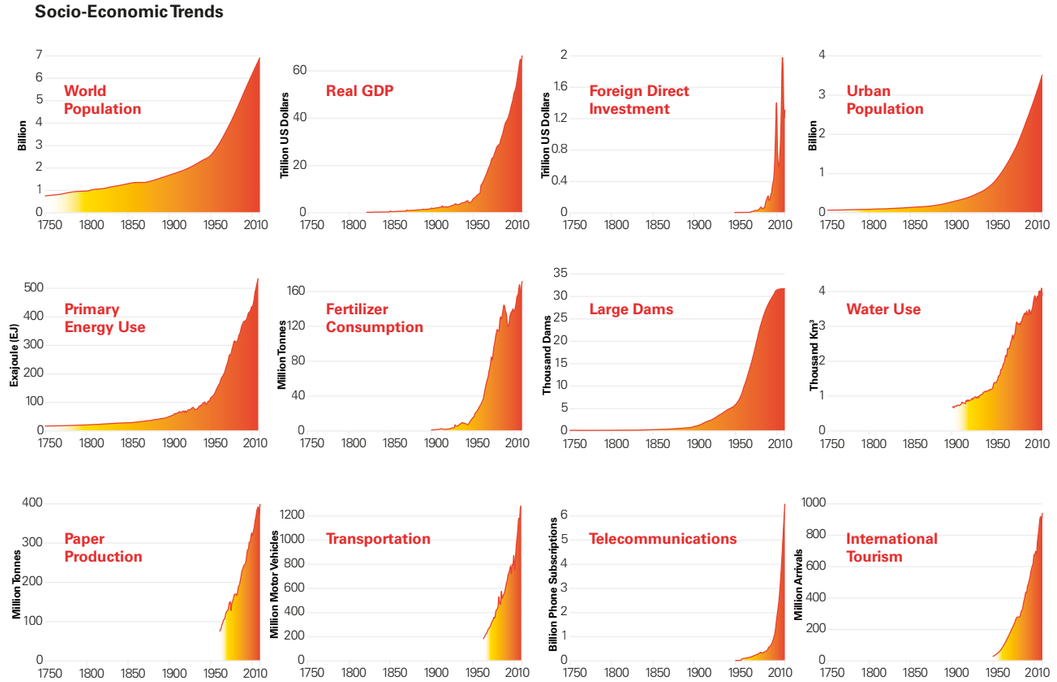
Joined-up thinking

The environmental problems we face are systemic: a mixture of physical, chemical, biological, and social change that all interact and feed back on each other. Trying to understand how our impacts in one area, such as river extraction, affect another, such as food provision, is a complex task. But that's what scientists, sociologists, economists, ecologists, and others are trying to do. And while our problematic practices in one area can impact many other areas, the good news is that so can our restorative ones: improving biodiversity in a wetland ecosystem can also reduce water pollution and soil erosion, and protect crops against storm damage, for instance. We are making our own Anthropocene and we can make it a good one.

The chapters that follow help to define our current state and identify the challenges we face in achieving a good Anthropocene. Crucially, they also suggest ways of improving our future prospects to create a sustainable society living within our environmental limits. By necessity these chapters are shaped by the authors' opinions, based on their own expertise and peer-reviewed research; other views of the future exist, of course, and together should help to stimulate further discussion.

As a species, our operations on the planet are organized through political structures, and the recent rise in the politics of populism is one concern identified by the authors in the chapters that follow. Populism is characterized by a denial of complexity, including the complexity of environmental damage and the systemic, multi-layered interactions required to achieve sustainability. Nevertheless, grassroots organizations, activists, and indigenous groups are beginning to join the dots between social justice and environmental protection. This is proving to be a powerful movement *(see "Politics")*.

Another important trend is the increasing financial risk of climate and environmental change – now named by insurers as the top risk for their industry. The first climate-change-related bankruptcy occurred in 2019, when California's largest electric utility company, PG&E, went under after sparking a huge forest fire. In the Anthropocene, the risk of natural disasters, extreme weather, and related human costs will increase, raising the price for insurance, resources, and other commodities. But our financial systems also have the potential to expedite our transition to sustainability. Green, socially responsible investments, loans,



Great Acceleration

Humanity's climbing influence on the planet can be seen across biogeophysical and social measures.

*Source: Adapted from Steffen, W. et al. 2015. The Anthropocene Review, **2(1)**, 81–89. https://doi.org/10.1177/2053019614564785*

A offshore oil rig during sunset, Australia.

and bonds are growing, helping to fund renewable energy projects for example. Green loans may even be less risky than traditional loans, because they are more resilient *(see "Finance")*.

Bolstering financial resilience must go hand in hand with increasing the resilience of our communities. Into the Anthropocene, people will need to adapt to changing and inhospitable conditions – extreme weather, coastal erosion, sea-level rise, depleted soils, heatwaves, and so on. Migration will continue to be an important survival adaptation, with the potential to improve lives and livelihoods for migrant and host communities alike. But impediments to migration can lead to increased human misery and loss of life. Much of this might be avoided with pragmatic planning that anticipates inevitable demographic change, and accommodates human movements with infrastructure and targeted social inclusion programmes *(see "Forced Migration")*.

Changes to where and how our global population lives are also having a massive impact on landscapes, nearly half of which are used to produce our food. Today, malnutrition rates are creeping upwards again for the first time in years, even as the amount of food produced per capita increases. As our population increases and a greater proportion desires meat diets, we will need to produce more food from increasingly degraded soils, in a less reliable climate, with ever more freshwater shortages. About one-third of food is wasted: in poor nations, this is often because of lack of refrigeration, poor roads, and other infrastructure issues; in rich nations, the waste happens after purchase, by supermarkets, householders, and food outlets. This represents significant opportunities to improve efficiencies. At the same time, improvements in irrigation, agricultural technologies, and a societal move towards reducing meat and dairy consumption offer hope for a more sustainable future *(see "Food")*.

The media plays an important role in how information is reported and contextualized, in holding powerful interests to account, and in amplifying the voices of marginalized communities. In 2019, we have seen a continuation of the spread of fake news, often funded by those with a vested interest in preventing social justice and environmental legislation. On the other hand, we have also seen the beginnings of a fightback by fact-checking groups, including Full Fact in the United Kingdom. Following fake news scandals that influenced elections in the United States, Kenya, and Europe, social media barons may also be held to account – there are signs that Facebook may face tighter regulation *(see "Media")*.

Despite these problems, digital media remains a vital part of the communication and collaboration tool that enables people from around the world to transmit knowledge, share ideas, and find solutions to our social and environmental problems. Digitization of other systems could improve sustainability. For instance, digital monitoring of resource use, such as water and fertilizer in agricultural production, could lead to greater efficiencies and help to change behaviours *(see "Digitial Innovation")*.

Unusually, there is no IPCC climate report being published in 2020 (although scientists are preparing major reports and international meetings in 2021 and 2022). It will, however, be an important year for the ocean, with the first international treaty being hashed out to protect earth's last wilderness, the high seas, from overfishing, deep-sea mining, and other threats *(see "Ocean")*. And the Convention on Biological Diversity will meet in Beijing in 2020 to negotiate a New Deal for Nature. In part this is an attempt to extend the agreement reached in 2010 to halt biodiversity loss by 2020, which has manifestly failed despite a few individual success stories *(see "Biodiversity")*. Perhaps the biggest policy decider, however, will be the US presidential election this year, which, apart from its role on the international stage, will set national funding for environmental and social projects, legislation, research, investment, and the nation's commitment to achieving sustainable Anthropocene conditions.

There is reason to be hopeful: there have never been as many areas of land and sea under some sort of conservation protection – the tiny Pacific island nation of Palau is to close off 80% of its marine area (an area larger than California) to commercial fishing and mining, to create a marine sanctuary for its 1,300 species of fish and 700 types of coral, for instance. There has also been a growth in urban farming and architectural ecosystems – city planners are increasingly greening artificial spaces with parks and gardens, creating novel ecosystems that encourage urbanites to get closer to nature.

The changes we need to make are huge; transformational. We need entirely new ideas about how to incentivize businesses, measure progress, value diversity, and acknowledge the importance of social equity. Such transformations are possible – they have happened before and must happen again *(see "Transformation")*. But even such major reformations of how society functions consist of the individual agency of voters, consumers, gardeners, parents, and witnesses.

In 2020, we can no longer claim we are unaware of environmental change – it is depicted everywhere across our media. Every day, our small and large choices ripple across society and are multiplied and added into the greater wave. Even if some environmental changes feel too locked-in or overwhelming to reverse, we have the power to change the social justice systems that underlie and manage their impacts on us. We live in our own small local environments that we can ourselves defile, restore, or enhance. Each is a part of the bigger whole, just as we are part of a bigger humanity.

GLOBAL RISKS

A SURVEY OF SCIENTISTS' PERCEPTIONS

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A survey by Future Earth of more than 200 scientists has revealed five global risks that have the potential to impact and amplify one another, in ways that might cascade to create global systemic crisis: failure of climate change mitigation and adaptation; extreme weather events; major biodiversity loss and ecosystem collapse; food crises; and water crises.

These are issues that already consume huge amounts of press and academic attention – they are highlighted, too, in some of the chapters of this report *(see "Climate", "Biodiversity", and "Food")*. But the emphasis of the survey results is that it is the interplay between these five risks that is most concerning.

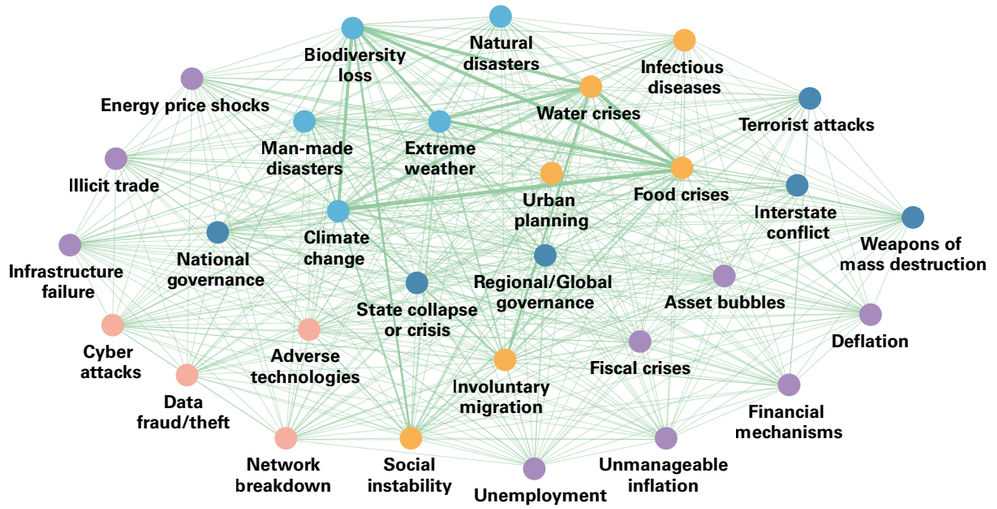
Various subsets of these risks also turned up as key issues across the various questions posed to scientists in our survey. Four of the five – climate change, extreme weather, biodiversity loss, and water crises – were perceived as the most likely and most impactful risks currently facing humanity. Two of them – climate change and biodiversity loss – were also the ones or which society seems to be currently locking in undesirable futures.

As the scientific advisors for this survey, we call on the world's academics, business leaders, and policymakers to pay urgent attention to these five global risks, and to ensure that they are treated as interacting systems, rather than addressed one at a time, in isolation. Appreciating their potential integration and interaction is critical for addressing the human and planetary challenges that lie ahead.

A web of risks

The new survey complements and expands other efforts to assess the likelihood and importance of various risks facing humanity and the planet. The World Economic Forum (WEF), for example, has been conducting a Global Risks Perception Survey since 2006 that targets decision makers across business, policy, academia, and civil society. Its 2019 Global Risks Report compiled answers from nearly 1,000 decision makers, who identified extreme weather and failure of climate-change mitigation and adaptation as the gravest threats over the coming ten-year horizon.[1]

In 2019, Future Earth undertook a survey of global change scientists' perception of risks. The participation of scientists both within and outside the Future Earth community was solicited using various social media outlets, email lists, and word of mouth. As a starting



Interconnected Risks
The network of potentially synergistic risks with the potential to lead to a global systemic crisis. The colour of the node indicates the category of risk (light blue=environmental; orange=societal; dark blue=geopolitical; pink=technological; purple=economic). The thickness of the lines connecting two risks represents the frequency of responses identifying a synergistic interconnection between them. *Source: Future Earth Global Risks Scientists' Perception survey, 2019*

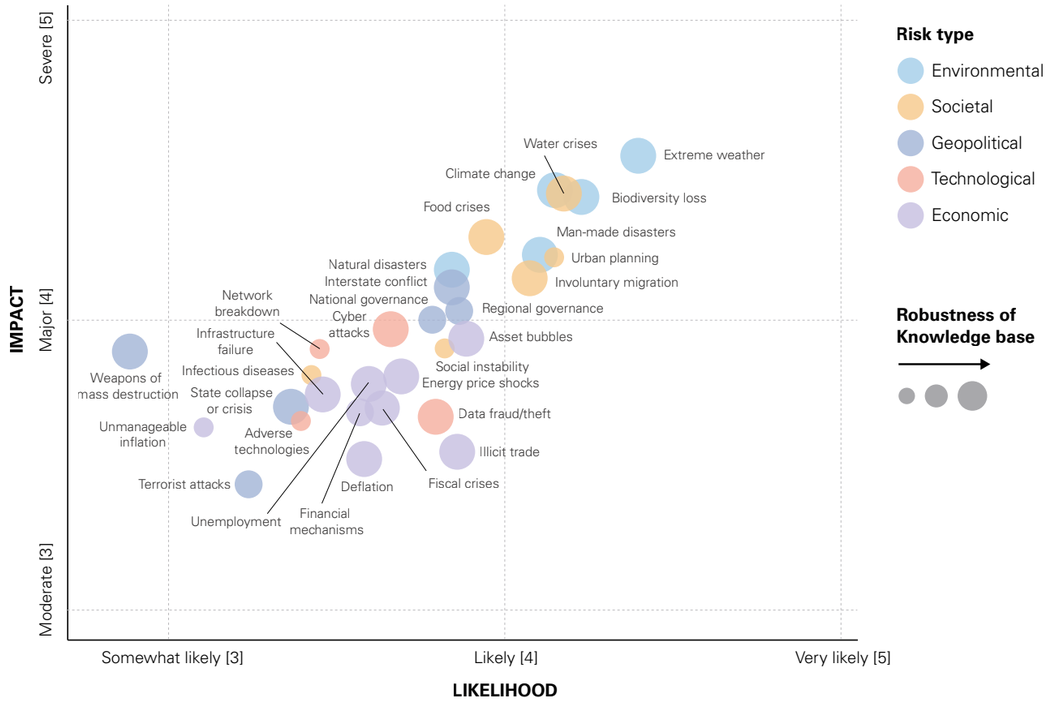
point the survey draws from the list of WEF top 30 global risks. Participants were asked to identify groups of risks most likely to have synergistic effects that could lead to a global systemic crisis; to share their perception of the likelihood and impact of these global risks; and to identify other emergent global risks.

In the end, responses from 222 scientists from 52 different countries were analysed (where "scientists" were defined as respondents having at least a master's degree and more than one year of experience in a scientific field). The "Future Earth Risk Report 2020" including the full survey methodology and results, is published concurrently with this report and can be found at https://futureearth.org/initiatives/other-initiatives/grp.

Not every respondent answered every question. When asked to identify clusters of global risks from among the list of risks that are most likely to have synergistic effects and possibly lead to a global systemic crisis, 82 scientists replied. A network map of those responses reveals how all assessed risks are embedded in a complex web of interdependencies, with a clear top five *(See Figure: Interconnected Risks)*. An event in any one of these dimensions could potentially trigger events in connected realms, multiplying the likelihood and impact of risks.

The potential for crises arising from interactions is well known; society has seen many crises coming from sometimes-unexpected cascading impacts across systems. In China, sleet and snowstorms of 2008 led to massive failures in the power grid across 19 provinces that interrupted basic transport; this stranded 6.5 million people, and disrupted distribution of basic goods including food and coal, leading to food price hikes and the shutdown of coal plants, further exacerbating the power crises.[2] The introduction of Arctic foxes onto remote Aleutian Islands by Russian fur trappers in the 1940s decimated seabird populations, whose guano provided the primary source of nutrient to the ecosystem, causing the islands to shift from a productive grassland to an impoverished tundra ecosystem.[3]

There are also well-known connections between the top five identified risks. Many extreme weather events have been clearly attributed to climate change, and climate change is making such events more frequent and intense.[4] In some cases, extreme weather events exacerbate climate change by triggering the release of carbon stored in terrestrial ecosystems.[5] Extreme weather events such as heatwaves or droughts impact crop production and water availability:



Likelihood and Impact
Mean ranked likelihood and impact of global risks and robustness of the knowledge base surrounding each risk (size of the circle) for the 30 global risks in 5 categories (colors). *Source: Future Earth Global Risks Scientists' Perception survey, 2019*

for example, after the 2012 heatwave in the United States, maize yields dropped by 13%.[6] Changing rainfall patterns predicted by many climate change scenarios are expected to make food and water crises more frequent and more severe.[7] Importantly, biodiversity can help buffer these effects: more-diverse grass and cropping systems are more productive than less-diverse systems when put under stress of climate extremes.[8,9] We are only beginning to piece together the ways these different systems interact, and other, unknown or unanticipated, interactions are also likely.

Despite this ubiquity of connections, many scientists and policymakers are embedded in institutions that are used to thinking and acting on isolated risks, one at a time. This needs to change to thinking about risks as connected.[10] Global agreements such as the United Nations conventions on climate change (UNFCCC), biological diversity (UNCBD), and desertification (UNCCD), among others, must work together to ensure that cross-cutting and interacting risks are considered as a system.

On the horizon
Four of the five top interconnected risks were also identified by survey participants as the most likely to occur, with the most significant impacts, and with a solid scientific understanding underlying those assessments. Collectively, our 221 survey respondents with complete answers perceived the likelihood and impact to be strongest for a group of four environmental and social risks – extreme weather, climate change, biodiversity loss, and water crises *(See Figure: Likelihood and Impact)*. These were each ranked as having a solid base of science underpinning their assessments. Interestingly, similar patterns emerged in the WEF report, which had extreme weather and climate change topping its list.

We also asked participants to identify risks for which they believe society may be committing to in the next decade with potentially catastrophic outcomes, or for which we may pass a threshold that will trigger longer-term catastrophic effects. In other words, we asked which risks have impacts which we may already be "locking in". Respondents provided their own answers here, rather than selecting from the list of 30 global risks. Out of the 69 responses, the most common answers were overwhelmingly focused on biodiversity loss and ecosystem collapse, and climate change.

Finally, we asked survey respondents if they considered that there were additional risks, not on our list, that should receive greater attention from the global community. A number of themes emerged from their 173 responses, including: the erosion of societal trust and values; deterioration of social infrastructure; rising inequality; a rise in political nationalism; overpopulation; and a decline in mental health. Interestingly, the majority of these touch on issues of societal well-being and social security, suggesting that societal risks may be growing and in need of greater consideration. This is especially pertinent as we consider how society can transition to a climate-safe and equitable future in light of climate

These five risks, or a subset of them, showed up repeatedly across the different questions of this survey

CLIMATE CHANGE
EXTREME WEATHER
BIODIVERSITY LOSS
FOOD CRISES
WATER CRISES

change and extreme weather being identified as the top risks in the current survey. Perhaps the most interesting theme to emerge from these responses was the failure to take into account feedback across different systems.

Many respondents provided narrative descriptions of compounding effects across environmental, societal, economic, technological, and geopolitical systems. As one respondent noted, "While extreme climate events are weakening the societal governance and infrastructure, food and water security will become more and more serious, causing large-scale immigration and further inequity. If several geopolitical crises occur in parallel, many states cannot handle the situation properly, due to lack of resources and with the internal conflict, it would cause catastrophic outcomes all over the world."

Given this repeated emphasis on the interconnectedness of risks, along with scientists' identification of the top five interconnected risks for global systemic crises, we urge that this nexus be ever more on the radar of decision makers and policymakers.

In order to avoid these threats and mobilize collective action, it will be imperative to engage different communities in dialogues on global risks and create a shared sense of risk. To this end, Future Earth will continue to administer the Global Risks Scientists' Perception survey annually, to foster a meaningful discussion with decision makers, business leaders, and civil society, and to develop paths to ambitious yet feasible collective action.

CLIMATE

DIALLING DOWN THE HEAT

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Extinction rebellion protester in Neuchâtel, Switzerland, September 2019.

In the summer of 2019, just after thousands of schoolchildren had taken to the streets to protest lack of action on climate change, the northern hemisphere was gripped by heatwaves. In the United States, Alaska saw record-breaking temperatures of more than 30°C, a full 10°C above normal. At the end of July, the Japanese government reported that 11 people had died and more than 5,000 were sent to hospital in a single week from heat. Across Europe and India, unprecedented heatwaves brought temperatures higher than a scorching 45°C.

Conditions like these are now being called the "new normal" by scientists and media, along with the associated increased risk of wildfire, heat death, water shortages, and power outages. The World Weather Attribution project, which aims to rapidly assess climate change's contribution to such extreme events, determined that every heatwave seen in Europe in 2019 had been made "more likely and more intense by human-induced climate change"; France's extreme June temperatures were determined to happen ten times more frequently today than a century ago.

The warming is global. In the Arctic, the last five years have been the warmest on record, and a combination of warming temperatures, sea-ice decline, and permafrost melting is triggering a cascade of impacts on wildlife, fisheries, and local communities much sooner than anticipated. In Greenland, a heatwave caused unprecedented ice-sheet melt of almost 200 billion tons in July 2019, enough to raise sea level by 0.5 mm.[1] In the oceans, marine heatwaves have doubled in frequency since 1982 and are now more intense.[2]

Over the last 18 months, major assessments by the Intergovernmental Panel on Climate Change (IPCC), the US National Climate Assessment, and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), have all argued that time is running out to reduce the greenhouse gas emissions that are causing the climate to warm. This has inspired declarations of a climate crisis or climate emergency by the leaders of more than 700 cities, states, and governments, including the Scottish, Irish, Portuguese, French, and Canadian governments, Sydney City Council in Australia, the Cities of Milan and Naples in Italy, the cities of New York and San Francisco in the United States, and a global network of 7,000 universities.

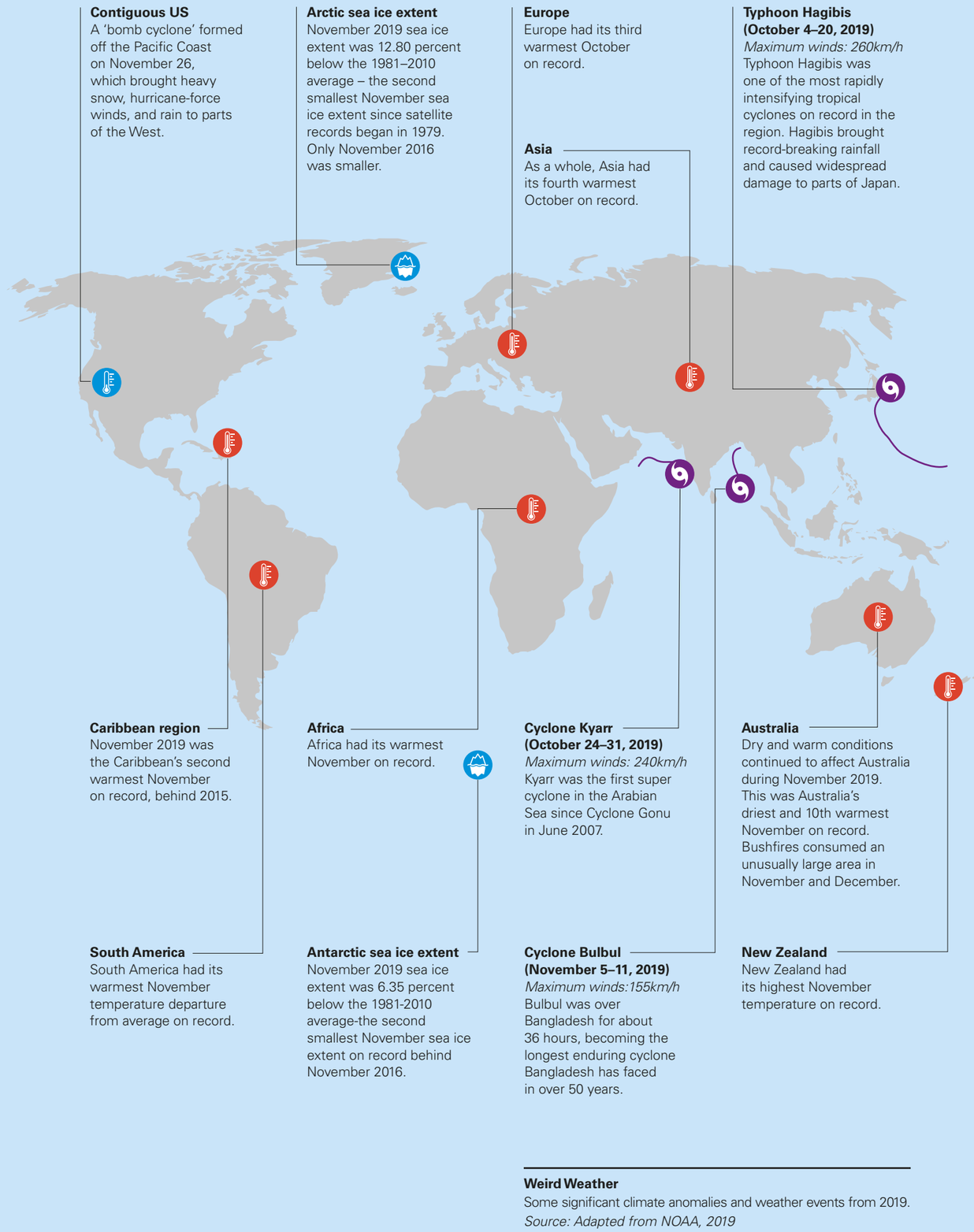
Greta Thunberg at the climate strike protest in Montreal in September 2019.

Humanity's response to this crisis, including the 2015 United Nations (UN) Paris Agreement, has not yet been sufficient to halt climate change. During 2019, the concentration of carbon dioxide in the atmosphere reached more than 415 ppm, and the five years from 2014–2018 were the warmest recorded over land and ocean since 1880.[3] Ice core records suggest that CO_2 has not been this high, nor risen so fast, in at least 800,000 years, and today's temperature is likely the warmest in 100,000 years.

While the amount of energy produced from carbon-intensive coal is declining, and energy from renewables is on the rise, these factors have not yet changed the trajectory of global emissions.[4] The Global Carbon Project estimates global emissions from CO_2 at 37 Gigatons (Gt) for 2018. That's an increase of 2.1% over 2017 after several years of slower growth.[5] While some analysts are optimistic about the falling cost of renewables and the growth of the electric vehicle market, they also note that use of fossil fuels, especially gas, is still growing in many national energy portfolios, and nuclear energy faces barriers to expansion in many countries. The global fossil fuel market shows few signs of the reversal and rapid decline needed to slow or stabilize global warming.

In the face of all this, youth and other civil society groups across the world are demanding urgent action on climate change.

Students have gone on school strikes and marches in more than 70 countries demanding action on climate change and have sued their governments for the right to a clean environment. Greta Thunberg, a Swedish teenager who took Fridays off school to protest outside the Swedish parliament, became a spokesperson for the youth climate movement, addressing UN climate summits, the World Economic Forum, and the European Parliament. New social movements arose to protest climate breakdown, including the Sunrise Movement in the US which advocates for political action on climate change including a Green New Deal; and Extinction Rebellion in the UK, which asks governments to declare a climate emergency and reduce greenhouse gas emissions to net zero by 2025.



