# CLIMATE CHANGE



WALTER ASTRADA/AFP/GETTY IMAGES

# The world on tilt

*Man has been endowed with reason, with the power to create, so that he can add to what he's been given. But up to now he hasn't been a creator, only a destroyer. Forests keep disappearing, rivers dry up, wild life's become extinct, the climate's ruined, and the land grows poorer and uglier every day.*

In the 115 years since Anton Chekhov put these words into the mouth of the doctor in his play *Uncle Vanya*, the planet has heated up by 1 degree Celsius and the atmospheric concentration of carbon dioxide has risen by one third. As every schoolchild knows, the two are closely linked; carbon dioxide makes up the bulk of greenhouse gases, which stop the sun's heat bouncing back into space. More carbon dioxide equals a hotter planet.

As can be seen from the graphs (figs 1 and 2), the upward trends show no sign of abating. Unless the world drastically reduces its emissions of greenhouse gases, the atmospheric concentration of carbon dioxide will soon reach 450 ppm. Scientists believe that concentrations above this will tip us beyond the 2°C rise from pre-industrial temperatures that marks the boundary between manageable and unmanageable climate change.

So far, attention has been directed at the economic impact of climate change, with less attention paid to the threats to human health and survival. To address this deficit, last year the *BMJ* and a consortium of partners convened a conference on the health and security aspects of climate change. This supplement is largely based on presentations to that conference.

Readers in need of a refresher on the science of climate change should be sure not to skip Chris Rapley's lucid account (p 23). As someone who has run both the British Antarctic Survey and London's Science Museum, he is a uniquely qualified guide. His article provides answers to the five most frequently asked questions about climate change. (To the last question, "Does it matter?", his answer is an emphatic "yes.")

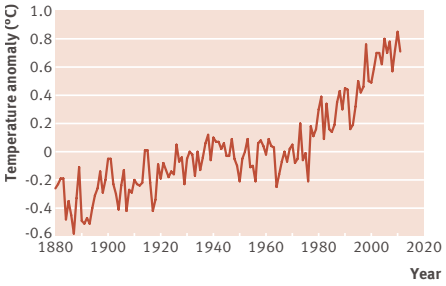


**Fig 1 | Global surface air temperature, 1880-2011 (base period 1951-1980)**

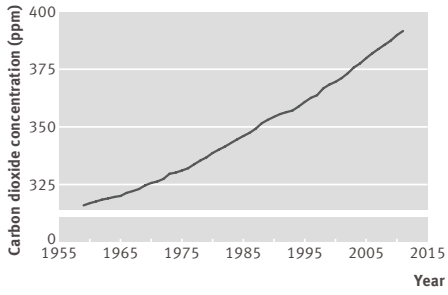


**Fig 2 | Atmospheric carbon dioxide, 1959-2011**

Tony McMichael and colleagues confront head on the health effects of climate change, now and in the future (p 26). For many poor and vulnerable people they're already here: undernutrition, diarrhoeal diseases, extreme weather events, and rising sea levels. Some of the pictures in the supplement show you who's bearing the brunt. Unfairly, it's not the citizens of the countries whose prosperity has been powered by the burning of half a trillion tons of fossil fuels since the industrial revolution.

Yet across the apocalyptic scenarios shines a wan ray of sunshine: efforts to reduce greenhouse gas emissions should also benefit health. While this point is touched on by several authors, it is the major focus of the paper by Andy Haines and Carlos Dora (p 30).

In their papers Hinrich Thölken and Neil Morisetti examine the security implications of climate change. "In human history conflicts arise over access to resources and territories," writes Thölken (p 33). "Climate change will affect both. We will increasingly be short of such vital resources as fresh water, food, and clean energy." Rear Admiral Morisetti doubts that climate change will be a direct cause of conflict but thinks that second and third order consequences—loss of land or livelihood—could increase the risks of global instability and conflict in those parts of the world already experiencing other stressors (p 34).