Weird Weather
Some significant climate anomalies and weather events from 2019.
Source: Adapted from NOAA, 2019

The Special Report on 1.5°C
In October 2018, the IPCC released its special report on "Global Warming of 1.5°C".[6] This provides an important and focused benchmark on the state of the climate, and an assessment of current efforts to limit global warming. The report received widespread public and media attention, and its findings continue to inform policy discussions across the world.

The 1.5°C report was unanimously approved by all countries at the intergovernmental plenary in Incheon, Korea, although some pro-fossil-fuel countries tried to undermine it at a subsequent meeting of the UN Framework Convention on Climate Change (UNFCCC). As indicated by its name, this report has a particular focus on the impacts of a global warming of 1.5°C, especially as compared with the UN's target of limiting warming to 2°C. It examines the pathways and options that might limit warming to 1.5°C and how response options might interact with sustainable development.

The IPCC report finds that human activities have already caused 1°C of global warming above pre-industrial levels, with global mean temperature estimated to reach 1.5°C before 2050 if current trends continue. The warming so far is higher over land than over the ocean and is up to three times higher in the Arctic. In the past, warming of 1–2°C has dramatically shifted ecosystems and increased sea levels by several metres over millennia. Today, warming has already resulted in significant impacts on natural and human systems such as coral reefs, ice cover, water resources, and health – and these impacts are expected to increase as the world warms further.

Although many countries have pledged to reduce their emissions under the UN Framework Convention on Climate Change Paris Agreement, the promised cuts are not enough to limit longer-term warming to 2°C, let alone 1.5°C.

Without the Paris pledges, overall emissions (CO_2, methane, and other greenhouse gases) are projected to increase from about 51 Gt of CO_2 equivalents in 2015 to 74–110 Gt by 2050. This would produce a warming of more than 4°C by 2100.[7]

The current Paris pledges and other policies, if implemented, would still result in global greenhouse gas emissions of 52–59 Gt by 2050 and a warming of 2.7–3.5°C: less than business as usual, but far higher than any pathway that would limit warming to less than 2°C.

The difference in impacts between 1.5–2°C are significant. At 2°C, the planet loses 99% of tropical coral reefs; at 1.5°C, about 10–30% of these reefs are projected to survive. Fishery losses could double from 1.5–2°C. Both levels of warming are expected to cause serious impacts on marine biodiversity, ocean acidification, and the livelihoods and economies of coastal-dependent communities such as those in South East Asia, the Caribbean, and the Pacific islands.

Limiting warming to 1.5°C rather than 2°C reduces the number of people exposed to climate risks and susceptible to poverty by several hundred million by 2050. Crop yield declines are much greater at 2°C, and the population exposed to heat and water stress is 50% higher at 2°C than 1.5°C. In Africa, the number of people at risk of hunger drops from 55 million to 43 million if we can limit warming to 1.5°C. In the Global South, 420 million fewer people would be exposed to heatwaves by limiting warming to 1.5°C.

The greater the warming, the greater the anticipated impacts of heatwaves in cities, mainly in places of high urbanization rates, poverty, and marginalization in South East Asia and Latin America. In urban centres, such as the megacities of Mumbai or Jakarta, each degree of warming is expected to further reduce productivity for people working outdoors or without air conditioning. A warmer world has higher risks of flooding, landslides, fire, and infectious and parasitic disease (*see box "Health hazards"*).

It is clear that every bit of warming matters, especially for the most vulnerable people and places. And the costs of adapting our world to 2°C will be higher than the costs of adapting to 1.5°C.

THE PROMISED CUTS ARE NOT ENOUGH TO LIMIT LONGER-TERM WARMING TO 2°C, LET ALONE 1.5°C

Mitigating and adapting to climate risk
The IPCC report suggests that for a good chance to limit warming to 1.5°C, global net anthropogenic CO_2 emissions need to decline by about 45% between 2010–2030 with similar deep reductions in other greenhouse gases. Given that we are already approaching 2020 and, so far, emissions are continuing to increase, this decline will need to be even steeper to meet the 2030 goal.

Net-zero emissions are needed by 2050. This means that whatever emissions are produced by human activity must be balanced by the removal of greenhouse gases by natural systems (like plants) or negative emission technologies (like bioenergy or capturing and storing carbon).

These emissions figures and projections are global averages. The IPCC 1.5°C report did not address who should be most responsible for making emissions cuts. Because CO_2 remains in the atmosphere for decades, some scholars, organizations, and governments believe that those with the greatest historical responsibility for emissions should make the greatest cuts – they point to Europe and North America as the most responsible, and suggest they should be seeking net-neutral emissions within the next few years.[8]

Are these cuts possible? The IPCC concludes that limiting warming to 1.5°C will require "rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems", and that "these systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options".

The 1.5°C pathways require a comprehensive portfolio of mitigation actions by 2030 including enhanced energy efficiency, reduced energy demand, steep decreases in the use of fossil fuels, increased use of renewables like solar, wind, hydro, nuclear, and bioenergy, and implementation of more ways to help the land soak up more carbon.

Given that some regions have already warmed more than 1°C, adaptation has already become an imperative in many places and sectors, and will be needed even if we are able to limit global average warming to 1.5°C.

The IPCC report assesses adaptation options that include constructing coastal barriers or planting mangroves to reduce the impacts of storms and sea-level rise; more efficient irrigation and water harvesting to conserve water; and designing buildings and planting trees to reduce urban temperatures. Adaptation options will vary from place to place: developing regions may focus more on health- and agriculture-related adaptation, for example, whereas in cities the focus may be on water and energy adaptation measures.

The UN Environment Programme's December "Adaptation Gap Report 2018"[9] notes that although many countries are starting to plan for adaptation, implementation is slow and finances are inadequate. The costs of adaptation, not even including the costs of protecting ecosystems, are estimated at up to US$300 billion a year by 2030, and US$500 billion a year by 2050. Currently pledged finance is less than US$25 billion.

Climate change and sustainable development
The IPCC's 1.5°C report was the first major IPCC assessment to be conducted since the adoption of the United Nations Sustainable Development Goals (SDGs) in 2015. The Millennium Development Goals, set in 2000, spurred success in reducing poverty and hunger, and providing drinking water between the 1990 baseline and 2015. Climate change now stands as a threat that could undermine those advances and the SDGs, making it harder, for example, to reduce poverty and hunger or to protect health and ecosystems.

News briefing for the IPCC special report on limiting warming to 1.5 degrees Celsius, in South Korea in October 2018.

HEALTH HAZARDS

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The number of reported Lyme disease cases in Canada more than doubled from 2009 to 2012, in part from the ticks that carry this disease spreading into warming regions. In the Baltic Sea, cases of illness from vibrios – bacteria that causes several illnesses – have been increasing with warmer sea surface temperatures.

There is limited monitoring of how climate change affects human health. Importantly, the magnitude and pattern of illnesses, injuries, and deaths depend not just on weather but also on public health preparedness, such as whether there are enough vaccines to tackle infectious diseases or a healthcare infrastructure resilient to the impact of floods.

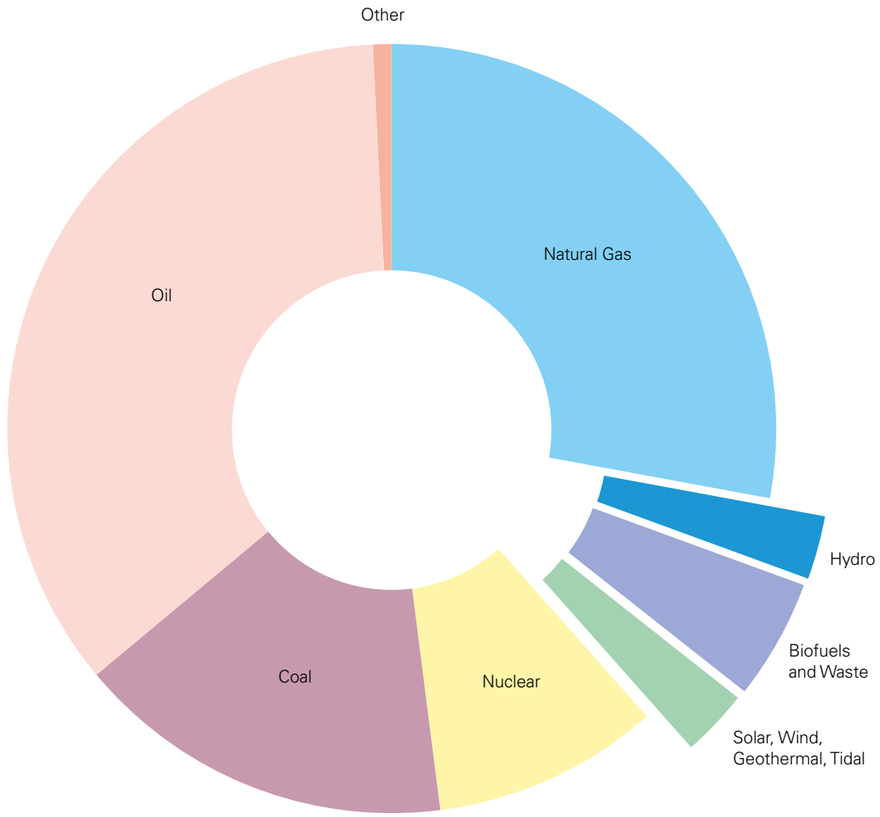
So far, there is no equivalent of the World Weather Attribution initiative for the health sector. But there are some cases where climate change was determined to be a cause of disease or death – including heat-related mortality, Lyme disease, and vibrios.[12] And as heatwaves have become more frequent and warmer, heat stress, hospitalizations, and deaths are projected to increase.

A continually warming world is expected to have mostly negative consequences for human health and well-being.[13] Increasing temperatures and heatwaves affect vulnerable populations such as older adults, children, and people with chronic diseases. Without additional preparation, increases in extreme weather events, such as flooding and drought, are projected to cause additional suffering.

Diseases carried by mosquitoes, such as malaria and dengue, are expected to spread to new areas – although these diseases may decline in other regions that become too hot and dry for the mosquitoes. Warmer temperatures can increase the concentrations of ground-level ozone, exacerbating respiratory illnesses. And the stress of extreme weather and climate events can lead to post-traumatic stress disorder, anxiety, depression, grief, and suicidal thoughts.[14]

One major risk will be changes in the nutritional quality and quantity of our food supply. Models project that crop yields are likely to fall in the Sahel, southern Africa, the Mediterranean, Central Europe, and the Amazon. Livestock will be affected too: rising temperatures may reduce the amount or quality of their feed and increase the spread of disease within herds. Experimental studies also show that higher carbon dioxide levels make crops such as wheat, rice, and barley grow faster, but with lower nutritional content. In experimental studies, CO_2 concentrations expected later this century caused protein concentrations to decline by about 10%, micronutrients such as iron and zinc to decline by 5–10%, and B vitamins to decline on average up to 30%. That could put about 600 million additional people in poor, rice-dependent countries at risk of adverse health consequences.[15]

Additional investment to tackle these challenges is critical. Today, funding for health adaptation is negligible, comprising about 1% of global climate adaptation finance. A bigger investment would improve our health – and that of our children and grandchildren – in a warmer world.



Fuel Shares
As of 2018, renewables still make up a tiny percentage of the OECD's primary energy supply.
Source: IEA Statistics, 2019

The good news is that efforts to limit or adapt to warming can be beneficial to sustainable development goals. For example, increasing energy efficiency and renewable use help provide energy for all. Protecting forests to soak up carbon in places such as the Amazon and Indonesia can also support the goal of protecting biodiversity on land. Adapting agriculture to deal with lowered levels of available water can reduce hunger.

But there are often trade-offs between actions aiming to limit or adapt to climate change and other sustainability goals. Increasing the amount of forest or land used to grow bioenergy crops, for example, may mean decreasing the amount of land for crops and pasture – which could mean less food production, unless crop yields increase on the remaining land. Some adaptation or mitigation projects do not sufficiently include or address the needs of the poor, indigenous groups, or women, and may increase social inequality. Projects to adapt to sea-level rise by building sea walls may degrade ecosystems and biodiversity.

These trade-offs are not always obvious or well understood. Decarbonizing the energy system by, for example, shifting to renewables and increasing efficiency is estimated to need an increase in investment of about US$830 billion, about one-third more than current costs of US$2.4 trillion. Some oil-producing or coal-exporting countries are concerned that this shift in finance will harm their economies or bring unemployment. But these costs need to be compared with the potential losses of a warming climate and the costs of adaptation, which have not yet been fully assessed. Development, if not carefully implemented, can increase the risks of climate change. For example, reducing poverty is often associated with increased consumption of fossil fuels and higher emissions.

It is possible to achieve all these valuable goals at once. The IPCC highlights the potential for fundamental societal transitions and transformations, including the potential of climate-resilient development pathways to "achieve ambitious mitigation and adaptation in conjunction with poverty eradication and efforts to reduce inequalities". Meeting this aspiration requires co-operation between national and sub-national authorities, civil society, the private sector, indigenous peoples, and local communities. Together they can forge fundamental societal transformations (*see chapter "Transformation"*) that simultaneously end dependence on fossil fuels, reduce consumption, and redesign cities and agriculture for the benefit of all.

Continued pressure
A steady drum beat of scientific reports has continued to document climate change and its impacts since the IPCC 1.5°C report was released.

For example, the 2018 US National Climate Assessment, released in November of that year, carefully documented the observed and potential impacts of climate change on the United States – overall, by region, and by key sector. The report received widespread media coverage, partly driven by recent disasters such as devastating forest fires in the western US and hurricanes in Texas and Puerto Rico. The assessment concluded that climate impacts were already disrupting economies and ecosystems, and that climate change poses serious risks to infrastructure, health, and the most vulnerable populations. Economic impacts could reach hundreds of billions of dollars by 2100. Reducing the risks of climate change through mitigation could save thousands of lives.

Many national, state, and local governments have taken these warnings seriously and introduced legislation to reduce emissions and adapt to impacts. For example, at a climate summit in California in 2018, CEOs of some of the world's largest companies (such as Unilever) pledged to invest in emission reductions towards carbon neutrality. China is implementing policies to limit its use of coal, mandate use of renewable energy, and promote electric vehicles, although emissions are still likely to rise as the economy grows and incomes rise.

But many countries have not yet risen to the challenge or are reversing prior commitments to climate protection. The United States saw rollbacks of federal climate mitigation efforts such as a weakening of the Clean Power Plan. In Brazil, the October 2018 election led to reduced protections for the Amazon forest and eliminated budgets for climate-change-related activities. In Australia, the government continues to subsidize coal despite public support for climate action.[7]

The UN "Emissions Gap Report 2018" highlights the inadequacy of the current Paris pledges and calls for greater ambition.[10] The IPCC report on "Climate Change and Land" shows how climate change is already reducing food security, and concludes that land use is responsible for almost a quarter of greenhouse gas emissions.[11] Forest protection and food systems transformation are called out as essential to limiting warming (*see chapter "Food"*).

The next few years will no doubt bring many new reports and actions. The IPCC has its next major assessment due to be published in 2021. And the UN has asked countries to increase their ambitions for reducing emissions before 2020.

Scientists can step up to address the critical gaps identified in international and national reports. These include the need for better assessments of costs and benefits, including those factors – such as disease or culture – that cannot easily be converted to financial values. We need improved regional detail on projections of climate change and its impacts; further studies of the connections between climate change, climate responses, and sustainable development; and evaluations of how various mitigation and adaptation measures affect equality.

The UN Climate Change Summit in September 2019 called upon leaders to develop concrete, realistic plans to enhance their commitments to reduce climate risks by 2020 by reducing greenhouse gas emissions by 45% over the next decade, and to net-zero emissions by 2050, in order to limit warming to 1.5°C. The question is whether sufficient action will be taken, and whether humanity's efforts to reduce warming will be compatible with sustainable development – without creating a bigger division of winners and losers.

The authors of this chapter were all involved in the writing and guidance of the IPCC special report on "Global Warming of 1.5°C".

MANY COUNTRIES HAVE NOT YET RISEN TO THE CHALLENGE OR ARE REVERSING PRIOR COMMITMENTS

BURNING UP

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Fire on the planet today is different than it has ever been before.[16] Climate change is increasing wildfire hazard over the majority of the planet, while a growing human presence is creating more sources of ignition and putting more infrastructure in the path of flames. Policies of fire suppression have made some forests more prone to larger fires. And the intentional clearing of rainforests for agriculture with fire is altering those landscapes forever – and creating deadly smoke.

There isn't necessarily *more* fire: wildfire activity today is actually less than it was 100 years ago. Nor is fire inherently bad. Fire is a natural phenomenon in ecosystems from temperate forests to grasslands; some pines require the heat of a wildfire to melt their resin and open their cones.

But fire becomes a concern when it burns our homes, rapidly and dramatically shifts ecosystems, or chokes the air we breathe. And it is doing more of that. In 2019, a dramatic number of fires in the Amazon – a region that saw little fire before humans arrived – grabbed media headlines. Indonesian skies turned red from intentionally lit fires. Australia was ravaged by bush fires in the midst of an unusual drought. And the Arctic Circle saw unusually high occurrences of fire from Siberia to Greenland. California's 2018 Camp Fire was the costliest ever in the world (at US$16.5 billion in total losses), and tragically killed 85 people. Countries around the Mediterranean Basin are under the stress of catastrophic fires every summer.

Climate change has been identified as part of the reason. Warmer air pulls moisture out of vegetation – creating drier fuel – and feeds winds to fan flames. Each degree of air warming is thought to increase lightning strikes by about 12%.[17] As mountain ice packs melt, there is less water to feed landscapes over a long summer. Globally, the length of the fire weather season has increased by more than 18% between 1979 and 2013.[18] The majority of the burned area happens over a few short days of extreme fire weather – extreme weather that is becoming more common.

Climate models predict that many dry areas will get drier. And while increasing rain in some regions might counteract fire hazard, that isn't always the case: more rain in winter and/or early spring, for example, can create more vegetation prone to burning in a later, drier summer. Global models predict that, overall, more regions will see an increased fire probability than a decreased one.[19]

Fire management is another part of the explanation for our current vulnerability. A kind of "war against fire" was initiated in the early 20th century, predominantly in the United States: authorities viewed wildfire as a blight and adopted policies to stamp it out early. Decades of intensive fire suppression changed some landscapes dramatically, altering traditional patchworks of different ages and types of vegetation to a more uniform forest prone to larger conflagrations. As a result of both climate and policy, the annual burned area in the western United States increased more than fivefold from 1985 to 2015.

Over the longer term, and globally, land use change has been the dominant determinant of fire regimes.[20] Fire has remained relatively steady over the past 1,000 years or so, with a dramatic uptick from the 19th–20th century as farmers and settlers used fire to clear land during the Industrial Revolution. The total area burned then declined in the first decades of the 21st century, thanks to less-fire-prone agriculture taking the place of tropical savannas and grasslands.

Australia was ravaged by bush fires in the midst of an unusual drought.

Models predict that climate change – in particular increasing temperatures – could become a prevailing force determining fire activity in the coming decades.

The amount of carbon dioxide released by wildfires can be striking. The summer 2019 Siberian wildfires, which burned an area larger than Denmark, produced more CO_2 than tens of millions of cars do over a year. If a forest regrows, over the long run a wildfire can be carbon neutral. But in Siberia and elsewhere the burning of peat – banked carbon that has been accumulating for thousands of years – or the thawing of permafrost leads to a net release of greenhouse gases, upsetting the balance. The replacement of rainforests with agriculture also hinders the planet's ability to store carbon long term.

Despite some media reports, razing the Amazon does not affect the "planet's lungs": vegetation is neutral when it comes to oxygen, absorbing as much as it emits. What it does do is affect human lungs, through the production of soot and smoke. Fire emissions are responsible for more than 300,000 premature deaths annually from poor air quality.[21] There are plenty of reasons to preserve rainforest ecosystems; saving people from air pollution is one of them.

A more sustainable planetary system will still have fire, and plenty of it. Humans need to learn to live with that, and to better manage the risk – in part by dialling back climate change.

POPULISM VERSUS GRASSROOTS MOVEMENTS

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Right-wing populism is on the rise around the world: a breed of politics that exploits people's fears during times of economic decline and growing inequality, and that focuses on nationalist tendencies to clamp down on borders and reject immigrants.

The causes of this rise are complex and varied, and so the symptoms differ from country to country. One significant factor was the global financial crisis in 2008: increased economic precariousness prompted greater social angst and created further opportunity for authoritarian populist politics to gain traction. In this sense there are many troubling similarities between the present global situation and the ascendancy of fascism after the Great Crash of 1929.

Climate change denialism is a thread that runs through many of the new right-wing nationalist and populist forces – of which US president Donald Trump is the most conspicuous example. At the very moment when international cooperation is essential if climate action is to be effective, many of the leaders of these right-wing populist forces are trying to dismantle or weaken multilateral organizations such as the United Nations or the European Union. These political groups threaten to derail progress on the global response to climate change, and on new thinking about how to rewire the economy in pursuit of a more sustainable world.

But, at the same time, there is a rise of countervailing voices, inside the formal political ring, among liberal elites, and especially in grassroots movements.

Traditional left-of-centre parties have, in many cases, been slow to understand the impact that climate change has on the poorer, working-class constituencies that they claim to represent – thus cutting themselves off from their traditional voter base. They have tended to think of it as an environmental conservation issue, failing to grasp its human rights and social justice impacts. This has been a mistake. But as part of a shift in global attitudes to the climate emergency, some left-of-centre political leaders have taken a lead. For example, in the United Kingdom it was the Labour Party that led the call for parliament to declare a "climate emergency" in May 2019, while in the United States, Democrat congresswoman Alexandria Ocasio-Cortez is one of the sponsors of proposed legislation to create a new "green deal".

A protester at the global climate change strike, October 2019, Nuremberg, Germany.

But it is the myriad popular movements across the planet whose collective sense of frustration and growing anger about the impending climate disaster is gathering real momentum and offers the more potent counterbalance to the rise of populism. These movements are not only asking penetrating questions of those in power, but cannot be dismissed as being inside the cosmopolitan bubble. They are beginning to apply real political pressure commensurate with the immensity of humanity's predicament because they are on the frontline of climate change and are feeling its impact more than any others.

The rise of right-wing populism

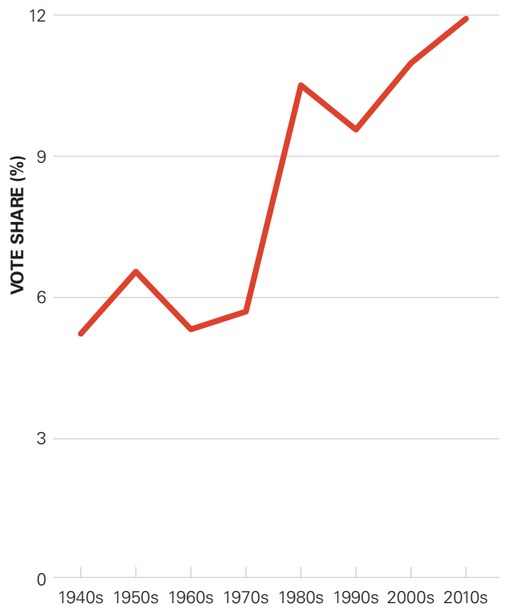
"Populism" is a contested term without a clearly defined meaning. Overall it has been described as a catch-all label for any kind of politics that promises to salve the fears of the discontented masses.

While populism claims to speak on behalf of the people, this rhetoric is often contradicted by the actions of populist leaders who seek to dismantle or undermine democratic institutions, or strike poses that are contrary to human rights – most blatantly by constructing an exclusionary nationalism that exploits prejudices against, for example, immigrants.

Nonetheless, populism is ideologically capable of being right or left wing, or combining both. It can also cut across classes. Not all populists are anti-democratic or anti-poor. For example, Bolivia's former president Evo Morales was often described as a populist, yet he was neither a climate denialist nor right wing: he brought inequality and poverty substantially down during his terms of office (2006–2019), and Bolivia was often at the front of the faction calling for radical climate action in international negotiations.

In the context of climate change, the more troubling form of populism is right-wing populism, or authoritarian populism as some analysts call it. Harvard Kennedy School political scientist Pippa Norris explained in 2016 that: "Populist authoritarianism can best be explained as a cultural backlash in Western societies against long-term, ongoing social change." As western societies have adopted more liberal social policies, from acceptance of same-sex marriage to support of agencies of global governance, some people have felt increasingly uncomfortable, Norris explains. "This long-term generational shift threatens many traditionalists' cultural values. Less educated and older citizens fear becoming marginalized and left behind within their own countries."[1] Those who feel left behind begin to rail against what they see as a cosmopolitan elite.

The data suggest that this trend started in earnest in the 1980s (*see graph: Populism Rising*). The mean vote share for populist authoritarian parties in post-industrial societies kept climbing, until 2016 earned a reputation as the year in which it became a powerful political force – with Trump's election and the Brexit referendum, as well as the rise of populist parties across Europe.



Populism Rising
Vote share for populist parties across 32 western societies, 1946–2017. *Source: Döring and Manow, 2016; ParlGov database; IFES Election Guide*

Some have argued that climate change and environmental policy occupy a symbolic place in the populist struggle against a perceived elite. In many respects, climate change has yet to shake off its brand as an issue only of concern to people well off enough to worry about the future – protection of the environment is seen as a middle-class preoccupation that is too much of a luxury for the majority of people struggling to make ends meet, find or keep jobs, and put food on the tables of their beleaguered families.

Efforts to introduce carbon taxes provide an instructive and revealing case study. Rationally, given the danger posed by fossil fuels and carbon emissions, and the long-time failure to price such externalities, a carbon tax would appear to be a no-brainer. But these taxes impose a short-term cost on the public in exchange for a less-tangible future benefit, often seemingly at the greater cost to the poor. In France, for example, protestors complained that the carbon tax revenues would be used in part to offset income tax cuts for the wealthy.

Hence Trump's enthusiasm for repeating numerous fake news tropes about climate change that promote the idea that it is an invention of an urban, cosmopolitan elite. This elite, so the thinking goes, is indifferent to the interests of working men (especially) and women in industries that are often a cause of the climate emergency – such as the coal, oil, and combustion-engine car industries.

One of Trump's earliest acts as president was to announce that the United States would withdraw from the Paris Treaty on climate action. When discussing this momentous decision with his staff, Trump is reported to have said to his National Economic Council director Gary Cohn, "Gary, my voters don't live on Park Avenue. They don't care about the same things you care about." One of many similarities between Trump and Jair Bolsonaro – often spoken of as "the Brazilian Trump" – is their rhetoric that climate change is a "liberal hoax", and their use of the threat of job losses in manufacturing and fossil-fuel industries to sell a climate denial message.

Beyond denying the facts of climate change, there is a further denialist characteristic of populism that undermines progress on climate action. As former editor of *The Guardian* Alan Rusbridger puts it in his recent book,[2] populism is also defined by "a denial of complexity".

In a complex world facing complex problems, it is seductive for politicians to identify a single culprit (like immigrants) or an evil force (like universal healthcare) to blame for the erosion of society, the economy, and the welfare of the masses. This is hardly ever true, but it is compelling. Take the bewilderingly complicated set of relationships between food, energy, urban infrastructure, and exponential demographic growth and change (at least in the developing world). Climate change and its impacts are perhaps the epitome of a complex issue of interlinked social, political, and physical forces, making it an easy target for this sort of denialism.

Supporters of Brazilian populist President Jair Bolsonaro in October 2018.

So, populism ends up denying not just the science of climate change but also the complexity of the entire issue – which is critical for both diagnosing the problem and determining the prognosis and the prescription. Populism strips issues of nuance, and thereby obstructs progress.

A 2019 study mapping the climate agendas of right-wing populist parties in Europe contains some revealing evidence:[3] two thirds of right-wing populist members of the European Parliament (MEPs) "regularly vote against climate and energy policy measures", while half of all votes against resolutions on climate and energy in the European Parliament come from right-wing populist party members. Of the 21 right-wing populist parties that were analysed, 7 were found to "deny climate change, its anthropogenic causes, and negative consequences". According to estimates based on World Resources Institute global greenhouse-gas emissions data, about 30% of global emissions come from countries led by populist leaders.[4]

Humanity is entering a crucial decade in which it will either set course for a new economic paradigm, or else fail to act with sufficient urgency and transformative intensity. Having left it so late to prevent a 2°C rise in global temperatures, bold and decisive choices will have to be taken by political leaders. But the political zeitgeist could not (in some respects) be less conducive to doing so.

The growing force of authoritarian populism will have to be pushed back by a political force of at least equal power and momentum. And on that front, things are changing – and fast.

The countervailing progressives
I first encountered the expression "authoritarian populism" in an article[5] by a fellow South African activist academic, Vishwas Satgar, in 2016. I had known him for years as an anti-apartheid activist – and then, post-1994 and South Africa's first democratic election, as an activist for social justice and a leading intellectual in the South African left. Satgar is now leading the call for a Climate Justice Charter[6] in South Africa, and collaborating closely with a global network of activists. As an international relations professor at Witwatersrand University, he is monitoring trends in civil activism and mobilization – potentially powerful countervailing forces against populism.

Interestingly, it has taken a long while for progressive activists, political leaders, and analysts to join the dots between climate change and social justice, forming what are sometimes called "red-green alliances" (the red referring to progressive, left-of-centre politics; the green to environmentalism). This has been in many respects a failure of left-of-centre politics, because the evidence that those most vulnerable to climate change are those with the least material wealth and other resources to defend themselves is overwhelming.

As Satgar noted at a European Education and Sustainability Leadership Summit in Berlin in May 2019, many far-left political movements have failed in recent decades, from Soviet to African socialism. Over the same time period, capitalism has risen to new heights – a type of capitalism that "is unresponsive to people's needs at a time of deepening inequality and systemic crises in natural resources such as water, escalated by climate change".[7] This has created a global crisis in support for liberal democracies, creating a space for authoritarian populists to exploit.

Yet simultaneously, Satgar pointed out, there has been a long, 500-year history of activism by mostly indigenous peoples to sustain the ecosystems upon which they depend. Since 1994, for example, the Mexican Zapatista Army of National Liberation has fought to return control of natural resources to indigenous hands; in 1999–2000, protests in Cochabamba, Bolivia, successfully fought to reverse the privatization of the city's water supply; and in the Niger Delta, Ogoni people continue to fight, against great violence, the environmental damage done by oil spills and the company Royal Dutch Shell. Satgar maintains that as the systemic environmental crisis grows, so these indigenous-led forces are also growing.

Elsewhere, there are other forms of protest and mobilization. Greta Thunberg's poignant as well as pointed advocacy has made her a poster child to juxtapose against Trump's crude climate denialism – a powerful voice against climate inaction by political leaders, matched by the energy both of the children-led #FridaysForFuture across the world and the Extinction Rebellion protests in many major capital cities.

At face value, this might appear to be a strong countervailing force. But is it politically strong enough and will it work? History suggests that previous efforts to build transnational progressive political movements have often failed to institutionalize the relationships between civil and social forces or develop a programmatic politics. In other words, they have been too disparate, too thinly spread, too incoherent in their strategy and communications to have the necessary impact.

[THERE IS] A GLOBAL CRISIS IN SUPPORT FOR LIBERAL DEMOCRACIES, CREATING A SPACE FOR AUTHORITARIAN POPULISTS TO EXPLOIT

Sociologist Zeynep Tufekci has thought a lot about this. She has firsthand research experience of the Zapatistas; she was in Tahrir Square for Egypt's revolution; and she was in lower Manhattan for Occupy Wall Street. She notes that the digital era is not always as successful as one might think in organizing movements: "Modern networked movements can scale up quickly and take care of all sorts of logistical tasks without building any substantial organization cavity before the first protest or march … However, with this speed comes weakness."[8] The lack of strategic organization can create a splintering of purpose, methods, and impact – and a lack of clear direction after change has been implemented.

There is clearly a new wave of activist energy – manifesting in movements like Me Too, the Women's March, Black Lives Matter, #FridaysForFuture, Extinction Rebellion, Sunrise, 350.org, and the successful global campaign against plastic and straws specifically. The trick will be to effectively connect these movements to matters of global social justice, and to give them enough coherence to be effective.

So, on the one hand, Thunberg and the student strike movement does serve to foreground critical inter-generational justice issues, while ringing the bell for more urgent action to be taken and raising awareness of the climate emergency. But Satgar argues that this isn't, yet, enough. Real socio-economic transformation will require movements that at their core defend life at the frontline of climate shocks. Thus, real transformation requires a focus on climate justice rather than climate awareness – one that not only joins the dots between ecological degradation and human rights, but also seeks remedial action and a transformation in the way the economy operates and capital is deployed.

How can Thunberg and the student strike movement in the global north connect, for example, with 1.6 million children that are displaced in Malawi, Zimbabwe, and Mozambique from the cyclones, or the 300,000 women and children impacted by drought in Kenya and Somalia? Such connections need to be made in order to turn these nascent movements into powerful advocates for climate justice, or "eco-social justice" as some call it.

This is far easier said than done (and far harder than simply dismissing climate science as a hoax with the flick of a Twitter pen). There are people seeking to study and effect large-scale transformations of society, and steer them in the right direction. But it is an emerging field with a lot of complexity (*see chapter "Transformation"*).

In South Africa, Satgar continues to work painstakingly with others to establish a Climate Justice Charter, whose purpose is to "unite important players in the fragmented civil society, environmental justice, and climate justice and water sectors of South Africa" while establishing a set of principles to guide a "transformative just transition" away from "carbon capitalism". Satgar has a vision of South Africa as a "climate justice state" or a "democratic climate emergency state". He believes it could carry the rest of the continent with it, creating a knock-on effect on the global political order: "it would contribute to a global tipping point".[7]

Inflexion point?

Writing in *The New Yorker* in May 2019, cofounder of the grassroots climate campaign 350.org Bill McKibben[9] alluded to previous "climate moments" – in 1988 NASA made a key presentation to Congress, and in the mid-2000s Al Gore's *An Inconvenient Truth* made waves. Neither led to sufficient action by Congress or the White House. But "this third climate moment is rooted in broad movements, not élite opinion," wrote McKibben "and so it feels different. Right now, a group of young people is touring the country pushing for action on a Green New Deal … which would push for the rapid decarbonization of America's energy supply. Polls show surprisingly widespread public support for it, and various versions are being introduced in cities and states across the nation, as well as in other countries".

Meanwhile the emerging overlap between environmental activists and left-leaning social justice activists – the so-called red-green alliance – is becoming clearer. A CNN poll in 2019 revealed that democratic voters cared more about climate change than about any other issue in the lead-up to the 2020 US presidential election. Many on the left have woken up to both the threats and the opportunities presented by the crisis. But you don't need to be on the left to recognize the danger and the need to press for urgent action. Everyone is vulnerable to the future risks from climate change.

For this to be an inflexion point – a turning point that changes the course of history – a political struggle will need to be won. And the fight for climate justice in the face of right-wing populist climate denialism is a titanic one.

A new paradigm for planetary living in a just world is possible, but the current wave of activism will have to overcome its present limits. Climate policy and politics need to be understood as occurring within a complex context involving a wide array of actors and different levels of governance.

Trump-like trajectories into the so-called "post-truth" world of climate denial, charged by the amplifying impact of social media, distract from and obstruct the necessary action. Despite its flaws, the digital age presents a huge opportunity to impose a counter-narrative, and for recruiting new activists. People can connect more easily across seas and time-zones. Climate denialism can be rebutted and populist rhetoric rebuffed. Protests can be arranged quickly. And the young will do it best, not least because they have the deepest vested interest of all: it is their future that is at stake.

Climate Stance

Where right-wing populists stand on climate change science. *Source: Adelphi, 2019*

GOVERNING THE HIGH SEAS

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Today, the ocean is front-page news. Officials from around the world are negotiating a new United Nations treaty to govern the high seas. Ocean plastic pollution has captured the world's attention. Mining of the international seabed is about to become a reality. And while future "fish wars" lurk on the horizon, scientists are just starting to understand the genes that enable life in the ocean's most extreme environments, and the biotechnology community is figuring out ways to use them.

The importance of the ocean for the biosphere and human well-being is immense. Over 3 billion people are dependent on functioning marine ecosystems as their primary source of protein, and the livelihoods of nearly half of humanity are linked to marine and coastal biodiversity.[1] The ocean shapes the earth's climate, and plays a vital role in the customs, traditions, and identity of coastal communities around the world. Life has evolved to thrive in diverse ocean habitats, with these adaptations encoded in genomes that have drawn growing interest as promising sources of future medicines.

While the ocean was once considered too big to be significantly altered through human activity, it is now clear that it too has entered the Anthropocene, an age in which humans are the dominant influence. Stressors from climate change to pollution, fishing, and shipping have on average nearly doubled over the past decade, according to one recent study.[2] Melting ice has opened new passageways in the north for shipping and human impacts.

Industrial fishing occurs in more than 55% of the ocean's area.[3] Climate change is leading to warmer, more acidic waters: 2018 was the warmest year for the ocean on record, part of a warming trend expected to rapidly increase throughout the coming century,[4] while the hydrogen ion concentration of the ocean, which determines acidity, has gone up about 26% over the past 100 years. Tons of plastic enter the ocean each day, with ecological impacts that are still poorly understood (*see box "Ocean plastics"*). Global maritime transport networks have contributed to the spread of invasive alien species, while overuse of antibiotics in aquaculture has contributed to the spread of antimicrobial-resistant pathogens. The Intergovernmental Panel on Climate Change's special report on the oceans and the cryosphere, released in September 2019, highlights how the resulting impacts on ecosystem services have had, overall, negative impacts on human health and well-being.

Alongside these storylines of bounty and degradation is a third, aspirational narrative of the ocean as a frontier and engine of future economic development. States have championed the notion of a blue economy that fosters human well-being, while simultaneously leading to greater equity and stewardship of marine resources.

Will we achieve this goal? How can the aspirations of more than 190 countries be accommodated, while avoiding degradation of the ocean and ensuring that future generations can continue to benefit from and enjoy its bounty? This is the domain of ocean governance, a complex network of rules, norms, mechanisms, and other instruments imposed on the ocean's fluid boundaries.

The High Seas

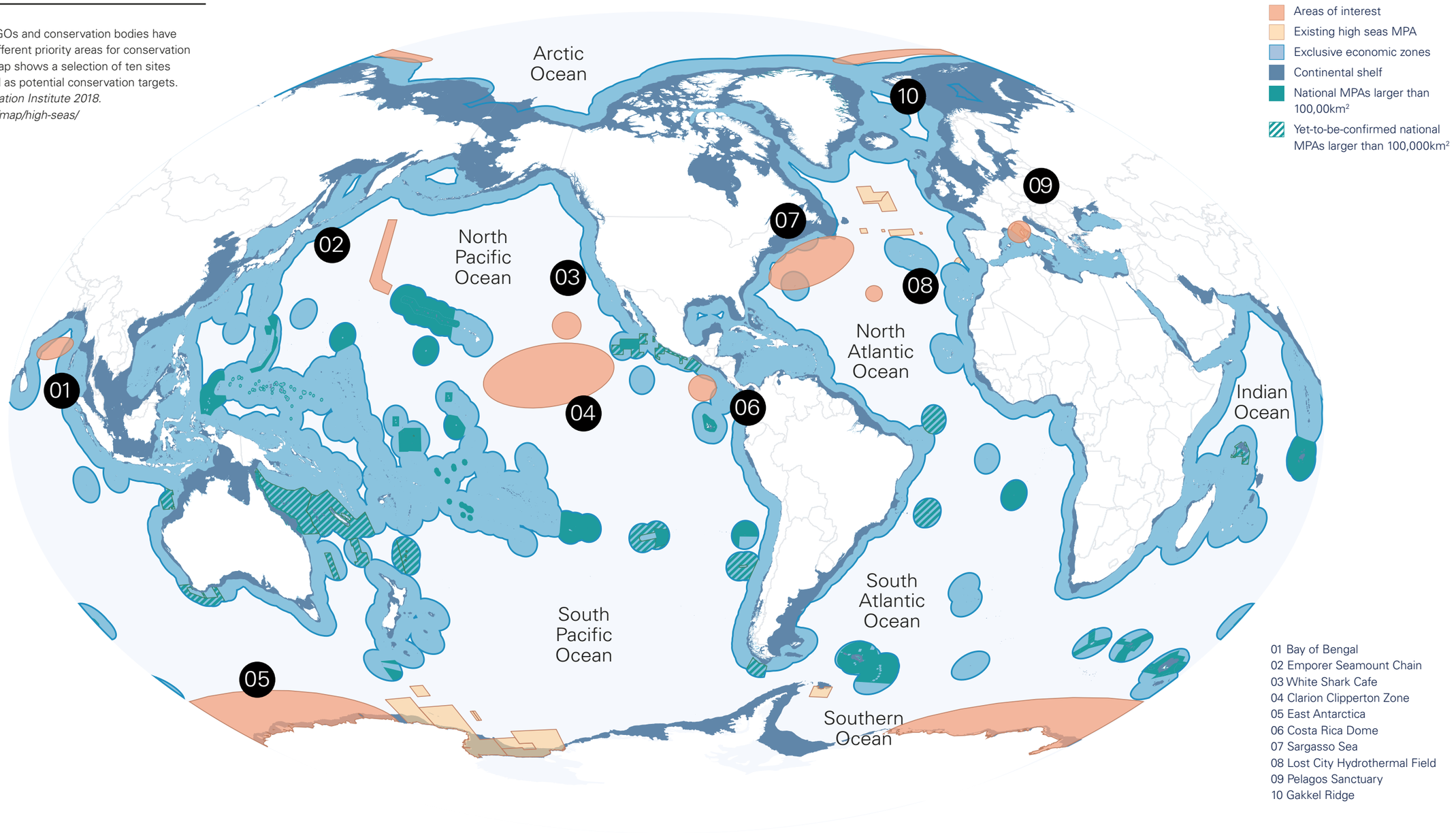
Today, the biggest story in ocean governance is, appropriately, about the ocean's biggest jurisdictional zone. Exclusive economic zones generally extend 200 nautical miles from national coastlines and mark an area within which states enjoy a broad range of autonomy in the use of the marine environment and its resources. But nearly two-thirds of the ocean exists beyond such boundaries in vast "areas beyond national jurisdiction" (ABNJ), which cover some 64% of the ocean and nearly 40% of the earth's surface.

In the popular imagination, ABNJ evokes the notion of a vast ungoverned territory where the "freedom of the high seas" prevails. In reality, a multitude of organizations have mandates to govern aspects of ABNJ – though many experts argue that the sum of these does not equal good governance.

The United Nations Convention on the Law of the Sea, for example, sets forth that the high seas are open for all states, subject to certain conditions, and that states shall cooperate on the conservation of marine living species. Many international fisheries are regulated under regional fisheries management organizations (RFMOs), which have been called upon to help protect vulnerable marine ecosystems by bodies including the United Nations Food and Agriculture Organization.

The International Maritime Organization, which is responsible for overseeing shipping, designates "particularly sensitive sea areas"; the International Seabed Authority, which is responsible for overseeing seabed mining, designates "areas of particular environmental interest"; and the Convention on Biological Diversity encourages states to conserve "ecologically or biologically significant areas" (EBSAs).

Priority Areas
Various UN agencies, NGOs and conservation bodies have highlighted a range of different priority areas for conservation on the high seas. This map shows a selection of ten sites that have been identified as potential conservation targets.
Source: Marine Conservation Institute 2018.
http://www.mpatlas.org/map/high-seas/



Yet there is little spatial overlap in these different areas designated for special attention or protection. More importantly, efforts by one sector to protect a certain area do nothing to limit the activities by other sectors. If an RFMO decides to ban bottom trawling in an area with sensitive hydrothermal vent systems, for example, this does not mean it is protected from seabed mining. RFMOs, like many international organizations, also suffer from the slow pace of consensus building: years of negotiations are needed to reach agreements that specify or restrict the rights of member countries.

This is a problem, given that states have agreed – through the 2010 Aichi Targets (part of the UN's Convention on Biological Diversity), and the UN's 2015 Sustainable Development Goals – to place at least 10% of coastal and marine areas under protection by 2020 (compared with the 7.6% that enjoys some level of protection today). Many calls have already emerged to extend these targets: both Greenpeace and the International Union for Conservation of Nature have called for 30% of the ocean to be protected by 2030. Only 36% of the ocean is within national jurisdictions; no one expects virtually all of this to be set aside as marine protected areas, nor would preserving only coastal habitats be sufficient for comprehensive ocean conservation. Reaching such targets presupposes the establishment of a mechanism to protect vast swathes of the high seas.

Some academics have recently called for closing the high seas to fishing entirely. They note that only a small number of countries are actually engaged in fishing in ABNJ (six countries account for 77% of the ABNJ fishing fleet); most fishing in ABNJ would be unprofitable without subsidies; and the fish caught in the high seas make only a small contribution to global food security (2.4% of seafood, by volume, comes from the high seas).[5,6] Within the current international governance landscape, any legally binding fisheries closures in ABNJ would need to take place through RFMOs, and large-scale closures are unlikely. Alternative avenues for reducing high seas fishing include phasing out subsidies enabling such operations, and consumer awareness campaigns aimed at generating market demand for locally sourced seafood.

Establishing a way to create marine protected areas in the high seas would be the most straightforward option. This is one element of UN treaty negotiations on the conservation and sustainable use of biological diversity of areas beyond national jurisdiction (BBNJ).

Protecting biodiversity

On December 24 in 2017, nearly 15 years of meetings concluded with UN General Assembly Resolution 72/249: a decision to convene an intergovernmental conference to ensure the conservation and sustainable use of biological diversity in ABNJ. While the UN General Assembly resolution gives state negotiators the opportunity to enhance governance of nearly half the planet, it also ties their hands to some extent, as it cautions not to "undermine existing relevant legal instruments and frameworks".

The focus is on four core issues: area-based management tools (including marine protected areas, or MPAs); marine genetic resources, or MGRs (including questions about the sharing of benefits from use of those resources); environmental impact assessments (EIAs); and capacity building and the transfer of marine technology (CB/TMT).

If one embraces acronyms, the BBNJ negotiations can be summarized fairly quickly: EIAs and CB/TMT are relatively straightforward; MPAs are tough; and MGRs are a nightmare of complexity. Yet the UN General Assembly resolution is clear that this is an all-or-nothing package deal, in which agreement is needed on all four elements. Addressing the comparatively simple issues and parking the tough ones for future negotiations is literally not an option. Moving from the current draft treaty to consensus text will certainly be a difficult task, but not impossible. At the time of writing, the intergovernmental conference, which has been envisioned as a series of four separate two-week meetings spread from 2018–2020, was three-quarters finished, and the draft text of what may become the BBNJ Treaty had been circulated.

THERE ARE MANY LEGAL INTRICACIES THAT STATE NEGOTIATORS WILL HAVE TO NAVIGATE

Devising the new mechanism for creating high-seas MPAs, for example, will require careful work in order not to undermine other existing legal instruments. There are many legal intricacies that state negotiators will have to navigate. Non-governmental organizations (NGOs) and researchers have already leapfrogged the negotiations to start suggesting where future high-seas MPAs could be located. A recent study, for instance, considers "ecological connectivity", mapping out and quantifying how various parts of ABNJ are connected to coastal ecosystems, in particular identifying parts of ABNJ that are most likely to impact coastal waters.[7] That could serve as a rational mechanism for identifying parts of the high seas that are critical to protect. Other efforts to identify candidate MPAs have focused on pinpointing irreplaceable systems such as those containing seamounts or hydrothermal vents (*see Figure: Priority Areas*).

It's worth remembering that even if an agreement is reached to establish high seas MPAs, effective implementation and enforcement will be hard to ensure, and the cost-sharing implications of such management activities will need to be considered further.

However tricky it is to decide upon MPAs, the truly Herculean task facing state negotiators is figuring out how to address genetic resources from ABNJ. Scientists have only begun to understand marine life in ABNJ, and the biotechnology community has just started to explore its commercial potential. But applications already range from a growing family of marine drugs (including five US FDA-approved cancer treatments) to anti-aging cosmetic creams containing bacteria from worms living in hydrothermal vents.

Experience has shown that achieving equitable access to and subsequent sharing of the benefits from genetic resources has always been a major challenge for the international community. While regulatory policy often moves more slowly than the science, it is particularly challenging in the case of biotechnology, which is moving at light speed. Within the past ten years, for instance, DNA sequencing costs have dropped by five orders of magnitude.

Take, for example, the Convention on Biological Diversity's Nagoya Protocol: an international agreement aimed at eliminating the worst forms of biopiracy through the establishment of access and benefit-sharing agreements. The need for such a protocol was already stated as the third objective of the Convention on Biological Diversity (in 1992), but the protocol was not agreed until 2010. By the time it finally entered into force in 2014, scientists had already grown less and less reliant on physical samples, depending instead on genetic sequence data – often transmitted digitally – which falls outside the scope of the protocol.[8]

For now, this gap may not seem to present a huge concern. When researchers (including the lead author of this chapter) analysed 7.3 million genetic sequences associated with international patent filings, they found only 862 of the genes came from marine organisms; the vast majority were from terrestrial sources.[9] In all probability a far smaller number came from marine organisms found in ABNJ.

On the one hand, this might imply that there is limited reason to regulate access to genetic resources from ABNJ, since they are such a tiny fraction of patented genes. On the other hand, there is still cause for concern, as the genes of life in two-thirds of the ocean are at stake, and their properties and potential are largely unknown. In addition, there is an equity consideration: only a tiny handful of wealthy countries have the capacity to engage competitively in this sector of the blue economy. In this study, just ten countries were responsible for over 98% of the patent filings, leaving over 160 countries completely unrepresented.

Given the speed at which biotechnology advances have outpaced regulatory policy in other areas, negotiators should be dedicating time and effort to urgently resolve this issue. Most importantly, states should ensure that private sector companies and universities engaged in filing gene patents are included in the negotiations, as their expertise can provide real-world insight into this fast-paced sector and could be leveraged for future capacity-building efforts.

FISH WARS

Back in 2007, a climate-related shift in the distribution and abundance of Atlantic mackerel led to a series of unilateral and escalating responses by fishing nations wanting to take their "fair share" of the fish. The conflicts, dubbed the "mackerel war", won't be the last.

Research suggests that changing ocean conditions will increasingly contribute to the poleward shift of commercial fish stocks. A recent study found that, on average, species were moving into new territory at a rate of 70 km per decade.[14] Under a high greenhouse-gas emissions scenario, some states are expected to see up to 12 new commercially important fish species entering their exclusive economic zones by the end of the century. As various states lose and gain fish stocks, there is increased potential for inter-state conflict.

In one 2019 study, researchers (including chapter author Blasiak) collected and analysed 40 years of English-language news reports covering international conflicts related to fish, ranging from public condemnation of fishing activities all the way to military actions resulting in loss of life.[15] This dataset revealed a marked increase in fishery conflicts over the past 15 years, with East Asia and South East Asia emerging as the primary hotspots for conflicts to occur.

OCEAN PLASTICS

The disposal of plastic at sea has been banned under the MARPOL Convention since 1988, but enforcement is a huge problem. It is estimated that between 13,000 and 35,000 tons of plastic enter the ocean every day. Around 322 million tons of plastic is produced annually, and only 20% is incinerated or recycled; the rest ends up in landfills or the natural environment.

Marine megafauna that have become entangled in abandoned, lost, or discarded fishing gear, or which have ingested large quantities of plastics, have become the topic of recurring news stories. Plastic does not decompose, but rather breaks down into smaller and smaller pieces: microplastic particles have been found in even the most remote deep-sea and polar regions of the ocean. The ingestion of microplastics by everything from filter-feeding mussels to commercial fish species has raised human health concerns, and while initial analysis suggests health impacts may be minimal,[16] the perception of seafood as a polluted food source could reshape consumption patterns.

China has been the primary importer of the world's plastic waste, but ceased imports in early 2018. In May 2019, nearly all countries agreed in an amendment to the Basel Convention to stop exporting plastic waste to poor nations. The long-term impacts of this realignment of global flows of plastic waste are unclear.

In June 2019, the leaders of the G20 developed the Osaka Blue Ocean Vision, with an aim to reduce additional pollution by marine plastic litter to zero by 2050. Although this is not a legally binding commitment, it is a signal for movement in the right direction.

Mining the seabed

Another controversial issue is seabed mining. Of particular interest are vast deposits of polymetallic manganese nodules spread across the ocean floor, cobalt-rich crusts around seamounts, and mineral deposits that form around hydrothermal vents. Metals such as cobalt, manganese, and nickel are needed for high-tech applications ranging from electric batteries to electronics such as smartphones.

Proponents of mining these deposits argue that demand for minerals has been rapidly growing, resulting in the land-based extraction of lower quality ore and the use of more energy-intensive mining methods.[10] From this point of view, the seabed offers a new opportunity for environmentally responsible mining. Opponents, however, underscore the extent of scientific uncertainty about the seabed (the surfaces of Mars, Venus, and the moon, for instance, have been mapped at higher resolutions), and about the potential future impacts of mining activities. Toxic sediment plumes kicked up by mining activity, for example, can extend for miles from their source, and lead to sediment deposition rates thousands of times above natural levels.

A 2018 editorial in the journal *Science* set out the arguments for a precautionary approach, highlighting the extent of our ignorance of deep-sea ecosystems and arguing against a US administration proposal to open 90% of the country's continental shelf to oil and gas drilling.[11]

The International Seabed Authority (ISA) already has the mandate to regulate all activities related to minerals in ABNJ and has developed multiple regulations on prospecting for polymetallic nodules (2000), sulphides (2010), and polymetallic crusts (2012). The next step is to develop regulations that move beyond the activities of exploration and prospecting to also govern exploitation. This process was started in 2014, and a set of ISA regulations to govern mineral exploitation in ABNJ is expected to be adopted by 2021.

The ISA has already designated nine Areas of Particular Environmental Interest (APEIs) that are protected from mining exploration, prospecting, and exploitation. This network covers 160,000 sq km across the Clarion-Clipperton Zone, an area of the Pacific Ocean characterized by rich deposits of polymetallic nodules. Recognizing the likely imminent expansion of commercial activities on the seafloor in ABNJ, independent researchers published a study in 2018 identifying other areas of the seabed to prioritize for conservation.[12]

Under the ISA's proposed mining code, contractors will be required to conduct EIAs and establish preservation reference zones to help maintain biodiversity and ecosystem functions. Another encouraging signal has been sent by industry, which has actively sought out engagement with the scientific community to gauge environmental impacts of bioprospecting and exploration efforts. Yet many NGOs and conservation groups have categorically rejected deep-sea mining and have repeatedly stated that it "has no place in the world's Agenda 2030 for sustainable development".

Future challenges

Climate change remains a major question mark hanging over future ocean governance, as it is already changing conditions and the distribution of marine life, and such impacts are only expected to increase in the future (*see box "Fish wars"*).

While international cooperation among states will be crucial for addressing existing and future ocean governance challenges, NGOs and the private sector are also key players. NGOs, for example, played a key role in pushing for the development of an international treaty on BBNJ, and are among the most vocal opponents of seabed mining. The private sector is also taking tentative steps towards embracing a role as ocean stewards rather than simply as ocean-based industries. Hopeful examples are provided by industry-based groups that aim to improve sustainable practices, such as the Global Salmon Initiative, the Seafood Business for Ocean Stewardship initiative, and the UN Global Compact Sustainable Ocean Business Action Platform.