All the authors quoted so far are unanimous that humanity needs to clean up its act, but how? Political will is the necessary condition, argues Tom Burke, but for a host of reasons it is sadly lacking (p 36). His own desperate remedy: "What it's really going to take politically to solve this problem is an insurgency of those under 40 against those over 40."

Robin Stott proposes "contraction and convergence" as the best route for getting where we need to be (p 38). This entails calculating the global total of emissions that will limit and stabilise atmospheric carbon and dividing this "carbon budget" equally among the world's adults. They can then use their entitlement as the basis of emissions trading.

If you take away a single message from this supplement it is that time is fast running out to implement a workable solution.

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**www.youtube.com/bmjmedia**
- Health and security aspects of climate change
- Climate change interviews from the BMJ Group conference

**bmj.com/video**
- Maisie & George and the future of their planet

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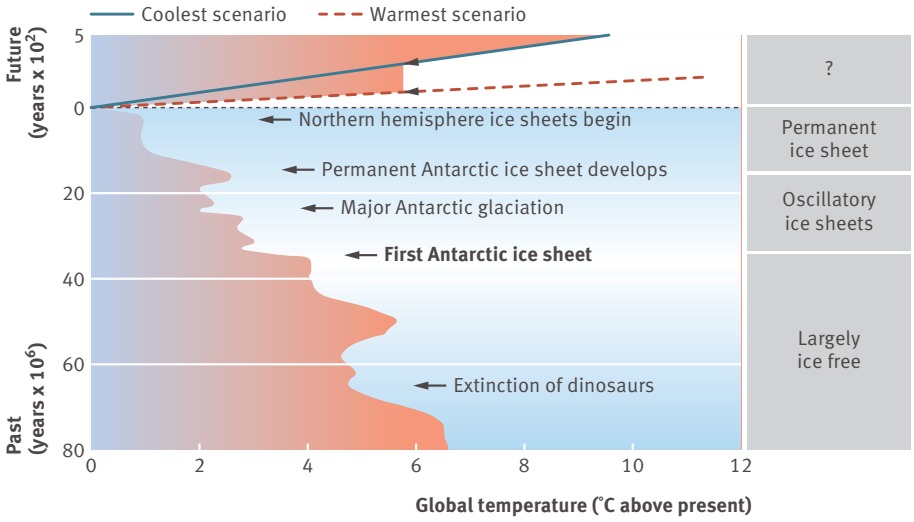
NOAA EARTH SYSTEM RESEARCH LABORATORY

# The science of climate change

Can we at last accept that the climate is changing, that we are making it happen, and that there are profound implications for us? **Chris Rapley** answers the key questions

No science is ever completely settled. However, among the tens of thousands of scientists working in the field of climate science worldwide there is almost complete agreement that our climate system is changing, and that human activities are the predominant driving force. This agreement is remarkable given what a belligerent, argumentative lot scientists are, and that they take great pleasure in proving each other wrong. I want to address the following five questions: Has the climate changed before? Are the current circumstances unusual? Is the planet warming (and how do we know)? Is it us (and how do we know)? And does it matter?




**Transitions in Antarctic glacial history including the sharp cooling associated with the formation of the first Antarctic ice sheet, 34 million years ago, ascribed to a decrease in the concentration of atmospheric $CO_2$. Global temperature projections from the Intergovernmental Panel on Climate Change are shown on a greatly expanded timescale. Barrett P. Palaeoclimatology: cooling a continent. *Nature* 2003;421:221-3**

### Has the climate changed before?

Yes, on many timescales and for many reasons, not least because the energy output of the Sun varies. As the primary energy source of the Earth system, the Sun drives the motions of the ocean and the atmosphere, as well as energising the photosynthesis on which the food chain of life depends. The Sun's luminosity has increased by about 30% over the 4.5 billion year lifetime of the planet, and its energy output fluctuates, albeit at the 0.1% level. So yes, the Sun changes, and in doing so it drives changes in the Earth's climate system.