While there is nervous optimism about the potential for the BBNJ negotiations to yield an ambitious and effective treaty, there are many more immediate and encouraging signals that ocean governance is moving in a positive direction.

Novel tools are enabling more direct action towards ensuring sustainable ocean governance. For example, the same blockchain technologies that underlie some virtual currencies are creating new levels of transparency and traceability in seafood supply chains. The Global Fishing Watch website, launched in 2016 by Google and nonprofits Oceana and SkyTruth, has made real-time vessel-tracking data publicly available and open to scrutiny. Attempts have also been made to estimate catches from illegal, unreported, and unregulated (IUU) fishing using satellite remote-sensing images in the north-eastern Pacific.[13]

Ocean issues are also motivating action that transcends traditional alliances. The world leaders at the G20 summit in Osaka, Japan, June 2019, recognized the importance of addressing IUU fishing for ensuring the sustainable use of marine resources and conserving the marine environment, including biodiversity, and reaffirmed their commitment to end IUU fishing. If the pillars of ocean stewardship can become mainstream issues that unite governments, industry, and civil society, then there is room for optimism.

EMPOWERING MOBILITY WHEN MOVING ISN'T A CHOICE

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In the 2010s, the media began reporting on groups of migrants from Central America walking thousands of miles to the US-Mexico border, fleeing poverty and violence and seeking a better life in the United States.

The US government labelled this migrant caravan phenomenon a "crisis" – not because of the devastating conditions faced by migrants at home and on the United States southern border, but because of the presence of unauthorized migrants in the United States. By November 2018, the real crises intensified: in Tijuana, more than 5,000 migrants were living in an overcrowded stadium awaiting their future; in the United States, child migrants were being separated from their parents.

The Central American migrant "crisis" is just one of many the world has seen in recent decades. As of September 2019, the Syrian conflict had resulted in over 5.6 million refugees seeking refuge mainly in Turkey, Lebanon, and Jordan. As of 2018, 800,000 people had fled their home countries in North Africa as asylum seekers and refugees, some embarking on often-deadly boat trips across the Mediterranean. In each case, climate-related stresses ranging from droughts to famines seemingly add to the instability and violence that forced migrants are fleeing, only to run into increasingly unfriendly border policies.

For many observers in the wealthy, industrialized global North, the influx of forced migrants from Central America and the Middle East has been seen as a sign of an impending flood: their assumption is that climate change impacts will spur violence and/or push hundreds of millions of people into their borders, causing yet more violence and other problems. Current evidence and projections do not support these extreme scenarios.

Despite headlines to the contrary, research suggests that climate change is not likely to spur new patterns of migration that don't already exist, nor is it a major determinant of political instability and interstate conflict. For every case in which a climate-change-related disaster was associated with violence or migration, there are hundreds where such disasters were met with peace and effective management. In the instances where climate change does accelerate migration, sound migration policy can play a critical role in the outcomes.

In other words, humanity is not at the mercy of forces seemingly beyond our control: human decision-making lies at the heart of crises, not climate change alone. Good migration policy, climate-adaptation interventions, and disaster-mitigation actions can help to stem difficulties and boost positive effects for migrants and their host communities, even in the face of violence and climate disasters. Misguided policy, based on incorrect assumptions, exaggerated fears, and alarmism, does little to help vulnerable people adapt to our planet's changing conditions.

Migrants from South America in an overcrowded sports complex in Tijuana in November 2018.

People in motion
How many people do we expect will move because of climate change? The answers depend almost entirely on how fast we reduce emissions, and on the policy interventions we implement to shape vulnerability. This cannot be overstated: the number of future migrants from climate change depends on what governments and policymakers do right now.

With the intent of highlighting the plight of climate-vulnerable people, advocacy and policy agencies have been keen to quantify migration and displacement due to climate change and conflict, and to attempt to predict future migration. An unfortunate unintended consequence of these predictions has been to feed alarmist, reactionary narratives.

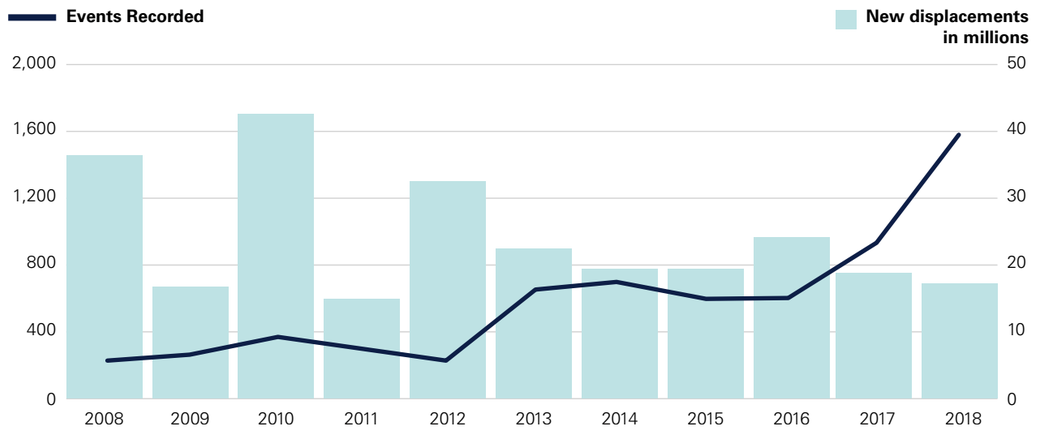
British environmentalist Norman Myers's 2002 paper, for example, identified 25 million environmental "refugees" in 1995 and predicted – based on broad assumptions – a doubling of this number by 2010, followed by as many as 200 million people driven from their homes by climate disasters by 2100.[1] Others, relying on vague modelling frameworks, have warned of climate migrants numbering up to 1 billion by 2100. Such statements, while intending to hammer home the severity of consequences from climate change, serve to fuel public alarm and xenophobic policy about, as one paper satirically noted, "Climate Barbarians at the Gate".[2]

Such predictions are speculative: the real numbers may ultimately prove lower or even higher. We just don't know. Given our uncertainties, it makes more sense to rely on methodical empirical observations of persons currently displaced, and focus on what can be done to accommodate forced migrants now. The Internal Displacement Monitoring Centre (IDMC) reports that in 2017, 18.8 million people were newly displaced by disasters,[3] but while the number of recorded disaster events is rising, the number of people displaced by them shows no clear trend (*see Figure: Disaster Displacement*). The total number of forced migrants, including persons displaced from conflict and other drivers, is much higher: 70.8 million in 2018.

While the movement of tens of millions of people around the globe is significant – especially for migrants and hosts who need help in their transitions – the world can accommodate tens of millions of displaced people per year if it chooses to do so. Even if numbers of forced migrations rise dramatically over time, it is possible for policies to keep pace.

Future climate change will likely bring more frequent and intense disasters related to rising temperatures, drought, and sea-level rise. Small island developing nations, such as Kiribati, Tuvalu, and the Maldives, may lose their entire land surface during the 21st and 22nd centuries, rendering their populations stateless. In this and other ways, climate change will surely prompt many people to move, whose potential difficulties should not be minimized or trivialized. Yet whether there are problematic "floods" of people crossing national borders depends less on these physical factors, and more on human decisions and actions.

To move or not to move
Observers in wealthy, industrialized countries tend to imagine that migration is what happens when something goes wrong, like when a person loses their home or livelihood due to some unforeseen disaster. But migration may be better thought of as a universal adaptive human strategy for pursuing well-being, prosperity, and development, a strategy that people all over the world use to manage economic and environmental risks.



Disaster Dispacement
While the number of disaster events each year has trended upwards, displacement events show no clear trend.
Source: Internal Displacement Monitoring Center, 2019

Throughout the whole of human history, people have been in motion. During the 20th century, the rapid rise in human development and standards of living is largely attributable to migration from rural agricultural areas to cities, where migrants built much of our modern industrialized societies (*see box "The Liveable City"*). Research shows that migrants contribute to their hosts' economic development (as well as development back in their original hometowns), provide economic and cultural diversity to their host societies, and are generally more law abiding than their hosts.[4]

Problems primarily occur not when people migrate, but rather when peoples' movement is impinged, for one reason or another. When people cannot move due to poverty, poor health, or discrimination, or because their cultural and personal attachments to a place are strong, they may enter what researchers call "mobility traps". In these circumstances, people are unable to access the many benefits of migration.

In the last 60–70 years, in the nation-state system that arose following the Second World War, borders have become a real impediment to movement. Restrictive border policies can have a range of negative consequences for migrants, including sharpening the disparity of wealth within and across our societies.[5] People are generally better off – both migrants and host communities – when we reduce such barriers.[6]

Heated conflict?
The facts about the relationship between climate change and conflict are equally muddied in the public mind.

Some studies have produced dramatic findings that seem to indicate environmental factors – such as temperature extremes or drought – universally determine complex social outcomes such as political violence. For example, one influential paper in 2013 claimed that each standard deviation change in temperature rise or rainfall prompts a 14% rise in intergroup conflict.[7] Such findings are very appealing to "common sense" desires for simple explanations of complex phenomena.

But the current consensus acknowledges that reality is far more complicated, and outcomes rely heavily on the social and political context. A recently published survey of nearly a dozen experts showed that while they generally agree that climate change may affect conflict within countries, they also judged socio-economic factors and political histories as far more important determinants of violence – especially between different nations.[8] Each case is different; there are few, if any, universal rules.[9]

Many of the studies that draw simple conclusions about the links between climate and conflict have been accused of falling victim to common research biases[10] such as the "streetlight effect" – the idea that people tend to look where it is easiest to look, rather than where they should look (like hunting for lost keys at night only where the streetlights shine). Studies tend to focus only on areas where there are persistent problems with violence; ignoring, for example, areas that might have seen climate change impacts, but no resulting violence.

Because climate change has already affected every region on earth, studies are able to find climate change impacts in nearly all instances of civil conflict. Spurious findings can be exacerbated by, or perpetuate, ideological biases: African countries, for example, are often a focus of studies on climate stress and violence, which may bolster racist notions that these countries are more inherently violent.

Research targeted at simple explanations tends to artificially simplify complex outcomes, or unhelpfully obscure the roles of colonial history and human agency. This can translate to incorrect or misleading narratives, particularly in the popular media.

Take, for example, the recent case of Syrian refugees. A narrative has emerged in some research that climate change and drought played a central role in precipitating the Syrian Civil War and the humanitarian crisis that surrounds it. One now-famous 2015 paper[11] claimed that drought in Syria led to unemployment in rural areas, which prompted migration to the nation's cities, where discontent with the government was most acute. In other words, climate change created angry migrants who later became political dissidents.

These ideas have been countered by researchers with evidence supporting an alternative explanation. While the drought and violence in Syria's cities coincided in time, as they pointed out, there was no evidence that one caused the other; a similar dry period in Iraq at the same time notably did not cause migration or violence.

The conflict in Syria was based on pre-existing popular discontent with the Assad regime. Emboldened by the Arab Spring movement, Syrian political dissidents led massive public demonstrations, which the government met with violence. The heavy-handed government response galvanized dissenters against the Assad regime, and violence ultimately escalated into civil war. If the drought played a role, it was to amplify existing popular discontent with the Assad regime for its removal of agricultural subsidies and poor drought-recovery choices, which disproportionately affected the working poor and further disenfranchised some segments of society.[12]

Where migration occurred in Syria, it consisted almost entirely of people fleeing civil-war-related violence.

Complex realities
The fact is that researchers struggle to find any uniform trends of migration creating social problems, such as violence or conflicts over resources. Mounting evidence indicates that migration, rather, is a key strategy for adapting to climate change, and when migration alternatives are readily available – when there are few social, economic, and political barriers to migration – then vulnerable people are better able to recover and contribute.

This is not to say that environmental stress has no role to play at all. In Central America, for example, where violence and instability have proven to be an explosive combination, disasters may have been a (less-often-acknowledged) contributing factor.

In autumn 1998, Hurricane Mitch dealt a catastrophic blow to Honduras, Nicaragua, and parts of Guatemala. The torrential rainfall inundated Honduras, devastating infrastructure, homes, and crops, "reversing 50 years of progress towards development", in the words of then-president Carlos Flores. As the floods subsided and the nation began to recover, it is estimated that a quarter of the population had been temporarily displaced, and about 100,000 had migrated to the United States.

What is not well understood (and is, indeed, very difficult to study) is whether Hurricane Mitch, its strain on institutions, its impact on development, and the needs it imposed on society, made these nations more susceptible to the street gangs that are largely responsible for criminal violence. After Hurricane Mitch, infamous street gangs, such as Barrio 18, proliferated in cities like Tegucigalpa, Honduras, where state institutions were reeling from disaster, displacement had totally reorganized society, and post-disaster recovery had stalled.

Likewise, in its disaster recovery response, the Honduran state prioritized rebuilding and expanding infrastructure, roads, and bridges into rural, historically disconnected regions. The post-disaster economic collapse and expansion of rural infrastructure could be offered as one among the many reasons that Honduras became attractive as a hub for drug trafficking.

Since the mid-2000s, with the proliferation of street gangs and the influx of narco-trafficking, Central America has held the ignominious claim to the highest homicide rates in the world. Cities like San Pedro Sula, Honduras, have rates of violent death higher than active war zones. Poor, disenfranchised boys growing up in these circumstances face very grim prospects, including impoverishment and recruitment into violent street gangs. If they do join gangs, or even appear to, they face persecution by state authorities. For many teenage boys, Central American cities are so dangerous that they may essentially be uninhabitable, and the migration of young people we have observed from Central America is a simple reflection of this reality.

It would be irresponsible to claim that a hurricane caused street gangs and drug trafficking in Central America. Other catastrophic storms have affected similarly vulnerable countries without the same outcomes. But there are specific ways that these factors may have worked together to shape the exodus of migrants we have witnessed this decade. The common denominator is the region's structural vulnerability to a range of social and environmental disasters.

Good hosts

Despite mounting evidence about the complex interplay between climate change, violence, and migration, officials often still rely on "common sense" narratives to justify the responses of governments and development or humanitarian agencies – often to ill effect.

For example, the notion that climate-induced migration represents a national security risk may inspire nations to prepare for climate change with increased border security, militarized surveillance and policing of migration. The practical implications of setting policy on the basis of unsubstantiated claims are deeply problematic for vulnerable people, and may encourage radical ideologies, including nationalism, militarism, protectionism, isolationism, and xenophobia.

VICTIMIZING VULNERABLE PEOPLE REDUCES THE SPACE TO DEVELOP WIN-WIN SOLUTIONS

Further, victimizing vulnerable people reduces the space to develop win-win solutions that help migrants build resilience and open opportunities for host societies to gain from migrants' energy, experience, and citizenship. When systems are hostile to migrants, such as imposing strictly enforced migrant quotas or increased border security, migrants are less able to participate fully in societies and economies.[6]

Instead of focusing on the climate determinants of conflict and migration, researchers should pay closer attention to instances when no violence occurred after disaster despite expectations to the contrary, or when no migration occurred in the face of an overwhelming climate stressor.

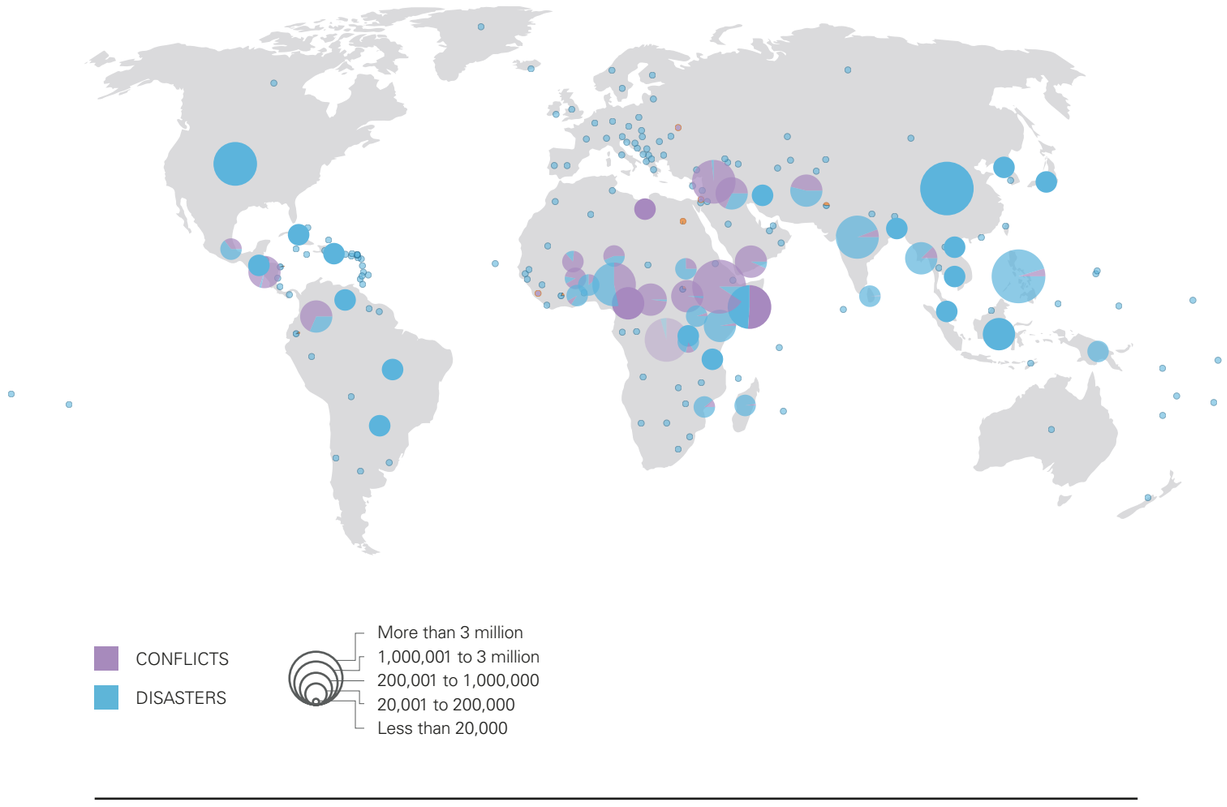
Important general lessons come from cases like Bangladesh, for example, where policies have dramatically reduced the destabilizing impacts of cyclones. In 1970, the Bhola Cyclone struck southern Bangladesh, resulting in large-scale displacement, famine, and the deaths of an estimated 500,000 people, making it the deadliest natural disaster in history. Partly in response to this, in the late 1990s the Bangladesh government began and sustained a set of policies to reduce disaster vulnerability, which included investments in early warning systems and cyclone shelters. As a direct result of these investments, when in the mid-2000s a series of cyclones struck Bangladesh with similar force (Cyclones Sidr and Aila), death tolls were dramatically lower, and only small changes in migration were observed.

Likewise, there are lessons to be learned from cases when climate change and conflict do drive migration, but social protections in host communities ease transitions. For example, one study on the integration of Afghan refugees in Australia showed that people given permanent protected visa status fared significantly better than those given temporary visas across a range of outcomes, including better mental health, stronger English language acquisition, and more social engagement.[6] When migrants are treated like permanent members of society, they contribute as permanent members of society.

Studies like these challenge narratives and policies that seek to block migration from climate change, and instead encourage decision makers to focus on reducing the risk of disasters and accommodating migration when it would likely enable adaptation.

Responding to the Central American migrants, US policymakers – lacking the appetite to address violence, instability, and disasters at their root in Central America, or to formulate social protections and accommodations to help migrants better contribute to American society – have created political turmoil within the American political system. Long-standing anti-immigrant sentiments in the United States have provided a basis for an official federal policy of separating unauthorized Central American children from their parents upon arrival – a move that has been sharply criticized as unethical, if not illegal. What this case highlights is that the "crises" around migration are in the public imagination: ideologies, attitudes, and feelings towards migrants, and how these justify our treatment of migrants.

How a society treats forced migrants is a test of its values. The world is facing unprecedented environmental stress. But if we choose to invest in solutions, we can greatly reduce potential conflict and strain. The costs of pre-emptive political action and timely humanitarian aid are far outweighed by the consequences of doing nothing.



On the Move

Numbers of migrants displaced from disaster and conflict in 2018. *Source: Internal Displacement Monitoring Center, 2019*

THE LIVEABLE CITY

Timon McPhearson
Urban Systems Lab, The New School,
New York City, United States

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In 2019, Los Angeles – a city renowned for its smog – vowed to plant 90,000 trees over the next two years as part of its Green New Deal. New York City passed a Climate Mobilization Act that requires green roofs or solar panels on new buildings, catching up with similar legislation in Germany and elsewhere. At the C40 World Mayors Summit in Copenhagen in October 2019, it was announced that 30 cities (a third of its membership), from Athens to Washington, have passed peak emissions and, on average, cut their emissions by 22% since 2009. At the same meeting, 35 mayors – from Amman to Quito – signed a clean air pledge, even while air pollution in New Delhi reached 50 times the level deemed safe by the World Health Organization.

As the world's population grows, people continue to flock to cities for the opportunities they provide. More than 4 billion of the planet's 7.7 billion people currently live in urban areas, and this is increasing by 1 million every 10 days.[13] By 2050, it is anticipated that two out of every three people on the planet will be living urban. In the face of this dramatic demographic change, many are working hard to ensure that cities of the future are more sustainable, resilient, and equitable: in short, more liveable.

Although cities' massive infrastructures have voracious energy demands and a traditional reliance on fossil fuels (and so produce more than 60% of the planet's greenhouse gases, according to Unique Nature Habitats), cities provide huge opportunities for sustainability. Carbon emissions are lower per capita, on average, in cities:[14] greenhouse gas emissions for New Yorkers have been estimated to be less than one-third of the national average for the United States, for example. Cities are engines of innovation, education, and creativity, and hotbeds for experimentation with new technologies or social systems. As the C40 shows, city leaders have proved more willing and able to commit to more stringent climate change initiatives than nations. Satellite images combined with social media posts and data from buildings and cars have spurred a revolution in data availability in the last five years, making it easier to measure how people are living in cities and where further efficiencies can be gained.

Yet cities are also some of the most vulnerable places on the planet. The urban socio-economic divide can be huge: two-thirds of the poor in Latin America reside in urban areas. Many cities are heating up faster than surrounding landscapes as the pavement soaks up more sunlight and the buildings generate more heat, aggravating heatwaves and their health impacts.[15] Some 90% of urban areas are on coastlines and potentially vulnerable to rising sea levels; all cities remain vulnerable to floods and droughts. Air pollution, especially from traffic, can be deadly: the 1952 London Smog is thought to have caused more than 4,000 deaths; Delhi and Beijing frequently have air pollution levels many times above standards.[16]

Pushing systems to be efficient, which is often the focus of smart cities and urban sustainability agendas, can strip them of much-needed redundancy: the backup systems and multiple solutions to social and technological issues that make cities flexible and resilient to heat waves, air pollution and coastal flooding.[17]

Fortunately, making cities more person-centric, or more liveable, often makes them both more sustainable and more resilient. Many of these solutions are based in nature, mixing the green with the grey.[18] In China, for example, so-called "sponge cities" use permeable roads and incorporate wetlands to build flood resilience into an urban landscape. Many cities are incorporating more green space to lower the heat island effect. Some desert cities are building bus stops with giant solar panels that simultaneously provide shade and renewable power.

The transition to "better" cities will not be easy, or uniform. The IPCC estimates that the energy use by buildings will have to go down by 80–90% by 2050, and transport by 30%, in order to hit a goal of 1.5°C temperature rise.[19] Some Asian cities are moving towards using more cars, for example (in China, cars on the road went from about 65 million in 2008 to 240 million in 2018, while in the United States numbers stayed fairly flat), but other cities, like Copenhagen, are fighting to bring back bikes (by 2025, they aim to have half of all commutes done by bicycle). In other places, developments are changing what we think of as a city: in parts of Africa and Asia, new urbanization sometimes consists of small villages and larger towns linking virtually to join their economies into city-like models, though populations remain fairly dispersed.

In the far future, digitization technologies may undercut the traditional model of more jobs being available in cities, changing the model of who desires to live where – and why. The key is to provide them with efficient, equitable, and resilient options.

The city of Los Angeles vowed to plant 90,000 trees over the next two years.

INDUSTRIALIZING DISINFORMATION

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Measles, one of the world's most contagious diseases, still kills over 100,000 children every year. Once on its way to eradication, in recent years epidemics have broken out in the Democratic Republic of Congo, Sudan, and the Philippines – and in the rich suburbs of New York and Auckland. In 2018, 140,000 people died as cases surged worldwide.

One cause of this unexpected rise in disease is online disinformation. A recent *Nature* opinion piece warned that the biggest pandemic risk today is "viral misinformation" eroding public trust in vaccines.[1] One study has estimated that about half of all parents with young children are exposed to anti-vaccine messages on social media.[2]

The flow of information in the world is changing. Today, around half of the planet's 7.6 billion people are online, where they are deeply influenced by social media, search engines, and e-commerce algorithms. These roll together into a new kind of extractive industry, which uses algorithms rather than shovels, to mine not ores but data. The information traders like Facebook, Google, and Amazon today wield immense power. With access to the private details, consumption habits, desires, and moods of the world's citizens, they have the power to influence behaviour, change the rules of commerce and communication, operate secretly, and destroy industries. Companies capitalize on their algorithms and wealth of data to allow laser targeting of audiences via computational propaganda.

Facebook's Mark Zuckerberg giving testimony before the House Financial Services Committee in Washington D.C. in October 2019.

Digital platforms, specifically social media, favour the spread of information designed to engage with emotion over reason. One study has shown that false news – which often triggers strong reactions of surprise, disgust, or fear – travels 6 times faster and can reach up to 100 times more people than accurate information.[3] Social media platforms have industrialized the spread of disinformation – and made political discourse more aggressive.

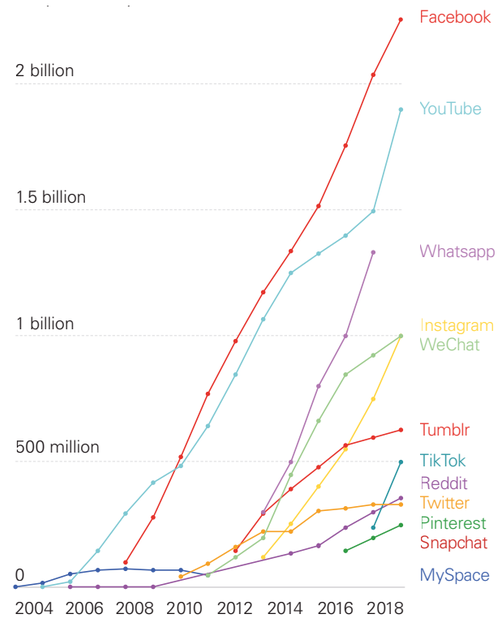
The scale of the problem is now frighteningly apparent. In the United Kingdom, the highly successful campaign to leave the European Union (Brexit) focused on emotionally charged messages of fear of immigration and "take back control", while the campaign to remain, based on the logic of economic cooperation, was destined for low engagement. As the last US presidential election reached its conclusion, about one in four Americans visited a "fake news" website, and about half of these people believed those stories, particularly if they favoured their preferred candidate.[4]

Another example comes from a recent report on planetary health, which recommended reducing excessive meat and dairy consumption to tackle the burden of disease and emissions. A small pro-meat countermovement rapidly evolved on social media (under the banner yes2meat), with some posts containing misinformation and even conspiracy theories or personal attacks. The number of tweets and links related to yes2meat rivalled those about the original report.[5]

Of course, social media can also spread evidence-based information and support societal goals. Some children are fighting back against anti-vaxxers, for example, by scouring the internet for reliable vaccination information and sharing it on social media. Swedish student Greta Thunberg's school strike for the climate became a global movement driven by online engagement through #FridaysForFuture and based on a simple appeal to rationality, "unite behind the science". Social media has been credited with a rise in awareness of ocean plastics. And, following the Notre Dame fire, and the rapid response from philanthropists, a #SaveThisCathedral hashtag emerged to highlight environmental commons such as the Amazon rainforest or Greenland ice sheet as other "cathedrals".

These changes to the media landscape come at a critical time – there is an urgent need for greenhouse gas emissions to fall precipitously in the next decade *(see chapter "Climate")*, driven by a dramatic economic transformation (*see chapter "Transformation"*). Digital information technologies and media, though messy, could support global action, through, for example, supporting a shared worldview based on scientific evidence. Yet it remains unclear whether information technologies will drive earth towards a pandemic or away from it; towards a destabilized climate or a potentially manageable 1.5°C warmer world.

FALSE NEWS TRAVELS SIX TIMES FASTER AND CAN REACH UP TO 100 TIMES MORE PEOPLE



Social Spectrum
The number of users active at least once a month on various social media platforms is climbing sharply. *Source: Statista & The Next Web, 2019*

Undermining trust
Since the 18th century Enlightenment, democratic nations have established complex interconnected systems linking the rule of law, due process, and systems of checks and balances, to support stable, fairer, democratic societies. All pervasive in this system, though little acknowledged, is the principle that reliable, unbiased information allowing a widely shared, defensible description of reality is essential to functional and fair governance. Along with science, the news media is central to this.

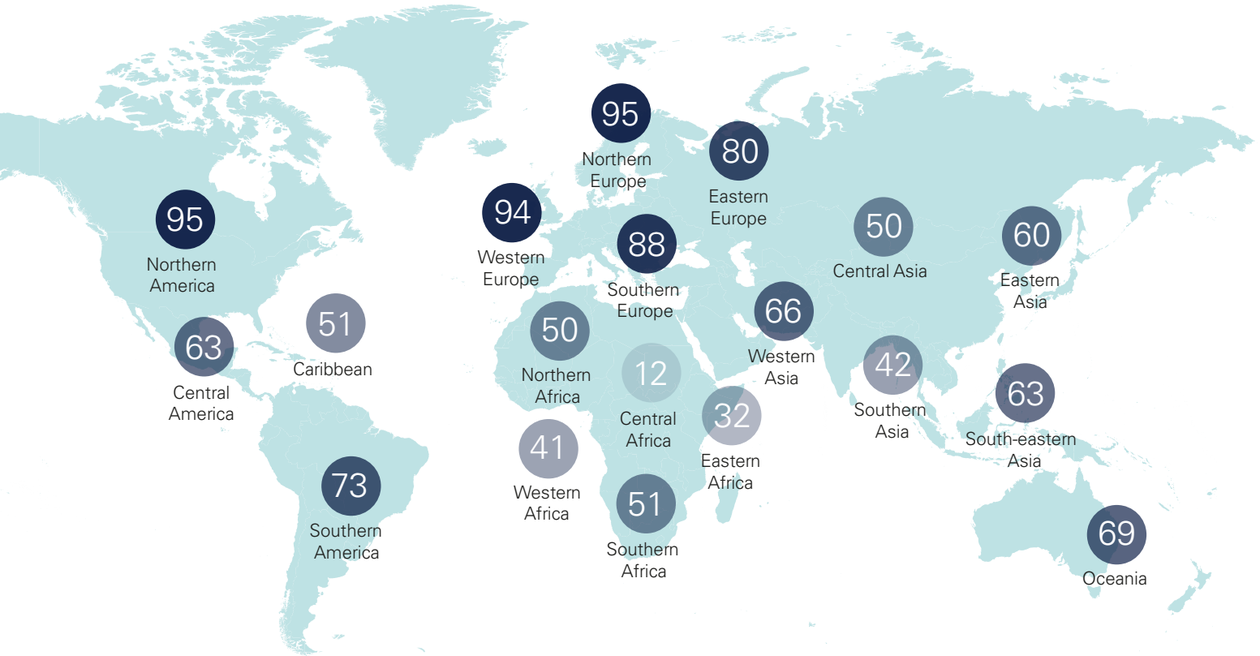
Many mainstream print media outlets spent time and money establishing a reputation for accuracy with high ethical standards cementing their role as a guard dog for society, so that consumers would go to them for trusted news.

Now, digital upstarts are bypassing or destroying many of the checks and balances established for print media. Anyone can broadcast with few or no financial or editorial constraints. In today's digital world, 65% of consumers' news content is discovered through search, social media, or other serendipitous routes, rather than through direct targeting of a particular, trusted media outlet.[6] In some ways, the utility of being a trusted brand has been undercut. In the future, the voices of Siri, Alexa, and Google will further distance the audience from the sources of information, limiting exposure to just single, potentially untrustworthy sources.

It is too simplistic, however, to blame social media for all of today's toxic confusion about information. In the 1980s, US president Reagan swept aside regulations forbidding ownership of TV stations and newspapers in the same market. This allowed Rupert Murdoch's media empire to grow fast, gaining unprecedented influence over political events in the United States. Reagan then disposed of the Fairness Doctrine, which had forced TV and radio companies to present both sides of contentious policy debates. Shortly afterwards, Fox News landed on the airwaves, marketed directly at US conservatives.

The result today is a highly divided media landscape – particularly in the United States. Liberals and conservatives inhabit entirely different media worlds, relying on sources with few overlaps: the right-wing Fox News and Breitbart have little that connects them with the rest of the media, relying on anger and fear to drive up readership of their stories. In this alt-reality ecosystem a statement doesn't have to be proved as true, just established as dominant.

Social media has deepened this divide. Although the serendipitous route by which people arrive at their news might be expected to broaden people's exposure to different ideas, much of the time people are bounced around the parts of the media landscape that already match their mindset: an echo chamber that reinforces what they already believe. Social media platforms tend to create a uniform look for all information, reducing any sense of where it originated or the trustworthiness of that source.



Rates of Connection
Internet penetration ranges from 95% in parts of Europe and America to 12% in the middle of Africa. *Source: Internetworldstats; ITU; World Bank; CIA Work Factbook; Eurostat; Local Government Bodies and Regulatory Authorities; Mideastmedia.org; Reports in reputable media; social media platform user numbers*

According to the 2018 World Press Freedom Index report, more and more democratically elected leaders "no longer see the media as part of democracy's essential underpinning, but as an adversary to which they openly display their aversion". The 2018 book *How Democracies Die*[6] argues that a main giveaway of a leader with authoritarian tendencies is how he or she treats media criticism and freedom of the press.

Together, political and technological changes are eroding public trust in the media around the world. According to a Reuters report,[7] public concern about disinformation remains high: about half of respondents agreed that they trust the news media *they themselves use,* but across all countries trust in the news on average fell to 42%; in France, perhaps spurred by media coverage of the populist yellow vest protests against rising fuel prices, media trust plummeted to 24%. In some nations, including Brazil, the United States, and the United Kingdom, more than two-thirds of people said they were concerned about what was real and fake on the internet.

The reassuring news is that public trust in news found via search and social media is significantly (and justifiably) lower than trust in traditional media. Across countries, over a quarter of people said they have started turning to more "reputable" news sources.

Warped democracies
The changing media landscape does not explain the rise of populism around the world: global austerity, rising inequality, and a sense that the "elites" have abandoned large swathes of society, are more likely drivers of resentment (*see chapter "Politics"*).

But the seismic shift in information flow has allowed for novel political responses. More radical left- and right-wing policies – from the Extinction Rebellion to draconian immigration policies – have found an audience. And the shift allows movements like the Arab Spring to swell rapidly and cross borders. Social media even opens the door a crack to new systems of governance: for example, direct representation or global democracy.

The new media landscape is ripe for political manipulation. The Russian government invests in disinformation campaigns to reduce trust in democratic institutions throughout Europe and the United States – with the goal of leaving Russia standing stronger at the end.[8] The direct impact of such campaigns on elections thus far seems limited: a study of millions of tweets from a Russian troll factory, for example, found no evidence that they had large-scale impacts on political behaviour, but they sow confusion and undermine trust, another goal of the Russian government. The media and researchers are keeping a keen eye on new media's influence on the upcoming 2020 US presidential election.

Not everyone, of course, is yet online to see such campaigns. Internet penetration in the United States and Europe is extremely high (typically higher than 90%), but elsewhere the numbers are, for now, much lower (*see map "Rates of Connection"*). In Central Africa, only 12% of people have access. In many regions of the Global South, the main issue around digitalization is often exclusion. In Malawi, for instance, a data bundle of 10GB costs over US$20, but three out of four people live on less than US$2 per day. Not having digital access doesn't just limit access to information; it also prevents the development of digital literacy skills and prevents a sense of digital belonging.

Things are changing fast, however. In 2019, India alone saw nearly 98 million new users come online (more than a quarter of the global growth). China, Facebook, Google, Amazon, and Elon Musk are now competing to provide greater internet access across Africa through various programmes. While these efforts may prove successful at quickly boosting access, they also threaten to limit which sites people can access most easily, or to monopolize consumer and citizen data.

AS CONNECTIVITY RISES, SOME WORRYING SIGNALS ARE EMERGING

As connectivity rises, some worrying signals are emerging. In 2019, at least 10 African countries enacted internet shutdowns before or during elections or protests. The governments usually say this is to help maintain safety and security; others maintain it is being done to restrict access to information and prevent movements from challenging leadership.

Social media is being co-opted by authoritarian regimes. According to a report from the Computational Propaganda Research Project,[9] conducted by Oxford University, the online world is being used as a tool of information control in 26 countries to suppress fundamental human rights, discredit political opponents, and drown out dissenting opinions. In China, the communist government has invested in a sophisticated mass surveillance system to track people's movements using data from phones, vehicles, and identity cards – a practice that is being targeted specifically at Muslim ethnic minorities in China's Xinjiang region. China has banned western social media sites, allowing the China-based app WeChat to dominate chat, banking, shopping, and travel. WeChat has blocked large discussions of politically charged topics, for example relating to the Tiananmen Square massacre in 1989 or Hong Kong's recent protests. It remains unclear to what extent the Chinese government has access to WeChat data. In early 2019, India floated new proposals to suppress internet content, prompting comparisons to Chinese censorship.

Surveillance technology using some sort of artificial intelligence (AI), is spreading worldwide. At least 75 countries are actively using AI technologies for surveillance, including "smart cities", facial recognition, and "smart policing" according to a report from the Carnegie Endowment for International Peace.[10] Chinese companies supply AI surveillance technology to 63 countries, 36 of which are part of China's Belt and Road Initiative.

Rebuilding trust
Until very recently, the dominant societal narratives about technology have been driven by tech founders themselves, and largely unquestioned by politicians and the media. Companies like Facebook and Google have propelled a narrative that technological development is inevitable, and that their services will help to unite humanity and make information more useful. Yet, in reality, information technologies are undermining democracies, sowing distrust in the media, and ultimately threatening social cohesion at a critical moment for global cooperation on sustainability.

The broad societal discussion about the role of the technology platforms in supporting societal goals is nascent. Politicians are figuring out how to navigate this new world, and the research community is just beginning to engage. Future Earth created an initiative, "Sustainability in the Digital Age", to bring together academics and leading tech companies to explore a research agenda to expand this conversation. Elsewhere, the German Advisory Council on Global Change and The World in 2050 are exploring the role of digitalization in future low-emissions pathways.

The emerging solutions tend to group around three areas: learning to live in this new information ecosystem; self-regulation by information platforms; and more effective government oversight.

Research is accumulating on how to inoculate people against fake news, online propaganda, and misinformation. The Cambridge Social Decision-Making Lab created an online game "Bad News" that allows people to spread conspiracy theories in a safe environment. Results of their study involving 15,000 users showed that playing the game helped create "mental antibodies" to false information.[11]

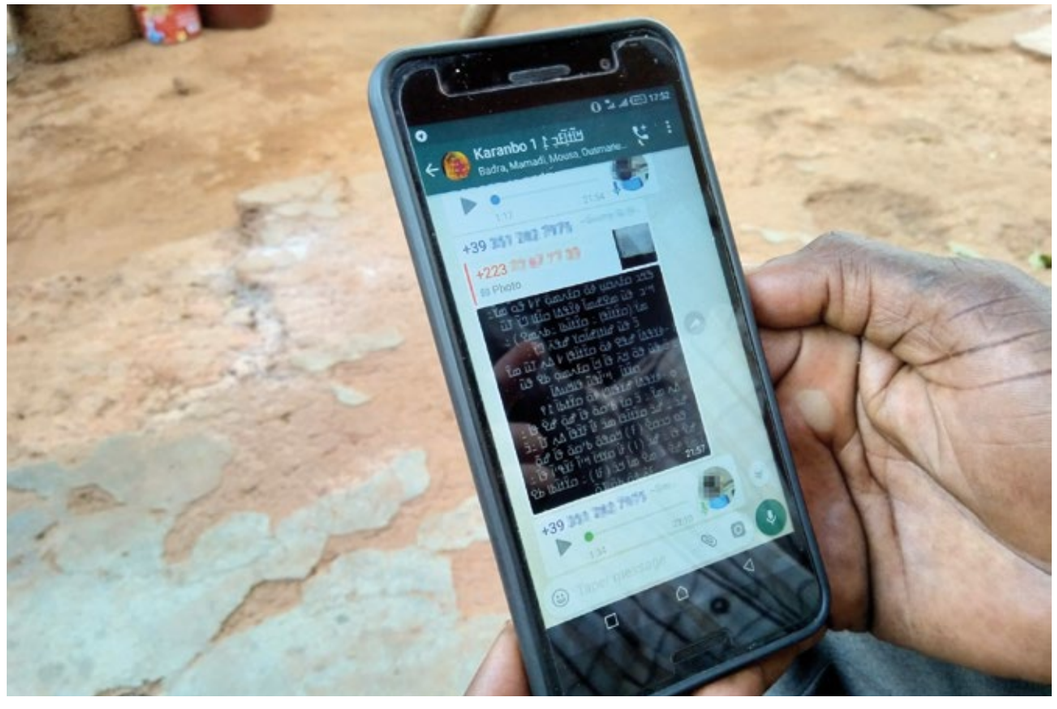
Other research has shown that it is easier to replace false ideas in people's minds if an alternative is provided.[12] Saying the MMR vaccination does not cause autism, for example, is less persuasive than offering an alternative explanation for an apparent rise in diagnoses. Those attempting to counter the rising tide of fake news can use these emerging tools to help improve the effectiveness of their messaging.

Several fact-check companies now patrol WhatsApp, sometimes with funding from the International Fact-Checking Network, to help to flag incorrect information. The bigger goal though, is to prevent it from circulating in the first place. Leading tech companies are beginning to acknowledge that misinformation is a problem and are rolling out solutions ranging from cracking down on fake accounts, to policing search engine page rankings.

In 2019, WhatsApp announced it would limit the number of times a message could be forwarded to five, in an attempt to stop provocative content from spreading (although initial research suggests this is ineffective at blocking misinformation campaigns).[13] Google has rewritten its algorithms to elevate search results that are judged (by Google) to be in-depth original reporting requiring "a high degree of skill, time and effort". Facebook has created an independent oversight body to adjudicate over content moderation and announced a series of measures to prevent election interference, ranging from anti-hacking protections to labelling state-owned media and removing campaigns from, for example, Russia and Iran. At the same time, though, the company exempts political adverts from fact-checking, while Twitter recently banned political adverts on its platform.

Governments have been slow to react to these issues; indeed, some are often complicit in data surveillance of citizens, or eager recipients of the collected data. Now, tech companies are increasingly facing antitrust, anti-competition, and privacy legislation. As lawmakers deliberate, tech companies are pouring money into lobbyists to influence the regulatory agenda.

While the United States remains cautious about regulating the industry, in 2018 Europe clamped down harder than any other region on data privacy with new laws that give people more control over personal data. Europeans now have the right to be forgotten. Under the General Data Protection Regulation, personal data collection must be declared, and collectors must state how long the data is being retained and who it will be shared with. In July 2019, German authorities in the state of Hesse banned the use of Microsoft's popular cloud Office 365 services in schools, citing privacy concerns and potential exposure of student data to American authorities. In the same month in the United States, Facebook was fined $5 billion by the Federal Trade Commission for privacy violations.



An online WhatsApp-based N'ko classroom as seen through a man's cellphone in Bobo-Dioulasso, Burkina Faso.

Power play

A century ago, rail and telephone companies were broken apart under anti-trust and monopoly legislation to reduce concentrations of power. In recent decades, the definition of a monopoly has focused on protecting consumers from high prices. Since digital platforms often provide services for free, they have slipped under the monopoly radar. In 2017, the European Commission fined Google €2.42 billion after it found the giant's promotion of its own price comparison service over that of its rivals illegal. The case began in 2010, highlighting the complexity of bringing these types of cases before the courts. Since April 2019, new EU rules force Google and Amazon to tell companies how they rank products on their platforms.

Some politicians, including Democrat presidential candidate Elizabeth Warren, are now calling for the tech giants to be split up, arguing that their power and dominance is bad for democracy. Decentralization and more competition should help constrain the power of any one company, but there could be negative impacts too. As more companies enter the market, they may try to gain an edge over their competitors by using even more biased algorithms to promote even more emotionally charged content, driving greater polarization.

Nick Srnicek, a lecturer in digital economy at King's College London, has argued that these platforms operate more like utilities, providing essential services for societies – from online shopping to communications and banking. As such, Srnicek argues, they should be regulated to support the common good rather than profit. This might mean shifting ownership of online platforms away from private companies.

There is no obvious consensus on how to harness the power of platforms to support societal goals. But it is clear that a transformation to a sustainable planet needs three things: a shared acknowledgement of the need to act; trust in collective decision-making; and a system to support behavioural change. Our globally connected digital ecosystems can support these aims, but this presents the need for a new social contract between technology and society – Tim Berners Lee, the founder of the world wide web, recently proposed something similar.

The biggest opportunity from the digital revolution may not be the development of an internet of things, biotech, or even artificial intelligence, but rather the tools to distinguish fact from fiction – and to harness new digital media for the good.

SOME POLITICIANS ARE NOW CALLING FOR THE TECH GIANTS TO BE SPLIT UP, ARGUING THAT THEIR POWER AND DOMINANCE IS BAD FOR DEMOCRACY

BIODIVERSITY

THE UNRAVELLING WEB OF LIFE

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In 2018, the world's last male northern white rhino died in his Kenyan enclosure. The Brazilian blue parrot, Spix's Macaw, was declared extinct in the wild, among a handful of other birds. A 2019 study showed bird populations across North America have declined a staggering 29% since the 1970s.[1] And those are just the things that grabbed the media's attention or scientists' notice.

In May 2019, scientists released the most comprehensive report yet produced on the status of and trends in biodiversity, ecosystem services, and their links to human well-being. The news from that Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report isn't good.[2] Humans have now "significantly altered" 75% of our planet's land area and 66% of the ocean. More than 85% of wetlands have been lost. The report estimates that about a quarter of species in assessed plant and animal groups are threatened: that means about 1 million species face possible extinction, perhaps within decades. The rate of extinction is currently tens to hundreds of times higher than the average over the last 10 million years. Since 50,000 years ago, the mass of wild mammals on the planet has declined by a factor of six:[3] today, the mass of domesticated livestock and poultry vastly outweighs that of wild animals and birds.

THE MASS OF DOMESTICATED LIVESTOCK AND POULTRY VASTLY OUTWEIGHS THAT OF WILD ANIMALS AND BIRDS

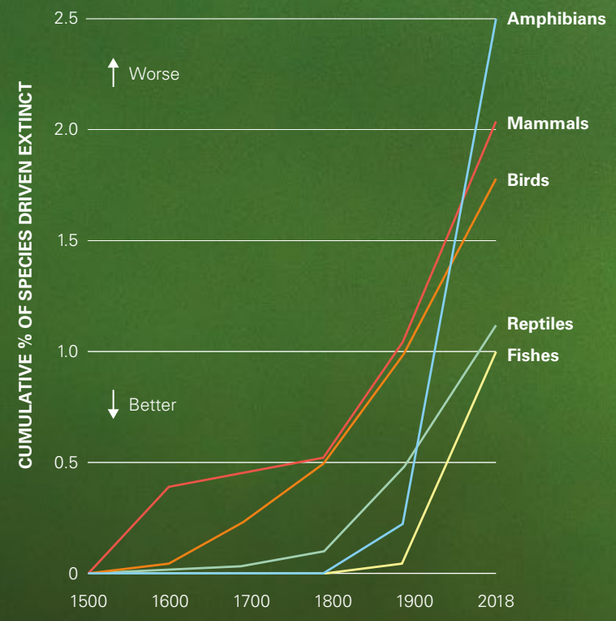
Around the world, biological communities are becoming more and more similar to each other – whether those ecosystems are managed by humans or not. In the last 60 years, according to the United Nations Food and Agriculture Organization, wheat, maize, and rice have become the main staple foods across the globe, replacing traditional crops like cassava, yam, millet, and sorghum, and leading to a loss of 90% of crop varieties. Invasive species like African grasses have wiped out local species and made one ecosystem more like another.

This is not just a philosophical or moral problem: these profound changes to the fabric of life have considerable impacts on human well-being. Ecosystems provide us with resources for fuel, medicine, food, and clean water, all of which depend on complex, biodiverse systems for their healthy maintenance. About three quarters of food crops, including cash crops like coffee, rely on animals for their pollination, for example. Yet recent years have seen a 75% decline in insect abundance, including pollinators.[4] The very soil that we use to grow our food has seen a decline of 10–15% in organic content over the last decades.[5]

In 2010, parties to the Convention on Biological Diversity (CBD) adopted the Strategic Plan for Biodiversity 2011–2020, and its 20 Aichi Biodiversity Targets, to halt biodiversity loss. Despite increasing calls to conserve biodiversity, it is very unlikely that most if not all of these targets will be reached by 2020, jeopardizing the achievement of the Sustainable Development Goals by 2030.

Countries are now in the process of negotiating a "Global Deal for Nature": a new global biodiversity framework to be discussed through the CBD in 2020. The development of the post-2020 strategic plan for the CBD provides a critical opportunity to set out a new ambitious plan of actions to conserve and restore global biodiversity.[6] Fulfilling this goal – and reversing the trends of loss of life on this planet – will require some new ways of thinking about conservation.

Known unknowns
The IPBES extinction estimate is based on well-studied species that are obvious (like mammals and birds) or of particular interest to society or science (like rare, ancient seed plants called cycads). A lot less is known about many other species, some of which are, undoubtedly, vitally important to ecosystems.



Extinctions
Cumulative percentage of species extinctions, based on background rate of 0.1–2 extinctions per million species per year. *Source: IPBES, 2019. "Summary for Policymakers of the Assessment Report on Biodiversity and Ecosystem Services for the Americas".*

The IUCN Red List estimates 40% of amphibians are threatened with extinction, facing problems from habitat loss and disease to climate change. Source: IUCN Amphibian Specialist Group. https://www.iucn-amphibians.org/

THE TRADITIONAL APPROACHES TO CONSERVATION ARE UNLIKELY TO WORK BY THEMSELVES

Very little is known about invertebrate species, for example: soil invertebrates are not included in assessments, and changes in invertebrate diversity often go unnoticed.[7] Invertebrates are thought to be experiencing even more rapid change than other groups, thanks to their short lifespan and complex life cycles; many species may even go extinct before their discovery. Yet invertebrates are central to the functioning of a wide range of ecosystems – the majority of pollinators are insects, for example, and invertebrates living in the soil are crucial for nutrient cycling. Their disappearance has direct impacts on food security.

Even less is known about microorganisms or microbes, which make up the majority of life on earth. These occur in virtually all habitats and are fundamental to biogeochemical cycles and the health of plants and animals.

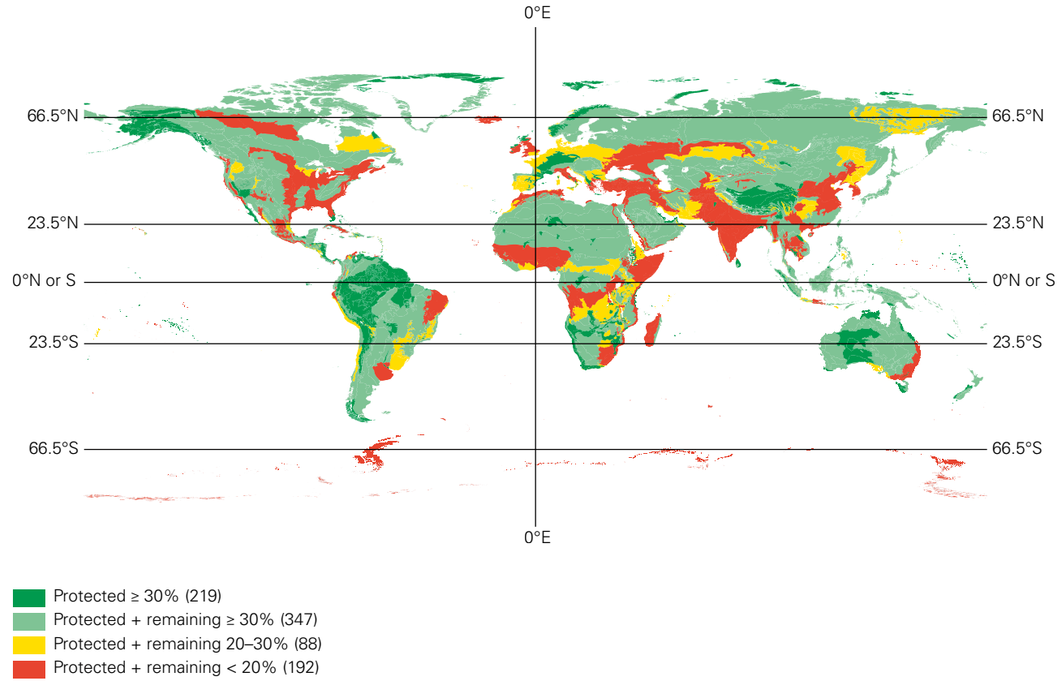
Microorganisms, in particular phytoplankton, soak up a huge amount of carbon dioxide from the atmosphere and play an important role in the carbon cycle. Soil microbial diversity is important for plant health and plant growth, and researchers know that plant diversity has a positive effect on soil microbial diversity (likewise a decline in plant diversity leads to a decline in microbe diversity).[8] Researchers know that climate change and land-use changes affect the function and composition of microbial communities[9] – the diversity of soil microbes decreases as conditions get hotter and drier, for example – but the exact details of what we are doing to our planet's microbes, and the long-term impacts of that, are unclear.

Researchers know from studies at small to large scales that a decline in the number of species reduces ecosystem function, and an increase boosts it. To be specific, in grasslands, an increase in the total number of species increases the sheer mass of plant material that grows in any given time: more species means more productivity.[10] In sub-tropical forests, the amount of carbon soaked up by plant life is higher in stands with a greater number of tree species.[11]

A decline in the number of species, and a homogenization of ecological communities, reduces ecosystems' function in many ways, from the total amount of growth to resistance to invasive species. This effect has been seen in grasslands sites across five continents.[12]

In the driver's seat

What's causing all this biodiversity loss and its knock-on effects? The IPBES report identifies five main direct drivers. First, there are changes in how humans use the land and sea, such as the conversion of vast swathes of forests to agriculture – between 2000 and 2010, the planet lost some 1.5 million sq km of global forest.[13] Second, the direct exploitation of organisms: raw timber harvesting, for example, has gone up by 45% since 1970. Third, climate change: coral reefs, for example, are vulnerable to heat stress and ocean acidification, and are expected to decline 10–30% with 1.5°C of warming. Fourth, pollution: algal bloom in lakes, for example, can wipe out other resident species. And finally, the invasion of alien species: zebra mussels, infamously, are outcompeting and threatening dozens of other species of freshwater mussels in places including the Great Lakes of North America.