In addition, the growth of the biosphere itself has completely altered the chemistry of the atmosphere. Before the rise of the cyanobacteria, some 2.5 billion years ago, there was no oxygen in the atmosphere. As Jim Lovelock pointed out in his Gaia theory,[1] the Earth's biology isn't a passenger. It is an active, interconnected part of the system that drives change that affects the climate system. This is especially true of heat trapping trace gases, such as carbon dioxide, which keep the surface of the planet significantly warmer than would otherwise be the case. Changes in the carbon cycle, and hence in the carbon dioxide content of the atmosphere, have had major impacts on global temperatures, and have been implicated in continental scale transformations, such as the glaciation of the Antarctic.

Even the slow drifting of the continents changes the way that heat is absorbed and reflected from the surface of the planet, which alters the climate system. We know that within recent geological history subtle changes in the tilt, procession, and shape of the Earth's orbit have caused either 41 000 year or 100 000 year cycles of ice ages and interglacial periods.

So there is plenty of evidence that the system is driven by change. In addition, because it is a highly interconnected and complex system, it exhibits internal variability on a variety of timescales.

Those who would deny that climate change is a problem often point to these forms of variability, as if it made everything all right. But what this variability tells us is that the climate system is quite a frisky beast. It reacts to relatively subtle driving forces and can respond dramatically.

### Are the current circumstances unusual?

In 2011 the world's population exceeded seven billion people. We know that human impacts on the planet scale with population and consumption, and that these impacts can be mediated or reduced by the efficiency with which we use resources and energy. Paul Crutzen, winner of the Nobel prize for chemistry, has dubbed the present epoch the Anthropocene, because future generations will see the evidence of humans as the dominant influence on the planet at this stage in its geological history.[2] We are in a "no analogue state": there has never been anything like it before. We have, for example, transformed nearly 50% of the Earth's land surface, and the effects on habitats, species, and the nitrogen cycle through our use of fertilisers have been dramatic.

Our biggest impact, from the point of view of climate change, has been the burning of half a trillion tonnes of fossil fuel carbon to power the wealth and prosperity of the modern world. By doing so, we have unwittingly increased the concentration of carbon dioxide in the atmosphere by 100 parts per million. This is the same amount as the natural shift between a glacial period and an interglacial period, when global temperatures change by about 5°C. But this has occurred in 100 years, which is over 100 times faster than anything found in the geological ice core record (see, for example, Luthi et al[3]).

In the mid-19th century, John Tyndall was amazed to discover that the nitrogen and oxygen constituting the bulk of the atmosphere are transparent to heat. It is the trace gases—carbon dioxide, water vapour, and others—that are the active ingredients that prevent heat radiating straight out to space. Without trace gases the surface of the Earth would be 30°C cooler than it currently is—or minus 15°C on average—and the surface of the planet would be frozen.

The physics of this greenhouse effect has been well understood for more than 100 years. Indeed, at the end of the 19th century Svante Arrhenius, the Swedish atmospheric chemist, spent two years calculating by hand the effects of doubling the amount of carbon dioxide in the atmosphere, His figure of a rise of about 4°C is not very far from what modern models and calculations have produced. Interestingly, Arrhenius thought warming would be a good thing, because it would increase agricultural productivity. But he also thought it would take mankind 1000 years to achieve it. He had no concept of how quickly we would dig up and burn the Earth's coal, oil, and gas.

**Is the planet warming?**

To answer this question it is especially important to look at two places: the ocean and the ice caps. The ocean covers 70% of the planet's surface and is darker than the land. As a result, it absorbs about 90% of the heat imbalance due to the enhanced greenhouse effect.