Potential for Protection
Amongst the world's 846 terrestrial ecoregions (A), there are variable potentials for reaching a target of 30% protection by 2030 (B). In this assessment, 219 of the regions have already met a target of 30% protection; 347 have high potential for reaching this target (given the amount of land already protected plus the amount of remaining land with potential for protection); 88 have moderate potential; and 192 are imperiled. The ecoregions that have or could reach 30% protection are distributed among all of the 14 terrestrial biomes. *Source: Dinerstein et al. 2019*

Underpinning these direct drivers are indirect effects. As humanity changes its patterns of consumption, for example, different patches of land are converted to agriculture and different shipping routes are established. Government policies intended to do one thing, like boosting agricultural production, often end up harming biodiversity. These drivers do not work in isolation: they interact with each other, and the impacts of combined drivers are often bigger than the sum of their parts.

In part because of all this complexity, it is hard to predict how ecosystems will change in response to factors like climate change. The current models that predict large-scale alterations to vegetation patterns in the face of climate change, like the expansion of boreal forests into Arctic tundra, can't predict the actual species-level changes to plant communities on a smaller scale. On a local scale, other things are more important, from the type of soil to the presence or absence of herbivores and pollinators.[14]

Seeking solutions

Addressing the challenges linked to a deteriorating web of life and the consequences for human well-being requires urgent action that tackles the root causes of environmental decline.

The traditional approaches to conservation are unlikely to work by themselves: creating an isolated protected area, for example, or working to conserve one single species, may ignore the complex interrelations between ecosystems and social patterns across huge scales.

The future of biodiversity conservation will have to take into account all the direct and indirect human drivers of biodiversity loss, from economics to governance, as outlined by IPBES, and also needs to consider "tele-coupling": the impact of local decisions and actions on other parts of the world.

There are plenty of examples of local decisions that seemed to make sense but had negative effects elsewhere. In the early 2000s for example, European countries made a big push to increase biofuels in order to reduce CO_2 emissions from transport.

THE LONG VIEW

The drivers of biodiversity change aren't exactly new; climate change is a constant, and Homo sapiens have been around for more than 300,000 years.

As early as 125,000 years ago,[18] people contributed to the Late-Pleistocene megafaunal extinctions: a combination of climate change and hunting led to the extinction of many large mammals on virtually every continent, from the woolly mammoth to cave bear and sabre-toothed cat. That was perhaps humankind's first major alteration of ecosystem structure, with long-term legacy effects on plant communities and fire regimes. Some 50,000 years ago, humans in Australia burnt large tracts of grasslands, reducing shrubs and trees, and increasing grassland productivity. In Southern Africa, hunter-gatherers used fire to promote edible plant species, and pastoralists burned grasslands to improve grazing for their herds.

In Europe, deforestation began as early as 6,000 years ago, as people made room for agriculture. Hunter-gathers, farmers, and pastoralists began to have truly significant impacts on land use by about 3,000 years ago, when ancient Greece was in full swing.[19] Trees were felled and burned to make way for more and more people until the end of the Industrial Revolution.

This long-term view is important for understanding the history of an ecosystem, the likely impacts of future human-induced changes on the biosphere, and the extent to which altered ecosystems can cope with future climate changes – all of which contributes to what conservation efforts might aim to achieve.

On the Galapagos islands, for example, conservationists are keenly worried about the detrimental impacts of some 750 non-native plants introduced over about 500 years of human habitation. But a study of fossil pollen dating back 5,000 years proved that six suspect plants were actually old natives making a comeback.[20]

Other studies help to show which ecosystems might prove stable, and which might require management. At the tail end of the last ice age, some 14,000 years ago, North American ash and spruce occurred in the same habits; today, their ranges do not overlap.[21] A swathe of such studies can help to show which species can happily coexist, even if they don't do so today.

Studies of the past extent of forests and deserts inform the models that tell us what vegetation to expect in a warmer future, or how much fire we might see in a warmer world.[22] The long view tells us to expect boreal forests to expand polewards and to be replaced by more drought-adapted species in southern regions.

Interestingly, the palaeoecological record is also revealing an increasing number of examples of species and ecosystems that were surprisingly resilient to higher temperatures and increased levels of CO_2.[23] The most common response to past periods of fast warming was actually a replacement of plant biomes rather than extinctions. That isn't necessarily good news for the future, however. Today's ecosystems are being affected by a rapidly warming climate while also being heavily degraded by human activities. That adds uncertainties to the end effect.

Image from an investigative report from Rainforest Action Network that presents evidence of two undisclosed palm oil plantations in West Kalimantan, Indonesia.

But this contributed to an increase in palm oil and sugar cane plantations, in part to meet these demands, resulting in mass deforestation in Indonesia and Malaysia – it has been estimated that 45% of palm oil expansion since 2008 has been at the expense of forest. In March 2019, after years of controversy, the European Commission concluded that palm oil biofuel shouldn't be eligible for renewable transport targets.

Likewise, restrictions on logging in one area have led to booms elsewhere; restrictions on fish catches in one place have boosted catches, and problematic bycatches, elsewhere.

The new goal is to establish targets that are useful and relevant both locally and globally; and to "decouple" economic growth and improvements to standards of living from environmental degradation and unsustainable resource use.

The proposed solutions are varied. There are suggestions, for example, to keep the food system within environmental limits by encouraging dietary changes: it seems possible to feed more people a healthy diet, using less land, by relying less on meat and dairy products and more on vegetables and grains.[15] This approach has several benefits: it frees up land for conservation, reduces CO_2 emissions and pollution, and also improves human health (*see chapter "Food"*).

To address land degradation more broadly, wider initiatives are being developed. The United Nations Convention to Combat Desertification (UNCCD) aims to achieve Land Degradation Neutrality, for example, by counterbalancing loss of productive land with recovery of degraded lands elsewhere. For example, the Great Green Wall Initiative has the stated intent of restoring millions of hectares of degraded land in the Sahel region of Africa. Other initiatives are gaining momentum, such as the Coalition of the Willing on Pollinators, which aims to promote sustainable land use supportive of pollinators. These efforts contribute to the protection of biodiversity and ecosystems, while simultaneously increasing food security, and securing local and national economies.

Land use remains a huge challenge: the competition between land use for food, biodiversity, and biofuels has many knock-on effects on greenhouse gases, human welfare, health, and more. One possible solution is to rely more on lifestyle changes to reduce energy demand, and the reduction of non-CO_2 greenhouse gases, to keep climate change in check.[16]

Yet it is also true that conserving ecosystems is an extremely effective way to stabilize the climate while also protecting biodiversity and human health. The Global Deal for Nature being negotiated now aims to deliver a deal to protect and restore 50% of the world's land and oceans by 2050, with an initial target to bring 30% under protection by 2030. The effort has divided the earth up into about 1,000 different ecoregions, from tropical forest to tundra, to work out which regions are already well preserved, and which need the most urgent attention (*Figure: Potential for Protection*). Conserving half of our planet is an ambitious target that is expected to save the majority of species and help make the planet more liveable for humanity – at an estimated cost of about US$100 billion per year.[17]

Keeping the web of life from unravelling, and meeting the environmental and societal goals for the next decades, requires rapid action that addresses the challenges synergistically and in a concerted fashion. We need to address the root causes of environmental destruction, transforming society and governance, and rethink our values.

MAKING MONEY WORK FOR GREEN GOALS

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In 2019, the world saw the first ever climate-change-related bankruptcy. The owner of California's largest electric utility company, PG&E, filed for bankruptcy in January, after their equipment was blamed for sparking California's devastating Camp Fire, which devoured more than 150,000 acres and took more than 85 lives in the summer of 2018. Transmission lines may have created the spark, but climate change amplified the hot, dry conditions that left vegetation vulnerable to fire. Climate change, many say, was partly to blame.

Finance is a risky business. But the global situation today – economic, political, and environmental, especially climate change – is conspiring to make it riskier.

We live in a "full" world with at least 7.3 billion people, which has seen explosive financial growth over the past 50 years. From 1970–2018, global GDP grew from under US$3 trillion to US$80 trillion; and global debt skyrocketed from 35% to 290% of GDP.[1] At the same time, the growth in wealth has been skewed towards just a tiny fraction of the global population, leading to huge economic inequality. Today, less than 1% of the population owns over 50% of economic assets, nearly 20% of the world lives in poverty, and much of the "middle classes" have not seen real improvement in their economic condition for several decades.[2] These economic inequalities spawn financial, social, and political risks.

A search and rescue team rakes through remains of the devastating Camp Fire in Paradise, California in November 2018.

But climate and environmental change has perhaps the biggest impact on financial risk today. The number and severity of extreme weather events and natural disasters is rising, at huge cost – and poorer people who depend on nature for their livelihood suffer most from these changes in natural systems.[3] The transition to an economy powered by renewables brings great opportunities, but also great risks to companies currently invested in fossil fuels. Global disturbances to biodiversity, along with the carbon, nitrogen, and phosphorous cycles, have deep and not-well-understood impacts on societies and food production, which in turn brings economic risk.

Fortunately, there are a few efforts under way to better document, manage, and reduce these risks, including the nascent Task Force on Climate-related Financial Disclosures (TCFD). But there is still a very long way to go.

While the impact of earth system changes on finance is huge, the impact of finance on the earth system is also immense and growing. The great acceleration of economic growth over the 20th century put a lot of pressure on the earth system, emphasizing resource extraction and profits over sustainability. In recent decades, ecological economists have highlighted the grave risk posed by economic growth on ecosystem health. Today, financial products like green bonds – and a trend towards environmental, social, and governance (ESG) investing – will hopefully begin to reverse this trend and instead promote more sustainable activities.

In 2018, the United Nations estimated that there is an annual investment gap of US$2.5 trillion to meet global sustainable development goals. Public funds won't be enough to close this gap: mobilizing private finance is key. Guidelines for sustainable investing, along with products like green bonds, can help financial investment to drive the planet towards, rather than away from, sustainability.

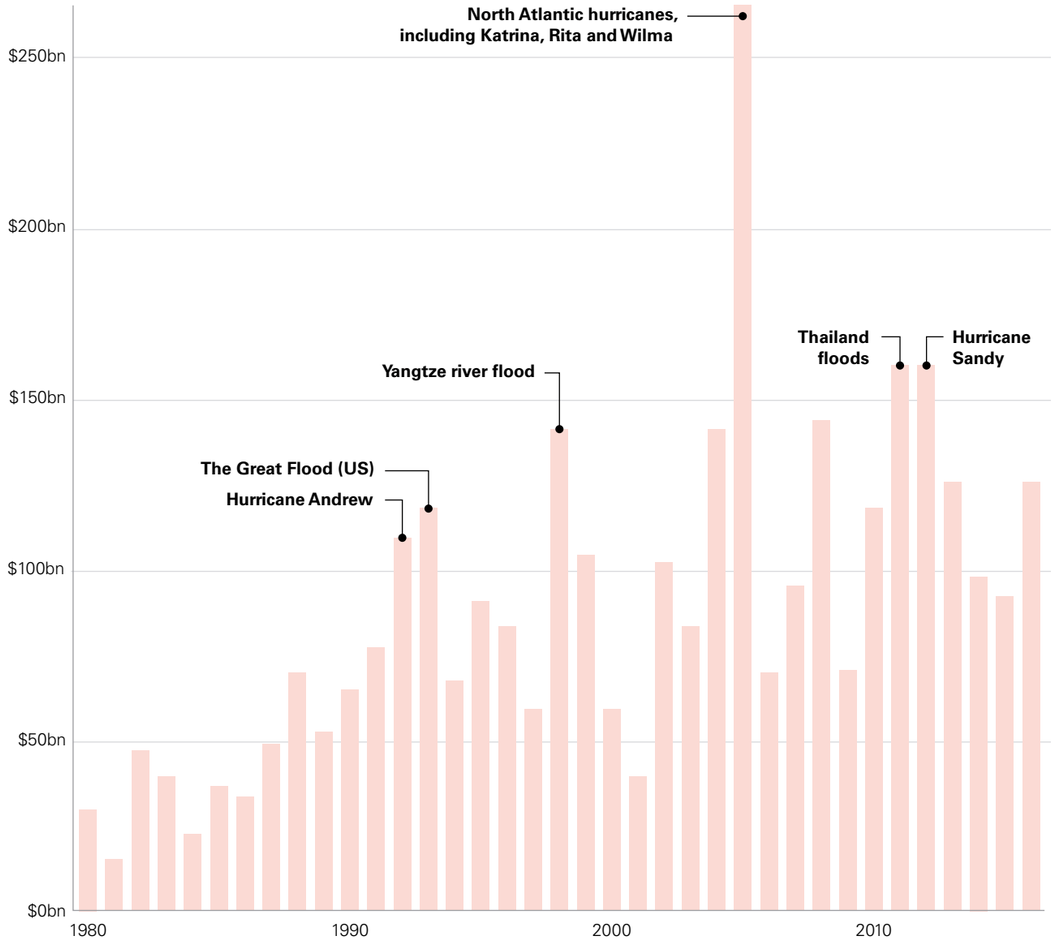
Rising climate risk

As the PG&E bankruptcy shows, climate change is bringing significant financial risk to the business world. Scientists have long been warning about this. Insurance companies were among the first in the financial sector

to take the message on board, as extreme events like floods and droughts ramped up and caused more insured losses. A recent survey by three actuarial organizations found that insurers now name climate change as *the* top risk for their industry.[4]

Central banks and business leaders are sitting up and paying attention. In April 2019, the Bank of England's governor Mark Carney (along with the Network for Greening the Financial Services, a coalition of central banks formed at the One Planet Summit in Paris in 2017), penned an open letter. It hammered home the importance of climate-related financial risks and what needs to be done to manage them. Business leaders and experts surveyed by the World Economic Forum ahead of its annual summit in Davos said that extreme weather, failure of climate change mitigation and adaptation strategies, and natural disasters are the three risks they're most likely to face in 2019.[5] A 2019 report from BlackRock affirmed that investors can no longer view climate-related risk as something lying far off in the future.[6]

Financial reports often group climate-change-related risks into two categories. The first of these, physical risk, refers to the problems caused by climate-related hazards such as sea-level rise, heatwaves, droughts, and extreme weather. These can be sudden, like the California wildfires in 2018. They can also be chronic, such as sea-level rise and increase in global mean surface temperature, as changing climatic conditions have knock-on effects on industry.



Disaster Losses
Global economic losses from extreme weather events have trended upwards over the past decades. *Source: Münchener Rückversicherungs-Gesellschaft Aktiengesellschaft in München ("Munich Re"). 2018*

Climate change is expected to impact the growth of coffee, for example. The world's most popular farmed coffee type, *Coffea arabica*, can only thrive in specific climatic conditions. One recent study found that 60% of the wild species of coffee are at risk of extinction.[7] This poses a risk to the coffee industry and farmers; to the quality, price, and availability of coffee; and finally to financiers. Meanwhile, changing patterns of hurricanes and storms in South East Asia could disrupt the global supply chains of technology companies, and increased water scarcity is expected to impact beverage companies like Coca-Cola.

The second category is transition risks, which refer to the risks resulting from the transition to a low-carbon economy. The development of renewable energy and electric cars, to name a few examples, provide both huge opportunity but also risk for the companies invested in fossil fuel technologies.

Both technological development and government policies can change rapidly, creating uncertainty that adds to financial risk. Companies might be caught off guard by the introduction of a carbon tax, for example, or by a new regulation that makes a major investment in infrastructure obsolete – stranding assets, and creating financial loss. The Norwegian Oil and Gas Association recently warned that increasing political activism could dramatically hit its nation's largest industry. A study by the European Insurance and Occupational Pensions Authority (EIOPA) found that 10–13% of European insurers' assets are exposed to climate transition risk.[8]

Pricing the problem

The BlackRock report concluded that climate risks are likely not being correctly priced by the market. The report notes that it seems to be hard for investors to grasp the realities of how climate change will impact their portfolio, for two reasons: the tendency of financial markets to underprice risks that seem low probability and distant; and lack of data and tools.[6]

Lending and investment decisions are often made on short-time horizons, typically less than 10 years, while the time horizons presented in climate change studies are usually 20–30 years or much more, sometimes centuries. This means that investors are encouraged to act in ways that promote short-term returns at the expense of long-term planning. The EU Sustainable Finance Action Plan, adopted in 2018, acknowledges this as one of the key barriers to a sustainable finance system. The plan details strategies to foster long-termism in governance – along with other steps to foster sustainability.

In the meantime, a lack of solid, public information on climate risks remains a problem. A recent review of investors' needs for information on physical climate risk, for example, revealed that this information is mostly provided by consultancies that aren't transparent about their methods and provide limited public accessibility to their underlying data.[9] A common truism in business is that you cannot manage what you do not measure; climate risk is no different.

THE TASK FORCE ON CLIMATE RELATED DISCLOSURE (TCFD) HAS MASSIVELY RAISED AWARENESS IN THE FINANCIAL COMMUNITY

One of the best-known efforts aiming to close this gap is the TCFD, established in 2015 by the Financial Stability Board at the request of the G20. The TCFD developed a set of recommendations to streamline the disclosure of climate-related financial risk by all financial actors and companies, explicitly creating a framework for climate risk to become a part of standard financial reporting. This has massively raised awareness in the financial community about how climate risk translates into financial risk, and has given the community a common language to talk about it.

As of 2019, 340 global investors managing nearly US$34 trillion are asking companies to report in line with the TCFD. A recent survey by S&P Global found that of the largest 2,500 companies in the world, 70% have at least limited TCFD filings.[10] But fully fledged TCFD reporting has been slow to start. The TCFD recently published a review of climate-related financial disclosures over three years for over 1,000 companies.[11] The review found that while disclosure has increased, the level of disclosure is still insufficient for investors.

There are a number of frameworks and guidelines for tackling even broader sustainability risks, beyond just climate. For example, the Sustainability Accounting Standards Board sets some voluntary guidelines for transparent reporting to investors. The EU Sustainable Finance Action Plan includes an update of the 2014 EU

directive on the disclosure of non-financial information, which requires large companies to disclose material ESG risks and how these risks are managed. The proposed updated guidance to companies includes reporting in line with the TCFD recommendations.

But for reporting companies and their investors, it remains a hard task to assess and disclose these risks. There are many overlapping guidelines and initiatives at international, national, and regional levels. When the Center for International Climate and Environmental Research (CICERO) interviewed Norwegian financial-sector stakeholders in 2018, they found "reporting fatigue" was common among respondents.[12]

The availability of data on climate-related financial risks is expected to get better with improved corporate reporting efforts like the TCFD, and there are a myriad of new tools emerging for the investment community. Several major rating companies and specialized ESG providers offer climate-risk datasets, for example. The current offerings are not considered adequate by all investors, but there are emerging initiatives by research institutes to bridge this gap. An example is the CICERO-led initiative to categorize corporate revenue and investments according to how aligned they are with a low-carbon, climate-resilient future.[13]

Driving sustainable finance

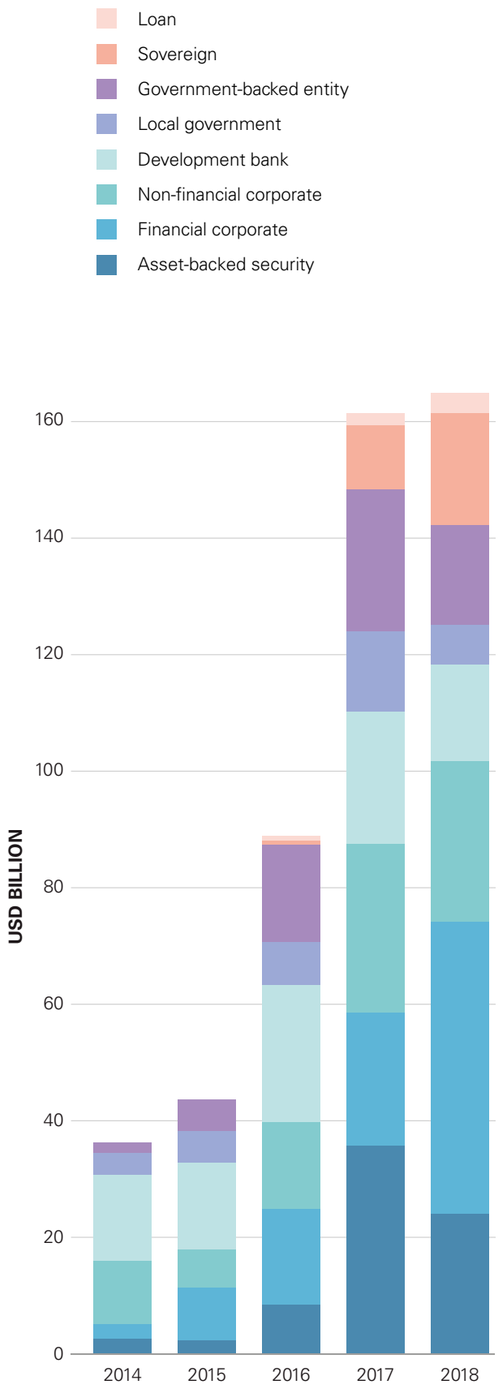
The good news is that sustainable finance – the notion of using investments and financial instruments to create a more sustainable earth system – has recently grown from niche to mainstream.

The Principles for Responsible Investment, for example, launched in 2006, now has more than 2,000 signatories in the financial sector. This body, which was started by the United Nations but is now a stand-alone effort, lays out good principles for ESG investing, helping investors to target projects that encourage everything from environmental sustainability to ethical working conditions.

Within the ESG universe there are many different investment strategies. A commonly used strategy among ESG investors is to exclude companies with poor ESG performance from their portfolios. In 2019, the Norwegian pension fund excluded several companies for being overly invested in coal, or for serious violations of human rights.

Another ESG strategy goes further, screening all companies in a portfolio for factors like carbon emissions or gender equality, and considering those criteria in addition to financial performance. One such example is Generation Investment Management, which announced in 2019 a US$1 billion fund specifically to invest in the themes of planetary health, human health, and financial inclusion.

Some studies now suggest that ESG investing decreases financial risks for lenders and investors. A 2015 review of 2,000 empirical studies found that the majority of them report a positive relationship between ESG and corporate financial performance.[14] A more recent study in China found that allocating more green loans to a loan portfolio



Green Bonds
The number of green bonds has risen dramatically in recent years, with a diversity of different issuers.
Source: Climate Bonds Initiative, 2019

reduced the share of loans in, or close to, default.[15] This suggests that green loans may be less risky than non-green loans.

In addition to considering sustainability in existing financial products, there is a growing world of sustainable finance instruments. The sustainable debt market, for example, consists of bonds (tradable debt) that have a green and/or social purpose. This is a voluntary market driven by investor demand for sustainable debt. The market reached US$247 billion of issuance in 2018.[16] Sustainable bonds still represent just a few per cent of all bonds (the entire debt market is not well documented, so the total figure is unknown). But the market is increasing dramatically, more than doubling from 2016 to 2018.

The biggest and most mature part of the sustainable debt market is "green bonds", with about US$182 billion of issuance in 2018.[16] These finance a broad range of environmental activities, from green buildings to wind farms, as guided by the voluntary, international Green Bond Principles (GBP).

Since the first green bond was issued in 2008 by the World Bank, the market for green bonds has expanded greatly. Today it is not just multilateral development banks that issue green bonds, but also financial institutions, municipalities, and national governments. In 2018 there were six new sovereign green bonds from Belgium, Indonesia, Ireland, Lithuania, Poland, and the Seychelles. These sovereign green bonds provide funding for important green infrastructure projects.

The first green version of an Islamic bond (sukuk) went towards building a 50-MW solar power plant in Malaysia. And Indonesia raised US$1.25 billion from a green sukuk towards projects including enhancing rapid transit in Jakarta, the capital city.

So far, the environmental integrity of the green bond market has been maintained mainly by a voluntary system of external reviews, such as those carried out by CICERO. But several countries are considering regulating the market. China, the second biggest national market for green bonds, has detailed regulations in place for the green bond market; the People's Bank of China published green bond guidelines in 2015. In early 2019, the European Commission developed a draft green bond standard, building on existing GBP. Increased regulation will provide standardization to the green bond market but might also increase the barrier to entry if transaction costs go up.

The success of the green bond market has spurred new products, including social and sustainable bonds that incorporate both environmental and social goals. So far these are nascent markets, with just shy of US$14 billion of social and US$18 billion of sustainability bonds issued in 2019.[17] But, though just a small slice of the pie for now, they have attracted the attention of some major players: notable issuers include the City of Los Angeles, Starbucks, and the National Bank of Canada.

In 2018 a brand-new product, sustainability-linked loans, was introduced and saw substantial issuance – in the first year, over US$36 trillion of loans were issued.[16] These debt instruments include incentives for the issuer to achieve sustainability goals, tying together ESG and financial performance. These products still represent a small share of the total debt markets, but their growth gives reason for optimism.

The path forwards

In April 2019, the Network for Greening the Financial System released its first report,[18] laying out suggested actions for greening the financial system and for the whole financial system to become more resilient to the risks inherent to climate and environmental change.

The report recommends integrating climate-related financial risks into financial stability monitoring; integrating sustainability into central bank portfolio management; and bridging data gaps by publicly sharing relevant data. It encourages policymakers to promote adoption of the TCFD recommendations, along with other internationally consistent environmental disclosures. And it supports enhancing transparency about both the potential climate impact – and the climate risk – of economic activities.

The financial sector has a key role to play in the low-carbon transition, in reducing vulnerability and in strengthening adaptation to the impacts of climate change. By financing activities that either fit into a low-emissions economy or represent a step in that direction, the financial sector – along with policy and regulatory measures – can help to bring about the necessary transformations in a way that reduces climate-related risks and safeguards economic development. Connecting financial decisions to the biosphere and the earth system as a whole should help to provide a just and sustainable livelihood for all.

There is still a long way to go. But the strategies and instruments developed over the past few years provide a reason for optimism. As Mark Carney said in a speech to the European Commission in March 2019, "In the future, climate and ESG considerations will likely be at the heart of mainstream investing." He predicts that better corporate reporting and better data analysis – aided by the latest artificial intelligence trend of machine learning – will help investors to tailor their investments in ways that help the planet.

FOOD

RETHINKING GLOBAL SECURITY

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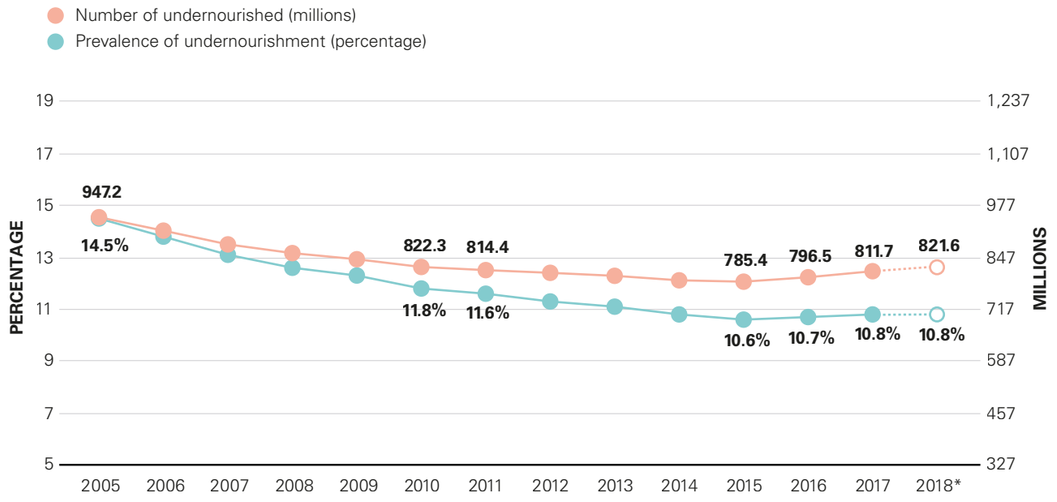
Today, humanity produces sufficient calories, in theory, to feed the 7.7 billion people on the planet: the amount of food produced per person on the planet has gone up more than 40% since the 1960s. Yet, ironically, the prevalence of undernourishment – which had been declining for decades – has started to tip upwards again: the total number of people undernourished in 2018 stood at more than 820 million people, up from a record low of 785 million in 2015 *(see Figure: Hunger rising)*. At the same time, some 1.9 billion people are overweight, and 650 million are obese.[1]

Achieving food security means producing enough nutritious food that is safe to eat, affordable, and accessible to those in need. Strains on food production are expected to increase, as a result of changing climate and environments (including biodiversity loss), and growing food demand due to population growth. By 2050, we will need to feed an estimated 9 billion people on a planet with diminished natural resources.