So what do we observe? Until about 20 years ago the source of sea level measurements was a large number of tide gauges distributed around the world's coasts. It's difficult to correct their readings for pressure and ocean dynamic effects, and to calculate a single measure of sea level averaged over the surface of the entire ocean. Nevertheless, we have a record that extends back to the early 20th century. Although tide gauge data are still an important source of information, these days data from satellites continuously orbiting the planet are used. Radar instruments on satellites fire radio pulses down to the ocean's surface, and every 10 days or so provide a figure for the average height of the ocean, relative to the Earth's centre of gravity.

From the combination of the two datasets we know that over the 20th century the sea level was rising at about 1.8 to 2 mm a year. Before that, for at least 2000 years and maybe longer, it had been stable, having settled after the massive 120 m rise at the end of the last ice age in the transition to present climatic conditions. So although 1.8 mm per year doesn't sound very much, it is significant. But what we find now is that sea level is rising at about 3.5 mm a year, which corresponds to an increase of at least 35 cm by the end of this century, assuming no futher acceleration. In fact, the projections of the Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report lie in the range of 18 to 59 cm, though they take no account of the contribution from the ice sheets.[4] More recent and comprehensive estimates suggest that even 2 m might be possible.[5] Sea level rise will increase the likelihood of extreme high water events overwhelming sea defences, critical for low lying coastal areas. A rise of 50 cm in the average level, for example, can change the probability of an extreme high water from a 1 in 1000 year event to a 1 in 100 year event, with a further 50 cm rise bringing this down to a 1 in 10 year event.[6]

Why is the sea level rising? Because the ocean is getting warmer, and if you warm a liquid it expands. The ocean is on average 4 km deep, so you don't have to warm it very much to see a significant rise. Remember that the traditional way of measuring temperatures was to put a liquid—either alcohol or mercury—in a glass bulb with a graduated tube. As you warmed it up the liquid would expand. In the case of the Earth, gravity is very conveniently holding the liquid on to the planet, and we can see it expand by looking at these satellite data.

The other place to look for evidence of warming is the cryosphere, where water is frozen. The cryosphere is showing accelerating melting, and some of that water is flowing into the ocean and raising sea level. Parts of the ice sheets of Greenland and of Antarctica are growing because a warmer atmosphere carries more moisture and dumps more snow on the very high, cold plateaux. But around the edges—where the temperature is on average about zero degrees—we see very substantial acceleration in the loss of ice in many places, which is also contributing to the rise in sea level. Of course the ice does not have to melt to raise sea level. Archimedes would have understood that ice that slides off the land into the ocean displaces its own mass of water and raises sea level also. It can then melt at its leisure without further effect.

**Many densely populated parts of Bangladesh are vulnerable to flooding**

We also see strong warming in the Arctic basin, which is an ocean covered with a thin crust of floating ice. Satellite data show a very dramatic increase in the amount of melting in the summers of the last 30 years. The area of minimum summer ice cover has been reducing at about 7% a year. The record in 2007 was almost but not quite broken in 2011, with huge impacts in terms of the connection between the ocean and the atmosphere in the Arctic. This reduction will completely change the dynamics of that coupling, affecting high and mid-latitude weather, and will change the characteristics of the biology in the entire region. The loss of summer ice and opening of ship access will have major geopolitical consequences also.

**Is it us?**

We have seen that the planet is warming, but we have also seen that this could be for all sorts of reasons. How can we tell if it is us? If the planet is warming because of the enhanced greenhouse effect we would expect to see more infrared radiation coming back at the surface from the atmosphere. We would expect to see less infrared radiation making its way out into space. Both of these are found to be true from measurements made on the ground and by satellites. Very difficult measurements—lots of noise; very noisy signal—but the evidence is emerging.

We would also expect to see the warming that has occurred over the last 40 or 50 years being stronger by night than by day, and stronger in winter than in summer. And again the data support that. But for me a clinching piece of evidence is that if it were the Sun that had warmed up (we make measurements of the Sun; we know it hasn't) you would expect the whole atmosphere to warm. If it's greenhouse gases that are reducing the amount of heat making its way through the atmosphere to space, you would expect the lower part of the atmosphere to warm, and you would expect the stratosphere to cool. And indeed we see stratospheric cooling. So is it us? The fingerprint, the pattern, says yes.

Of course it's always possible to find some temperature records somewhere that go the other way, or some glacier growth somewhere that implies local cooling. But that's because it's a hugely complex system with lots of processes going on within

NASA/JPL IMAGING RADAR TEAM

Radar imagery, which penetrates several metres beneath the Saharan sand, shows a dense network of streambeds

and lots of local and regional variations. You need to look at the overall pattern to decide and it is this pattern that has led the IPCC to conclude that humans are the dominant cause,[4] and the science academies of the world to agree.[7]

## Does it matter?

The climate system is interconnected. Think of it as a heat engine. More heat comes in at the equator than at the poles. It is the fluids of the planet that transport this heat from the warmer areas to the colder areas, creating the winds that carry and distribute water vapour around the planet in patterns that we have inherited—that civilisation has inherited—and to which we have adapted, for our water supplies, our food supplies, our transport systems, and much more. Changes can be disruptive. Recall that it was the UK government that blamed the snow and unusual cold spell just before Christmas 2010 for a 0.5% drop in GDP. So economies are brittle to extreme events, underscoring the fact that climate change matters, not just to the poor people of the world, but to all of us.

We are in any case imperfectly adapted to the climate system that we have inherited. The irregular sequence of changing conditions in the Pacific, known as El Niño and La Niña, connects to other regions of the world, including the grain belts in South America and in Africa. During a strong El Niño there can be a loss of up to 50% of grain harvest in those areas.

Moreover, we know that the climatic zones themselves are able to shift. A stark example is provided by the Sahara, which is now a featureless desert supporting very few people leading a very harsh lifestyle. But about 5000 years ago the Sahara was a verdant zone with a huge east-west river system running across it. The landscape supported vegetation and even hippopotami. We know about this change because satellite radar has imaged through several metres of arid desert sand to reveal the pattern of dried up and choked river channels lying beneath. A massive regional shift in climate had a huge impact on this area, as a result of a massive change in the availability of water.

As Nick Stern noted in his report on the economics of climate change,[8] the prime interaction between climate change and humans is mediated through water; either extreme lack through extensive drought, or extreme excess through massive inundations and floods. And we are beginning to see the patterns of extreme flooding and extreme drought that are suggestive of climatic change taking place now. There is not a climatologist that would put their hand on their heart and say that the trend is yet statistically significant. But the frequency and patterns of 100 year events that we have been observing over the past few years is beginning to look suspicious. How long should we wait while the statistics grow before we take prudent action?

## Conclusion

A consensus has developed that we should limit the concentration of carbon dioxide in the atmosphere to 450 parts per million in order to avoid the degree of climate change that has been judged to be dangerous to humanity. If we don't do more than we're doing now to reduce our carbon emissions, then the projections for energy demand (a 36% increase by 2030),[9] suggest that we could experience not just an atmospheric concentration of 450 parts per million of carbon dioxide by the end of the century, or even 650 parts per million, but that 1000 parts per million or more could be feasible. That would be ten times the change that took place between the last ice age and the current interglacial period, and would force a warming far beyond the 2°C deemed safe. You would have to be very optimistic to believe that under those circumstances things would be fine and humanity could simply adapt.

A corporate leader who ignored such an evident material risk to the future wellbeing of their business would be deemed reckless, and would be dealt with harshly by stakeholders and history. This is the moment—a turning point in human affairs—for all of us who can influence human carbon emissions to step up to our responsibilities and ensure real and effective action.

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CR has run the International Geosphere-Biosphere Programme, the British Antarctic Survey, and the Science Museum in London. He was one of the architects of the International Polar Year 2008-2009, and President of the Scientific Committee on Antarctic Research. His current interests include the communication of climate science and the science-policy interface. This article arose from an invitation to speak at a conference on health and security aspects of climate change. CR is guarantor.