To get food to the right place, networks of food trade in our increasingly globalized world will become ever-more important but their role in global food security is a double-edged sword. Global trade can facilitate food accessibility and help individuals or nations to pull out of poverty; but it can also further deprive the poor. The profitabilityof so-called flex crops, which can be used as biofuels, has resulted in large investments in sub-Saharan Africa, for example, but this also often displaces local small-scale farmers who are important for local food security. Rapid increases in exports of local or indigenous crops can lead to unintended consequences such as agricultural expansion into marginal lands and desertification, and displacement of small-scale farmers. The growing popularity of quinoa in Europe and North America, for example, has led to an almost doubling of the number of hectares devoted to growing this crop in Peru, displacing other crops important to local food markets.[2]

The vulnerability of the current food system has been highlighted by recent financial shocks. The global economic crash of 2008 resulted in a price hike of 300% for rice within a single year, as countries like India closed their doors to exports to protect their own population. During the past two years of trade-war between the United States and China, soya bean prices have been volatile, putting a strain on US farmers.



* Values for 2018 are projections as illustrated by dotted lines and empty circles.

Hunger Rising
The number of undernourished people in the world has been on the rise since 2015, and is back to levels seen in 2010–2011.
Source: FAO, 2019

WE WILL NEED TO SQUEEZE EVER-MORE FOOD OUT OF THE SAME AMOUNT OF LAND

Meanwhile our current food system is driving the planet towards more extreme climates. A quarter of humanity's greenhouse gases come from agricultural land. This includes methane released by ruminant livestock and paddy rice production, emissions from farm machinery or production of agricultural chemicals, and the carbon released through deforestation to expand agricultural land. Rapid soya bean expansion in Brazil comes at the cost of clearing carbon- and biodiversity-rich forests.

The predicted increase in extreme weather events such as floods and droughts will hit agriculture hard: in October 2019, the United Nations World Food Programme warned that the drought, cyclones, and floods seen recently in Southern Africa will make a record 45 million people across 16 nations severely food insecure in the next six months. Higher atmospheric carbon dioxide (CO_2) boosts some plant productivity but also lowers the nutritional content of some crops, which will affect the poorer countries disproportionately.[3] Most global agricultural models predict that the changing climate alone would decrease agricultural production; but a possible boost in plant productivity from elevated CO_2 levels has the potential to offset some impacts on yields.

As the world continues to warm, the regions where major food and cash crops can grow are shifting, placing further strain on traditional food supply networks and on communities that rely on marginal lands for their own sustenance. The forecast is that the overall amount of land suitable for growing crops will stay the same, but we will need to squeeze ever more food out of that land for our growing population in our changing climate.[4] The biggest boom in population over the next century is expected for sub-Saharan Africa, in areas often unsuitable for intensive agriculture due to poor soil quality and scarce water resources.

As well as contributing to climate change, the way we produce our food has other serious consequences for the environment and the livelihoods of people growing our food. Our current food system causes 60% of land-based biodiversity loss, 33% of soil degradation, and 61% of commercial fish stock depletion[5] *(see box "Seafood")*. More than 40% of insect species are now threatened with extinction.[6] This is a huge problem given that three out of four fruit or seed crops used for human food depend, at least in part, on insect pollinators.

Chemical pesticides, herbicides, and fertilizers used in crop production come with significant health and environmental concerns. The safety of the most widely used herbicide, an organophosphate compound called glyphosate, is hotly debated; it is known to disrupt some amino acid production pathways in the lab, and may be linked to conditions including Alzheimer's and cancer.[7] There are also concerns surrounding the intensive use of antibiotics in livestock and aquaculture: nearly three-quarters of all antimicrobials sold globally are used in animals raised for food, and this has been linked to a rise in antimicrobial-resistant infections in animals, fish, and people.[8]

The future of our food security may sound rather bleak. But some positive stories suggest that if we radically rethink our food systems and consumption patterns across the globe, this could enable us to produce sufficient nutritious food to meet the growing population demand, while minimizing the environmental impacts. This would achieve greater levels of human health, well-being, dignity, and livelihoods – rather than the opposite.

Rethinking food systems

In response to all these global issues with food security, the research community and policymakers have been encouraged to rethink the food problem more broadly than just zeroing in on agricultural production. The issues are more than just being able to grow enough food: they're about getting the right food to the right places, making sure that food is serving public health, changing consumption patterns towards more nutritious choices, and ensuring the ecological and social sustainability and resilience of food systems.

Although the concept of a broad "food system" has been in the making since the 1960s, a more holistic understanding of food has really gained traction among both scholars and policymakers only in the past few years. In 2017, for example, the Food and Agriculture Organization's (FAO) High Level Panel of Experts on Food Security and Nutrition produced a report that marked a fundamental shift: it called on scientists to study all aspects relating to "the production, processing, distribution, preparation and consumption of food, and the output of these activities, including environmental outcomes".[9] Scientists and stakeholders are now teaming up to co-generate knowledge needed to address the water-energy-food nexus.[10]

This holistic approach makes sense for developing system solutions.

In India, for example, a complex interplay of subsidies, renewable energy, and food production has caused a water crisis. In the face of a booming population, the Indian government subsidizes the cost of electricity for pumping water for agriculture; solar energy-based water pumps have also become extremely popular. The country's expansion of irrigated agriculture may have resulted in increased carbon sequestration, which could help to mitigate future climate warming.[11] But there is a lack of financial incentives or advanced irrigation technologies for farmers to use this water wisely, or to conserve it. As a result, groundwater use has increased 500% over 50 years.[5] Fortunately, new management policies that restrict electricity use for irrigation have started to replenish the aquifers in western and southern parts of India.[12]

Another example of the necessity of holistic thinking comes from hydropower. Globally, thousands of dams have been constructed in the pursuit of renewable hydropower, while managing water for irrigation and flood prevention. But this can also disrupt hydrological cycles and redistribute water resources in politically contentious ways. A recent study of the boom of large-scale dams in the Mekong River Basin, for example, showed that major fluctuations have been caused in the flow of river tributaries, "severely damaging downstream crops, livestock, fishery, and livelihoods".[13]

Flooding and water damage in the Park and Tongue River Watersheds located in Cavalier, Pembina and Cavalier Counties in North Dakota on May 23, 2013.

Eating meat

From a planetary health perspective, it's clear that a more plant-based diet would be better than current diets, particularly in Western contexts. The recent Intergovernmental Panel on Climate Change (IPCC) land-use report[14] emphasized that reducing meat and animal-sourced food consumption around the world could reduce greenhouse gas emissions significantly, while freeing up land for growing fruit and vegetables, or for other uses like ecosystem restoration. The IPCC report showed that 58% of all current greenhouse gas emissions from the food system come from animal-sourced foods, of which 85% is from beef and lamb. Using global average data, it was shown that an extreme scenario of removing animal-sourced foods from human diets by 2050 could avoid about 8 gigatons (Gt) of greenhouse gas emissions per year. Limiting consumption of meat or seafood to once a month accomplishes about three-quarters of that goal.

Reducing meat consumption would also have huge ecosystem implications. Since 1970, about 20% of Brazil's Amazon has been deforested – mainly to make room for cattle ranching and the production of soya, 80% of which is used for animal feed (mainly for pigs). Reducing meat consumption would also help to liberate more food overall: it can take up to 9 kg of grains to produce 1 kg of meat. Many efficiencies can be gained by not feeding human food to animals. At the same time, some animals can process vegetation that humans can't digest, and some animal grazing can be beneficial to grassland ecosystems.

From a human nutrition perspective, animal-sourced foods provide high quantities of essential nutrients that can be easily absorbed by the body and help to prevent malnutrition, particularly in poor or rural communities that may not be able to access sufficient nutrients elsewhere. Some nutrients, such as B12, are not available through plant sources and therefore must be consumed through animal products. Nevertheless, excessive quantities of animal-sourced foods can also contribute to cardiovascular disease and some types of cancer.[15]

There are ethical issues too, regarding who deserves to eat a high-meat diet. Right now, meat, milk, and eggs (along with oils and sugars) make up about 29% of calories in developing countries, but 48% in industrialized nations.[5] Rapidly developing nations like China and Brazil have seen their per capita meat consumption double or triple since 1990, while in the United States and EU, meat consumption has held relatively steady. If the global consumption of meat is to be reduced, whose diet should it come from?

There is no clear single diet that is best for people and the planet. It remains controversial. For example, in February 2019, a report was published in the medical journal *The Lancet*, in conjunction with EAT Forum, a nongovernmental advocacy group based in Norway, aiming to develop a healthy, sustainable food system. The 46-page report[16] described a "planetary health diet" high in plants and whole grains and low in animal products and processed foods. This diet would require the global consumption of red meat and sugar to halve,

SEAFOOD

Fish and seafood currently make up about 20% of the animal protein consumed around the globe, and this figure continues to rise. The increase in fish consumption from the 1960s to the 2010s was about 3% per year – slightly more than the increase in meat consumption from land-based animals.[21]

More and more of this seafood comes from aquaculture rather than wild stocks. In the 1960s, aquaculture was a very small proportion of the 50 million tons of seafood consumed. By 2015, it made up more than half of the 170 million tons consumed.[21]

Aquaculture comes with its own host of environmental concerns, from excessive nutrients or antibiotics in the water to the spread of diseases like lice to wild stocks. At the same time, wild stocks are facing big pressures. From 1975–2015, the percentage of stocks that are overfished climbed from about 10% to more than 30%.[21] Climate change and a warming ocean are pushing wild stocks away from their traditionally fished grounds – this could have huge impacts, particularly in the South Pacific, where tuna are moving out of the island nations' coastal (and economically controlled) waters.

Efforts like the Marine Stewardship Council are working hard to make fishing more sustainable and innovative schemes have arisen to make aquaculture smarter.[22] Shellfish can be farmed alongside fin fish, for example, in order to soak up excess nutrients, and kelp can be grown to help lower the acidity of local waters, which can be beneficial to shellfish farms. Such projects both have environmental benefits and can make huge contributions to diets by diversifying sources of fatty acids.

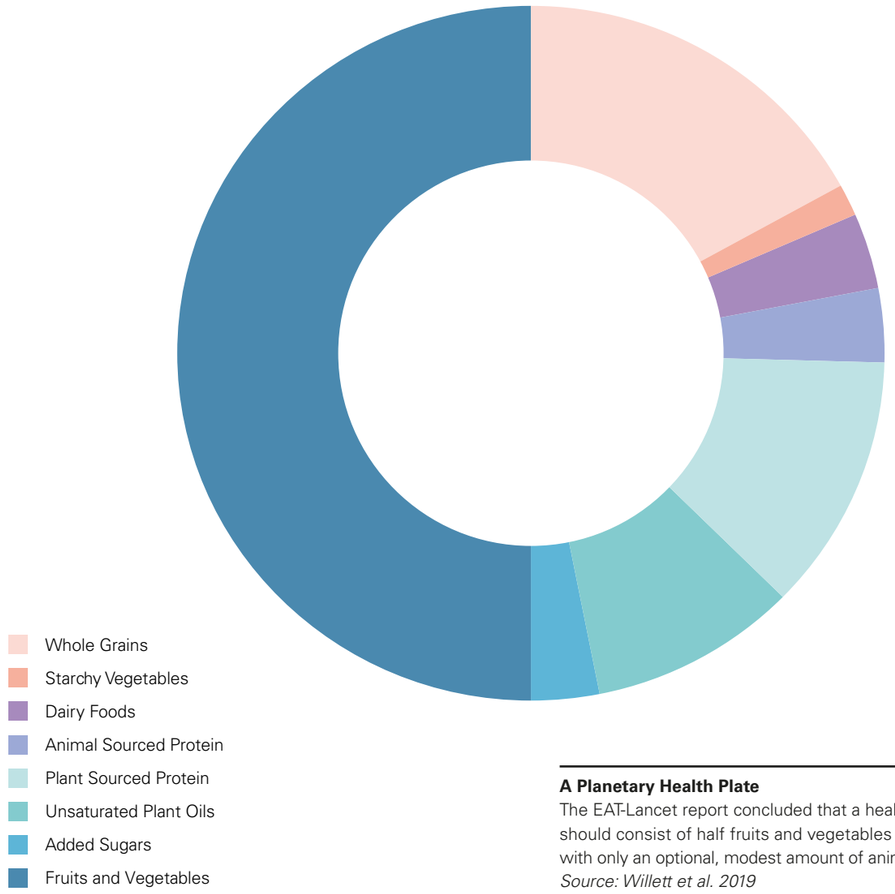
and the global consumption of nuts, fruits, vegetables, and legumes to double. Such consumption could improve public health, although it would require substantial and perhaps sometimes unrealistic changes to current dietary patterns.

Although the EAT plan received widespread attention and support, it was also criticized by animal agriculture lobbyists, international organizations, and members of the scientific community. Some warned that a planetary-wide switch to such a diet could lead to the loss of millions of jobs linked to animal husbandry and destroy some traditional diets. Furthermore, a recent analysis showed that this diet was in fact unaffordable for nearly 2 billion people.[17] There is a clear and urgent need to better understand the trade-offs among nutrition, social, environmental, and economic outcomes of our food system.

Spotlight on solutions

Several innovative programmes, innovations, and policies have arisen in recent years that show how things can change. For instance, farmers across Europe are subject to so-called greening rules. Under this system, 30% of payments given to farmers is linked to three practices: crop diversification, maintaining permanent grassland, and dedicating 5% of arable land to areas beneficial to biodiversity, such as hedges or fallow land. In the period from 2007–2013, more than €7.5 billion of public funds helped to manage more than 13 million hectares of land in the United Kingdom, encouraging farming methods that enhance biodiversity, protect water, and improve soil quality.

In other parts of the world, large-scale long-term policies such as "Grain for Green" in China incentivize farmers to return sloped and marginal farmlands to their natural state, in an attempt to reduce soil erosion and carbon losses. As of 2017, approximately 28 million hectares of farmland and land classified as barren or degraded had been converted to forests, contributing to a 25% increase in global greenness from 2000–2017.[11]



A Planetary Health Plate
The EAT-Lancet report concluded that a healthy diet should consist of half fruits and vegetables by volume, with only an optional, modest amount of animal protein.
Source: Willett et al. 2019

Approximately 30% of the food we produce globally ends up in the waste, according to the FAO. Not including greenhouse gases from land use, the carbon footprint of this wasted food was estimated by the FAO in 2013 to be 3.3 Gt of CO_2 equivalent: about 8–10% of 2018 global emissions. In 2013, UN Environment and the FAO launched a campaign called "Think Eat Save", which provides toolkits and infographics to help change behaviours from the institutional to the individual level. In China, the government-endorsed "Operation Empty Plate" aims to restrict things such as lavish banquets and over-ordering in restaurants.

Others are taking innovative approaches to increasing protein sources that are more sustainable than cattle. Although insects are yet to hit supermarket shelves in any dramatic way outside Asia, the insect protein market could be worth US$1 billion by 2025.[18] Other meat alternatives include crops like soya or lab-grown tissues (although debate continues about whether lab-grown meat is more sustainable).

Advances in technologies such as satellite imaging, drones, and sensors or microcontrollers connected through the internet of things (IoT), has enabled farmers to precisely apply water, fertilizers, pesticides, and insecticides in exactly the amount and time that they are needed. Although smart agriculture technologies have been around for decades, recent technological advances have enabled broader adoption. Precision agriculture has been shown in field studies to enrich soils[19] while maintaining profits.[20]

Much effort is now going into genetic modification (GM) of some crops, including rice, to increase yields and nutrition, especially in the face of climate change. Uncertainty remains about the long-term ecological, economic, and health impacts of GM crops.

Multilateral organizations are more commonly taking a food-system approach, with consultation processes that engage different stakeholders. For instance, in October 2018, the FAO Committee on Agriculture requested that the FAO spearhead an effort to develop Voluntary Codes of Conduct for the reduction of food loss and food waste by October 2020. This follows in the footsteps of the highly influential FAO Code of Conduct for responsible fisheries, which was adopted in 1995.

The notion that action towards a more sustainable food system is urgently needed is gaining ground throughout the world. But opinions still vary on what should be changed, how it should be changed, and who the key agents of that change should be. No one yet agrees what sustainable food looks, smells, and tastes like, or even how we should measure the sustainability of food. However, the global consensus is that food is critical in human survival and sustainability and must be secured no matter how challenging it is to solve these pressing problems.

IF THE GLOBAL CONSUMPTION OF MEAT IS TO BE REDUCED, WHOSE DIET SHOULD IT COME FROM?

HOW TO SPUR RADICAL CHANGE

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When more than 150 world leaders met in 2015 to develop the United Nations 2030 Agenda for Sustainable Development, their key phrase was "transforming our world". The 17 Sustainable Development Goals (SDGs) they agreed upon represent nothing less than a "shared blueprint for peace and prosperity" for the world: an unprecedented agenda to end extreme poverty, fight inequality, and protect the environment, among other significant goals.

The SDGs mark a departure from previous attempts to influence how humanity responds to modern challenges. In the face of rapid environmental shifts like climate change, the rallying cry has mostly been about "adaptation and resilience" – the important tasks of altering our societies to be able to bear the brunt of changing conditions and adapt to cope with them. What is emerging now is a realization that adaptation simply isn't enough; humans don't want just to survive in the face of rapid change, but to thrive. Doing that means transforming societies altogether.

The term transformation has become a common catchphrase in international media and policy circles. The Intergovernmental Panel on Climate Change's special report on limiting warming to 1.5°C[1] mentions "transformation" more than 300 times – that's almost every other page of the report. The 2018 "Living Planet Report"[2] from the World Wildlife Fund (WWF) argues that we are "on the cusp of a truly historic transformation".

So, what does transformation really mean? It can be defined as "profound and enduring nonlinear systemic changes, typically involving social, cultural, technological, political, economic, and/or environmental processes".[3] In other words, the world as we know it changes in a big way. Importantly, transformative change goes well beyond incrementalism or reform, both of which allow existing practices, goals, and structures to stay in place. Transformation, in contrast, involves change in fundamental norms or assumptions. Unlike a "transition", which implies moving from one place or state to another, "transformation" is more about completely reinventing shape or form – like the metamorphosis of a caterpillar to a butterfly.

Sometimes transformations are unintentional – like climate change, or the ongoing extinction of up to a million species. Some technologies or societal changes – like the development of artificial intelligence – are likely to prompt transformational change, but no one is in the driver's seat deciding what that transformation should look like, or what its goals should be. Other transformations have been purposeful, like the ending of apartheid in South Africa and the fight to allow marriage across all genders.

The SDGs require purposeful transformation. We need to rethink how we design economies and do business; how we produce and distribute the food we eat – even what we eat; how we design and construct our homes, workplaces, and communities; and how we get from place to place. Importantly, we need to transform how we humans relate to each other and to nature. Transformation needs to bring human enterprise of all sorts back into alignment with the realities of what this planet can sustain.

Purposeful transformation is hard. The innate complexity of the world means that the course of a transformation cannot be entirely planned or driven; there are always unexpected events. System transformations are fraught, with multiple actors and multiple leverage points for change. Actions in one part of the system ripple, creating unintended side effects. The proverbial "tipping point" of change is much talked about, but very hard to determine in advance, and even, sometimes, in hindsight. Importantly, transformations literally break down existing systems in the process of creating new ones; the hard reality is that there is stubborn resistance by people unwilling to relinquish the comfortable and familiar.

The goal is finding a critical mass of change-makers to move a system forward in a variety of ways, while including all relevant voices in the process. Instead of rational and linear planning, these change agents have to "nudge" things in the right direction, recognizing the inherent complexity of the system and the transformation process. That is why a set of aspirations like the ones embedded in the SDGs is so important: it provides a guiding framework that helps keep change-makers moving in similar directions even while they are taking independent actions. How can change-makers orchestrate that, or help to guide the process?

The name of the game

This is where Transformations-systems (T-systems) come in. A T-system comprises all those initiatives nudging a status quo system – anything from an issue like healthcare to a geographic area like a watershed – in a similar transformational direction. These efforts may operate alongside a status quo system, such as the zero-carbon energy subsidiary of a traditional energy company. But T-systems are focused on change and innovation, compared with the status quo's emphasis on production and administration. They require their own distinctive identity, skills, and organizing space to operate. Smooth transformations have many connections between the two systems.

There has been little recognition or study of T-systems – it is a new field. That means that many transformational efforts simply muddle along without coherence or guidance, with fragmented efforts going in different directions.

One task of those studying T-systems is to identify productive ways to support intentional transformation. Pioneering environmentalist and lead author of the pathbreaking book *The Limits to Growth* Donella Meadows identified some key leverage points or "places to intervene in a system".[4] Meadows argued that the most powerful leverage point is the power to transcend paradigms or mindsets – the narratives we tell ourselves about who we are, why we do what we do, and what we consider normal *(see box "Changing mindsets about plastic")*.

Another powerful change lever involves reconsidering a system's goals, which is where the SDGs are extremely helpful. Purposeful transformations are enhanced when the players have a clear, shared aspiration, such as the ones laid out by the SDGs. There are other levers too, including how the system operates, that is, the rules of the game including who has power and how they wield it. For example, for many years tobacco companies controlled information about the harmful effects of smoking. It took action by the US surgeon general and, ultimately, many cities and towns, to defy the ubiquitous practice and begin banning smoking from public places *(see box "Leverage Points")*.

T-systems typically develop in stages. Early on, individual transformation initiatives include diverse stakeholders working on a relatively small scale. This early stage focuses on the creation of safe spaces or niches for experimentation with radical innovation. Effective niches allow for learning during these early stages without punishing failures.

In Germany, for example, the shift to renewables, particularly solar, is generally called *Energiewende* (energy transition). The term was introduced in 1980 by the Öko-Institut, which called for a full transition away from nuclear- and fossil-fuel-based energy sources. Energiewende is tackling a century-old production model, with all its entrenched interests, with mixed results. In 1991, German law established financing that helped move windmills and solar panels from niche experiments to widespread use; later legislation proscribed a nuclear-energy-free future. In 2010, Germany passed a law mandating 80–95% reductions in greenhouse gases by 2050 relative to 1990. This had numerous transformative ramifications. In 2011, for example, engineering company Siemens announced its complete withdrawal from the nuclear industry, and the top utility company E.ON claimed it would withdraw from both coal and nuclear power generation. Although some criticized Germany for weakening its commitments, the country generated 54.5% of electricity from renewable energy in March 2019.

Picking up on a word coined by American futurist Alvin Toffler, some energy companies began to label households and farms with solar panels or wind turbines as "prosumers" – producers and consumers combined. Experiments in financing prosumer-produced energy provided investment security for renewable energy that made it possible for many more households to adopt this new technology, which in turn made renewable energy the more cost-effective energy form in many places. By 2016, a German report noted that an enormous transition in the production of energy had begun to happen: by then, some 46% of renewable energy generation was from various forms of citizen (prosumer) participation. The transformation has not been without issues. Some observers criticize the subsidies involved with Energiewende. And there is still resistance from Europe's largest energy companies.

The case of marriage equality in the United States also highlights the different stages of transformation. In the late 1960s and the 1970s, action focused on gay pride parades and the promotion of gay rights. Later, activists aimed to shift the mindset around love and commitment, as well as rights for families, no matter what the gender of the people involved. In the early 2000s, T-system actors deliberately pursued policy changes through the courts, media, and other avenues that could shift the existing laws and regulations regarding marriage. Ultimately, Vermont instituted the first civil unions in the year 2000. Then in 2004 Massachusetts became the first state to legalize same-sex marriage. By 2015, many "nudges" later, the US Supreme Court ruled that all US states were required to recognize and allow same-sex marriages.[5]

ADAPTATION SIMPLY ISN'T ENOUGH

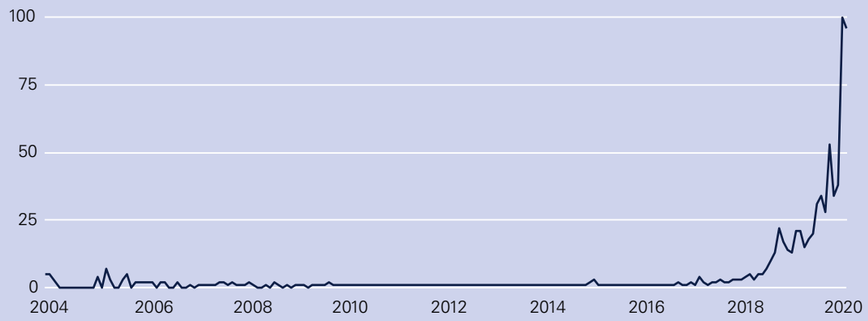
Solar panels have become common on residential homes in Germany.

CHANGING MINDSETS ABOUT PLASTIC

Plastics became wildly popular in the years following the Second World War and were touted as a utopian replacement for natural materials like steel, wood, glass, and paper. The famous line from the 1967 Dustin Hoffman movie The Graduate captured what proponents thought at that time: "Plastics. … There's a great future in plastics." The image quickly paled, however (as Hoffman's character recognized). Plastics soon took on an image of cheap, mass production. As early as the 1960s, plastic debris was discovered in the ocean. Today, of the 300 million tons produced annually, the vast majority ends up in landfills or waterways.

The continued business verve for plastics, thanks to its cheap price tag and flexible structure, has led to a boom in single-use plastics: things like disposable forks and spoons, plates, plastic bags and wrap, and drinks containers, particularly water bottles. One estimate is that about 500 billion plastic bags are produced annually – with an average "working life" of about 15 minutes each. More than 100 billion plastic beverage bottles were sold in the US alone in 2014 – about 315 bottles per person.

A mindset of broad awareness of the problems created by plastic waste is just now beginning to develop: Google Trends shows that searches for "single use plastic" have been climbing since 2017. The United Nations reported in 2018 that some 27 countries had enacted some forms of bans on single-use plastics. In June 2019, Vermont became the first US state to ban everything from straws to retail bags (to be in effect by 2020). Similarly, Canada announced a plan to ban such plastics nationally by 2021. The seeds for transformation have been planted.



Rising Awareness
Google searches for "single use plastic" are trending upwards. *Source: Google, 2019*

Four strategies
T-systems include four distinct strategies.[6] A key part of transformation is shaking up the status quo with a "warrior" strategy. Activist organizations like Extinction Rebellion (XR) disrupt and destabilize the current system, to create windows of opportunity for radical alternatives to become established and flourish. XR, founded by a group of academics in the United Kingdom in 2018, is attempting to reframe the debate on climate heating by declaring boldly "This is an Emergency!". XR draws its inspiration from past transformation efforts like those of Mahatma Gandhi and the Indian Independence Movement.

In 2019, British newspaper The Guardian reported that significant progress had been made on XR's three demands of telling the truth, zero emissions by 2026, and a citizens' assembly.[7] On telling the truth, for example, XR has influenced multiple British politicians to acknowledge that climate heating is the biggest challenge facing humanity. On zero emissions, XR has persuaded the UK's Committee on Climate Change to announce revised emissions targets, including a UK commitment to reach net-zero emissions by 2050, compared with the formerly agreed target of 80% reductions by that time. XR has (at the time of writing) been less successful on its third demand of having the government create a citizens' assembly; but it is early days.

A second strategy, a "lover" strategy, is associated with multi-stakeholder processes such as the Forest Stewardship Council (FSC). FSC is a global nonprofit oriented towards promoting responsible management of the world's forests, founded in 1993. Like many transformation efforts, it brings together unusual partners: in this case environmentalists, social activists, and businesses. Recognizing the power of markets in today's economies, FSC developed a new set of certification standards for managing forests responsibly. FSC ultimately gained the support of key environmental groups like the WWF, the Sierra Club, Greenpeace, the Natural Resources Defense Council, and the National Wildlife Federation, which pressured forestry companies into alignment with its standards. FSC used its certification and labelling approach to create a competitive environment in which companies had a new reputational incentive to gain a label certifying them as eco-friendly. The results are impressive: some 380 million acres of forest are now certified globally by FSC, with more than 2,500 companies certified in the United States.

The "entrepreneurial" strategy aims to create small, niche examples of the transformed future. This strategy has been used by organic farmers, alternative schools, farm-to-table restaurants, local currencies, and more. They typically face a challenge moving out of their niche status.

The fourth, "missionary", strategy is represented by people in status quo organizations who are determined to transform them. Paul Polman, CEO at Unilever (2009–2019), was an archetypical example. He undertook a wide variety of actions to push the company and its production processes in a transformation direction, such as co-founding the sustainable seafood initiative the Marine Stewardship Council, changing company performance metrics to include measures of sustainability, rejecting quarterly report filings in order to focus on long-term goals, and buying entrepreneur companies like Ben & Jerry's ice cream that focus on community building and sustainability.

All of these strategies interact in a T-System such as the Wellbeing Economy Alliance (WEAll). Formally launched in 2018, WEAll targets the major underlying concepts behind today's dominant economic systems: that endless economic growth is always good, indeed necessary; that businesses have the core purpose of maximizing shareholder wealth; and that markets are "free", with a so-called invisible hand that will correct all problems. WEAll is helping to shift this mindset, by connecting and aligning many initiatives already working towards the same ends and rewriting the narrative of how we define a healthy economy. It aims to shift the rules of the game, the practices of business, and the metrics by which nations judge economic success. WEAll and its affiliates' alternative approach emphasizes what ecologist Hunter Lovins, one of the founders, calls an economy in service to life: one that provides dignity and well-being for all, including non-human beings.

TRANSFORMATION INVOLVES CHANGE IN FUNDAMENTAL NORMS OR ASSUMPTIONS

Perspectives – What is the desired mindset?

For example, transform thoughts of "this can be thrown away" to "waste is a problem".

Power relations – Who needs to participate?

For example, take power out of the hands of a top-down, centralized elite, and distribute it among all important stakeholders.

Purposes – What are we trying to achieve?

For example, shift from "How can I make a more efficient car engine?" to "How can fossil-fuel use be eliminated from transport?"

Practices, policies, and processes – How should the system operate?

For example, transform the production of goods from a system that churns out cheap products for high-volume sales to one that leases more durable products.

Performance metrics – How should we measure and reward progress?

For example, transform the metric of national progress from Gross Domestic Product (GDP) to a well-being index like the Genuine Progress Indicator (GPI).

LEVERAGE POINTS OF TRANSFORMATION

Simple steps

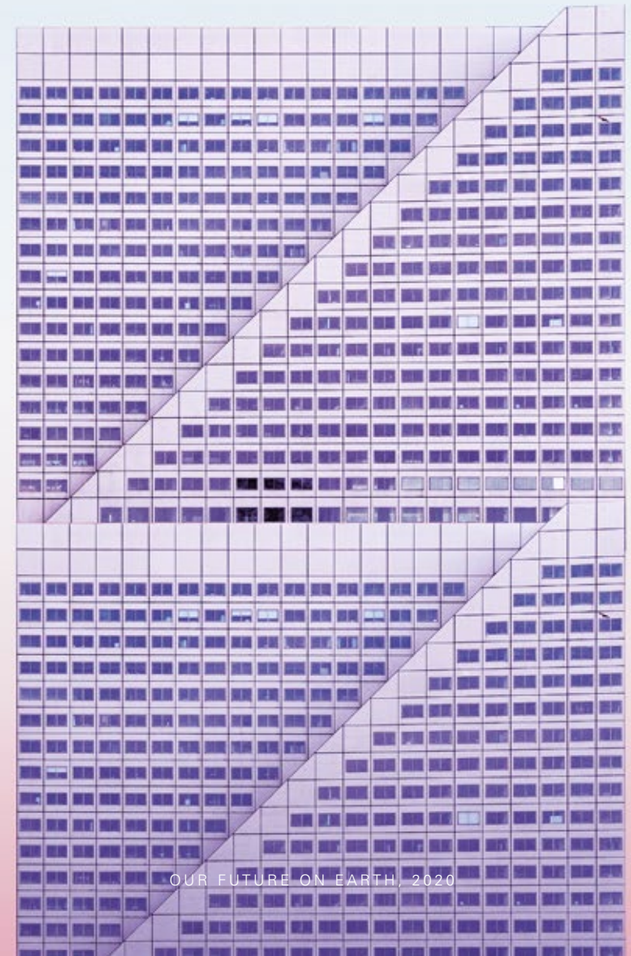
People often find transformation and large-systems-change work overwhelming. But it can be broken down into three manageable steps.

First, it is vital to really see the system undergoing transformation, often by mapping it. Seeing and mapping can be supported by technical means, such as data visualization, and more qualitative and soft techniques that bring stakeholders together. The next step is to connect those actors, many of whom may have different strategies and interests, into a powerful system that can identify radical actions and experiments to achieve their goal. The third step involves implementation of these actions – although the three steps are cyclical and interact.

In order for a T-system to be effective, stewards are needed to guide them through these steps. The Southern Africa Food Lab (SAFL), founded in 2009, is playing this "steward" role in developing a local T-system to address the problem of hunger. The Lab has analysed the local players in food systems from farmers to retailers, brought them together, and spurred actions such as encouraging food chains to diversify their purchasing networks to include small-hold farmers.

The lack of formal structure in T-systems can make them vulnerable and ephemeral. But it also makes them nimble: they have a loose and light institutional infrastructure. In contrast, the status quo system tends to resist change. Rapid transformation is resisted by attitudes like "but we've always done it this way", the benefits and power people receive from traditional ways of doing things, and existing infrastructure, bureaucracy, or processes. That is why transformational efforts often start in protected niches as a way of establishing their worth before tackling the broader institutional landscape or regime.

Purposefully transforming our societies is difficult, complex, and messy by its very nature. There is no cookbook approach or simple solution. Experimentation and failure are part of the process. But history provides evidence that it is possible to purposefully change deep-seated structures, mindsets, assumptions, and operating practices. Intentionally recognizing and understanding various actors as part of a T-system can help to promote this kind of change.



DIGITAL INNOVATION

HARNESSING TECHNOLOGY FOR GOOD

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We live in times of exponential technological change. In the last year, scientists 3D-printed a prototype heart. A tiny, swallowable device can capture cellular-level images of the gut without anaesthesia. And, rather than just obey simple commands, artificial intelligence (AI) assistants like Siri can perform conversation-based tasks like scheduling an appointment. But this is all the tip of the iceberg.

Massive amounts of data, new computational abilities, and AI methods such as machine learning are together spurring disruptive progress: technical systems are becoming as good (or even better) than humans at recognizing faces and voices, diagnosing cancer, translating languages, and producing news articles, music, and paintings. In 2019 an AI system even wrote a scientific book: a 250-page summary of more than 1,000 research papers on lithium-ion batteries. Big data analysis and algorithms are allowing for autonomous driving and self-repairing machine lines in factories. In October 2019 a Google research team announced[1] that its quantum computer was the first to perform a calculation (in less than three minutes) that would be infeasible for a classical supercomputer, which would need 10,000 years to complete it. Quantum computing will revolutionize AI as ever-more data can be analysed in ever-less time.

Martin Wooster, Professor of Earth Observation Science at King's College London and National Centre for Earth Observation (NCEO), measures air quality in an area of burned land in Palangka Raya, Central Kalimantan.

Yet, in the midst of all these technological disruptions, we are still not harnessing humanity's capacity for innovation to save the planet and to create just and fair societies. Instead, these technological changes have largely been used to increase consumption, economic growth, and resource extraction, putting further strain on our planet, generating negative consequences for vulnerable people, and escalating socio-economic inequalities.

Looking back, it is astonishing that in 2015, when the 2030 Agenda and the Paris Agreement emerged, digital breakthroughs were largely being ignored as a useful tool by sustainability communities (the only mention of "digital" in the 35-page, 2030 Agenda refers to the "digital divide" between people who do, and don't, have access to information technologies). The digital pioneers and supporters of sustainability transformations are still not cooperating enough; not learning from each other systematically; not reflecting how to harness future innovation cycles to create a more sustainable planet; not developing joint concepts for a sustainable digital future. While there is a substantive global debate about the ethical dimensions of AI, there are fewer conversations about deploying these intelligent systems for human-centred, sustainable development.[2] Digitalization and sustainability seem to be passing ships in the night. This has resulted in many missed opportunities.

Implementing the 2030 Agenda for sustainable development and the Paris Agreement for curbing climate change will require fundamental transformations in our societies and economies *(see chapter "Transformation")*. We know that climate-warming emissions must peak in 2020 and decrease by half each subsequent decade towards net zero by mid-century *(see chapter "Climate")*. But we are not at all on track to make that happen.[3] The Digital Revolution can and should be harnessed to help.

The revolutions

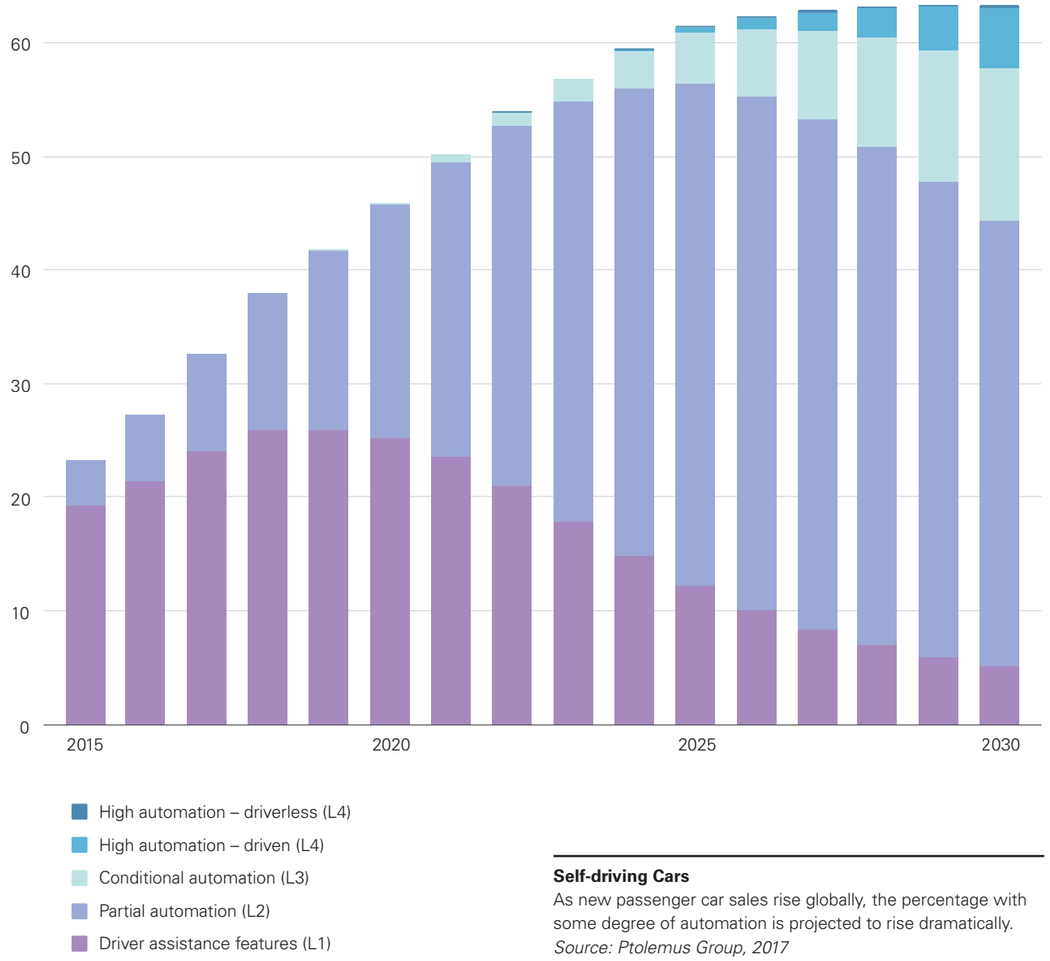
Human history has undergone a few major civilizational transformations. In the Neolithic Revolution, starting about 11,000 years ago, humans developed agriculture; the Industrial Revolution, starting just 200 years ago, developed fossil fuels and machinery. The Digital Revolution is upon us now.

These developments have allowed for explosions in human capabilities: innovation has allowed us to leave

our planet and reach the moon, develop systems of art and architecture, create complex social systems – global trade, democracies, the United Nations – and reach new levels of understanding about our universe. Since 1900, the human population increased more than fourfold, life expectancy at birth has more than doubled, and the number of people living in extreme poverty has declined.[4] But all this comes at a price: ever-greater pressure on planetary support systems, and huge socio-economic and power-related inequalities.

At the beginning of the 21st century, researchers started to identify a "Great Acceleration" of human activities and wealth creation:[5] population, economic activity, fertilizer use, water use, energy production, paper production, the emission of carbon dioxide, and more, have all exploded in recent decades *(see chapter "Introduction")*. This started after 1945 for countries within the Organisation for Economic Co-operation and Development (OECD), and expanded in the 1990s to emerging economies like China, India, and Brazil. This has driven the earth system towards "tipping points"[6]: points beyond which a tiny change in one variable, like CO_2, could result in large, possibly catastrophic change to earth systems that support human life. At the same time, social stressors have eroded social cohesion, resulting in nationalism and authoritarian backlashes *(see chapter "Populism")*.

In the past few decades, innovations have allowed some human impacts on our planet to decline on a per capita basis.[4] The amount of land needed to grow food per person, for example, has halved thanks to improvements in agriculture over the past 50 years. Per capita water consumption peaked around 1980 and has since gone down slightly. Global consumption of wood has levelled off. Yet greenhouse gas emissions continue to climb, and as most things become cheaper and more efficient (like computing and transport), humanity often responds by using ever more of it, resulting in an overall increase in consumption of resources. An overwhelming mountain of studies demonstrates that growth in population, production, and consumption continues to threaten the stability of many critical ecosystems and social structures.[7]



Self-driving Cars
As new passenger car sales rise globally, the percentage with some degree of automation is projected to rise dramatically.
Source: Ptolemus Group, 2017

Today we are at the start of a new wave of the Digital Revolution, driven by machine learning and autonomous technical systems, that is pervading all aspects of society and has the potential for enormous repercussions. Since the 1940s, computing speed has increased by a factor of more than 10 billion. Artificial general intelligence (AGI) – defined as a technical system able to accomplish any cognitive task at least as well as humans – has long been seen as only a pipe dream. But there is now a rising expectation that AGI could be achieved within the 21st century.[8]

AI-driven systems are already doing more and more of the world's work: making more and more decisions about who gets financial credit, access to health insurance, or employment; influencing who police officers target on patrol or how long prison times might be; and shaping investment decisions. AI and machine learning are triggering fundamental ethical questions about how and when machines can and should replace or support human decisions.[9]

Digital innovation now has the capacity to dramatically transform everything from labour markets to our understanding of planetary systems, from democracies to our view of cognition – and our understanding of human beings. This deep change will spur systemic uncertainty, making governance efforts challenging.[10,11,12] Investigating, understanding, and anticipating digital futures, disruptions, and trends during the next 1–3 decades in order to develop sustainable digital pathways will be a major task.

WE HAVE THE POWER TO CREATE NEW SOCIETAL AND ECONOMIC REALITIES WITH THE CLICK OF A BUTTON

Digital potentials for good
Technological change is a source of many pressures on the planetary systems and our societies, but also presents possible solutions.[10,11,13] Artificial intelligence, machine learning, digital platforms, the internet of things (IoT), robotics, 3D printing, big data analysis, virtual monitoring systems, and blockchain – all can be used to incentivize sustainable behaviour, spark resource and energy efficiencies, and generate circular economies that close the loop of production, recycling, and reuse of materials. They could be put to work to create a zero-emission future, and to more effectively monitor, protect global ecosystems, and enhance human capabilities.

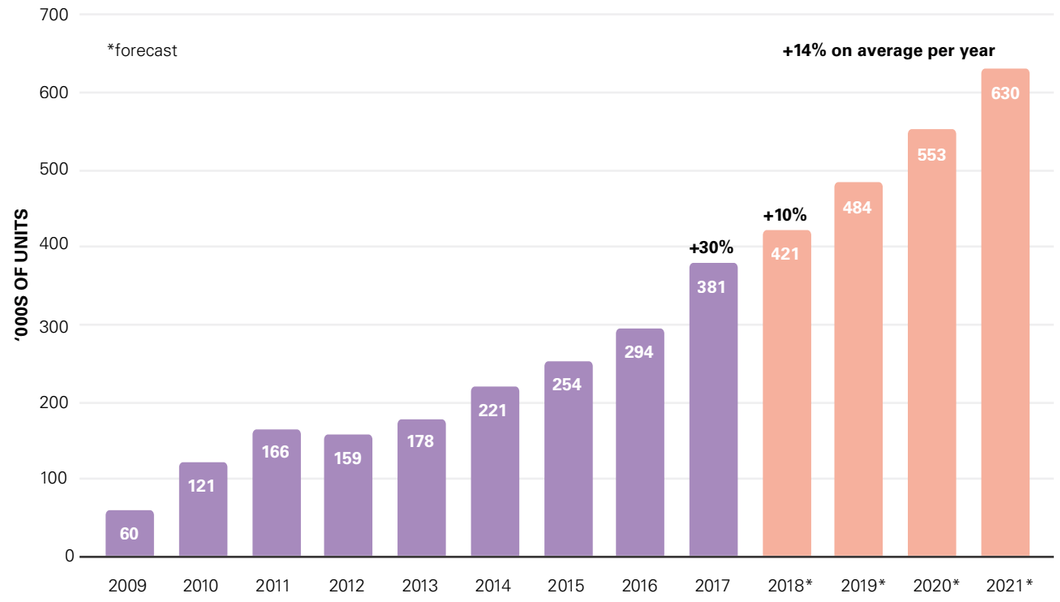
We have the power to create new societal and economic realities with the click of a button.

While there is no consensus on quantitative estimates, a recent report suggested that the digital sector has the potential to directly reduce fossil fuel emissions by 15% by 2030; changes to consumer habits and business models might spur a further 35% reduction.[14] In the energy systems, digitization can help by modelling factors including demand, generation, transmission, and costs – critical steps in integrating decentralized, variable energy sources like wind or solar into a reliable grid. Digitization will also help to get electricity to remote rural areas in developing countries: the University of California, Berkeley, and the Massachusetts Institute of Technology are developing models that help to determine the best way to electrify remote areas in countries like India or Rwanda, similar to the World Bank's Electrification Pathways web-based application.

Some of the greatest potentials for improving energy efficiency and reducing emissions lie in using digital technologies to control end-use systems like buildings, transport, and industry.[15] According to a report by the American Council for an Energy-Efficient Economy, for example, the use of occupancy sensors, smart thermostats, and lighting controls reduces energy use in offices on average by 18%. When Google trialled an AI-based system to control the cooling of one of its data centres in 2016, it reduced its energy use by 40%. In Colombia, smart public transport transit cards increased the use of public transport by 56% in one year. The Digital Revolution could spur more efficient food systems, by reducing food waste and improving agricultural productivity *(see chapter "Food")*.

The massive increase in images of our planet – both from cheap on-the-ground cameras and high-resolution images from space – has helped to disclose to the world what once went unnoticed. For example, Global Forest Watch is an open-source web application that uses satellite data to monitor forests in real time,

IT IS NOW TIME TO FORM A UNIFIED FIELD OF DIGITAL SUSTAINABILITY



Worldwide Supply Of Industrial Robots
Technology continues to replace various aspects of human labour. *Source: International Federation of Robotics, 2019*

letting anyone in the world (from journalists to decision makers) track deforestation or illegal forest activity.

Microsoft's AI for Earth provides open-source digital tools and grants to help people use technology to solve global environmental challenges, from identifying suspicious marine traffic that might be engaged in illegal fishing, to applying AI to soil data to make farming more sustainable.

Deeper change needed
Exponential technological changes could lead to a decoupling of wealth creation from pressure on ecosystems, which is good for the planet. But they do not automatically translate into sustainability transformations if they are not coupled with societal innovations.[16] Four major building blocks are fundamental to this shift towards sustainable digital futures.

First, public institutions need to play a role in shaping and governing digitalization towards sustainability. Today, the public administrations of most countries have negligible knowledge about digital change and its importance for societal and sustainable development.[17] The state cannot govern what it does not know. In the 1960s and 1970s, large-scale public sector modernization schemes took place in many OECD countries to make public institutions more knowledgeable in fields like economics, social protection, and environmental issues. The same is now needed for the field of digitalization. Finland is leading the way here, with comprehensive efforts on things such as open government, e-based education, and protection of privacy.

Second, sustainability needs to be put at the heart of the work of the digital pioneers, from research institutions like the Fraunhofer Society or MIT, to companies like Google or Amazon. For now, producers of algorithms, big data specialists, and machine learning experts are shaping the future of our technical systems and infrastructures, but do not necessarily consider sustainability challenges as relevant for their work, or appreciate the urgency of addressing sustainability problems. Much as the isolated fields of earth science and social science were melded to form sustainability science during the last decades, it is now time to form a unified field of digital sustainability.

One way to achieve this is for digital pioneers and sustainability research communities, along with government bodies, to formulate a new mission statement comparable to a moon mission: an international "Zero Carbon Missions in the Digital Age" or "2030 Agenda Missions in the Digital Age" could help to focus technological revolutions on solving most pressing societal needs.[18] For now, projects like UNEP's Sustainable Digital Finance Alliance, or the FAO's Climate-Smart Agriculture Sourcebook, are all too small in investment and scope. The European Commission has created five missions as part of Horizon Europe, its post-2020 research and innovation programme; climate change and leveraging digitalization for the public good are two key cross-cutting themes.

Third, market forces should be mobilized by getting the prices right. For now, in most countries labour is taxed significantly, but resources and greenhouse gas emissions are not. As a result, innovation is still targeted at substituting labour rather than reducing emissions and resource consumption. Carbon pricing and comprehensive ecological tax reforms would incentivize the mobilization of digital change in support of sustainable solutions.[19] Sustainability-oriented tax systems could mobilize the search for profit and traditional mechanisms of capitalism to drive sustainable action.

Fourth, social communication systems and other information and knowledge dissemination systems need to be harnessed to encourage sustainability thinking and actions *(see chapter "Media").* Digital innovations are based on infrastructures like "information highways", but sustainability in the digital age will require comprehensive literacy programmes to teach people how best to learn from new digital information systems and how to use digital tools. Our education systems need to be updated.

Avoiding risk
At the same time that digital technologies are harnessed to embrace sustainability, societies also need to avoid digitally driven systemic risks: large-scale changes that could trigger societal destabilization.[10]

Most previous technological revolutions came with huge turmoil, conflict, and war before societies adapted to their new conditions;[20] the combination of deep transformational change in both sustainability and digitalization has the power to cause huge disruption. Mediating this will require understanding the risks, developing preventative strategies, and planning safety nets for those negatively affected. The AI Now Institute at New York University, United States, is one interdisciplinary research centre working hard on this, primarily by considering the societal implications of artificial intelligence. The German Advisory Council on Global Change (WBGU), supported by major science organizations like Future Earth and the International Science Council, announced a charter for "Our Common Digital Future".[21] This should help to trigger debate about a global action agenda to align sustainability and digital transformations, along with ethical guardrails for the digital age.

One risk of digital change, for example, is large-scale disruption of labour markets by comprehensive automatization. Systems like autonomous vehicles have the potential to put drivers out of work;

GREENING THE DATA ECOSYSTEM

As the digital world gets ever-more prolific, concerns have exploded in the media about the potentially skyrocketing energy use of the digital sector. Those concerns are well founded, but there is plenty of reason for optimism that the digital revolution can be green.

Between 2010 and 2015, global data traffic quadrupled and the number of mobile subscribers increased by 30%. But, at the same time, emissions and electricity use by the digital industry – including everything from phones to data centres and televisions – declined by about 15%.[14] That's mainly thanks to dramatic increases in digital energy efficiency: users are switching to more energy-efficient handheld devices, for example, and the rising demand for cloud computing is largely being met by uber-efficient hyper-scale datacentres. But efficiency gains cannot keep up such a rapid pace forever.

Usage is also going up, thanks to unlimited services like Netflix, and the internet of things, which may soon see billions of household and community objects digitally connected. This makes it hard to forecast the energy use of the digital industry in the long term. In 2015 the information communication technology (ICT) industry globally was responsible for 3.6% of electricity use (and 1.4% of greenhouse gas emissions).[14] One controversial, much-publicized forecast from 2018 predicted that the digital industry could consume more than 20% of the world's electricity by 2030.[24]

The key to preventing a boom in greenhouse gas emissions is to push for the digital industry to switch to renewables. Many companies, such as Google, Apple, and Microsoft, have already made commitments to low-carbon operations. Google's data centre in Hamina, Finland, for example, uses naturally cold water from the Baltic Sea to cool its servers, and wind energy to drive operations. The digital industry can be a major driver of renewables – of all the corporate contracts signed to provide renewable energy in 2015, two-thirds were from ICT companies.[25] But much more remains to be done. In Northern Virginia, one of the highest concentrations of data centres in the world continues to get more than 95% of its power from fossil fuels.[26]

artificial intelligence could replace the skillsets of traditionally high-level workers like doctors, tax experts, and lawyers. Similarly, digitalization can lead to disempowerment of individuals. People's privacy and citizens' rights may be threatened by comprehensive digital surveillance and social scoring systems. Moreover, digitalization could undermine democracy by enhancing the power of authoritarian states or of uncontrolled private businesses[22] *(see chapter "Media")*.

Importantly, digitization could also, as have all other technological innovations of the last centuries, spur unsustainable growth and consumption patterns that trigger tipping points in the earth system. Increasing cheap access to information, for example, could spur a boom in electricity demand and create further greenhouse gas emissions *(see box "Greening the data ecosystem")*.

Others worry about uncontrolled human enhancement or artificial evolution methods that will lead to large-scale transformation of humanity. The first stage of the Anthropocene saw humans having unprecedented impacts on this planet; the next stage may see humans having unprecedented impacts on themselves. University of Washington computer scientist Pedro Domingos has said this all may lead to the evolution of a new species, *Homo technicus*, along with a biosphere "as different from today's as today's is from the primordial ocean".[23]

For every dystopic vision of the future, there exists also a different scenario, in which the Digital Revolution enables people to build transnational communities and create global cooperative cultures that tread lightly on the earth.

Ideally, the Digital Revolution will consist of three dynamics: one that supports a new field of digital sustainability and depresses social and ecological disruption; a second that builds a "new humanism" of enlightenment and awareness, while depressing totalitarianism; and a third that strengthens an ethical human-machine collaboration, while depressing abuse of new technologies.[10] AI and machine learning could enable human self-realization, enhance human agency, increase societal capabilities, empathy, and other social skills, and cultivate societal cohesion – instead of devaluating human skills, removing human responsibilities, reducing human control over technical systems, or eroding human self-determination.

Either way, new horizons of human development and human civilization are clearly emerging. The key challenge for the international community – researchers and society alike – is to develop a common vision for human-centred, sustainable development in the digital era. A lot of work lies ahead.

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