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# Health risks from climate change

**Tony McMichael, Hugh Montgomery,** and **Anthony Costello**

outline climate change's direct and indirect risks to health

There is now no serious scientific debate: human actions are changing the world's climate, and are set to do so at an increasing rate in coming decades.[1 2] Urgent action is now required to reduce emissions of carbon dioxide (the dominant long acting greenhouse gas), if global temperature rises are not to exceed 2°C—the International Energy Authority warns that "the door to 2°C is closing."[3] Indeed, emissions must be hugely curtailed within just two decades, and then zero net emissions achieved by later this century, assisted by increased biosequestration of carbon dioxide from the atmosphere.[4] However, emissions continue to rise, having increased by 49% since 1990 and by an accelerated annual rate of 5.9% in 2010.[5]

As warming proceeds, the frequency and intensity of extreme weather events such as heatwaves, cyclones, floods, storm surges, heavy precipitation, and droughts are forecast to increase substantially.[6] Many such changes are already becoming apparent worldwide.[7]

The meteorological (and resultant economic) impacts of climate change have been a major focus of public discussion, but associated threats to human health and survival have received much less attention. This may reflect, in part, a limited appreciation of the fundamental dependence of human population health on the natural environment's so called life support systems. People may also have a false sense of security engendered by the seeming invincibility of modern urban environments to inclement weather. But while industrialised urban societies may be complacent, many poor and vulnerable populations are already experiencing the health impacts of human induced climate change, whether through under-nutrition, diarrhoeal disease, extreme weather events, or sea level rise. However, as the tempo of extreme weather events increases,[7] such impacts will be felt worldwide as the environmental and social foundations of population health—food and water supplies, natural constraints on infectious diseases, natural barriers against environmental disasters, and the stability and cohesion of societies—are disrupted and weakened.

TONY KARUMBA/GETTY IMAGES

**Climate change is likely to make hard lives even harder**

PANOS

**The hot, dry summer of 2002, combined with one of the worst droughts on record, resulted in menacing bush fires across southeastern Australia**

## Risks to human health

Climate change may bring health benefits to some, at least in the early stages of the process.[8] Milder winters (albeit set against a rise in short term weather variability) may reduce deaths from influenza or cardiovascular disease in some temperate countries, while mosquito populations may recede in areas that become more arid. Improved coverage and use of bed nets, management of stagnant water and mosquito breeding sites, and greater availability of effective drugs may also (at a price) offset population risks from malaria vector expansion.[9]

The overall balance of health impacts of climate change, however, is anticipated to be substantially, and increasingly, negative.[8 10 11] These negative effects are mediated not only through progressive changes in average climatic conditions, as temperatures rise and precipitation patterns change,[8] but also through changes in regional weather patterns or their stability. Unpredictable weather (sudden cold, hot, wet, or dry spells) and extreme weather events (such as heatwaves, floods, and droughts) will become more common. These climatic changes affect human health through mechanisms that may be direct and indirect, immediate or delayed.[10 11]

Four categories of risk to human health can be described.

## Immediate and direct risks

Immediate and direct risks include the primary health impacts of heatwaves, extreme weather

events, and altered air quality (especially increased concentrations of ground level ozone).

The frequency of extreme heat episodes will increase as average temperatures rise, and heatwaves and extreme weather events are also expected to become more frequent as climatic conditions become more variable. Ascribing any one particular extreme weather event to climate change is difficult, but scientific confidence has grown that we are already seeing such attributable impacts.[12-14] For example, it is estimated that climate change has already approximately doubled the probability that a heatwave as severe as the European heatwave in August 2003 will occur again.[15] In November 2011 the Intergovernmental Panel on Climate Change (IPCC) special report on managing the risks of extreme events and disasters suggested that with a scenario of continuing high emissions it is likely that the frequency of heatwaves will increase in most regions. Heavy precipitation will occur more often, and the wind speed of tropical cyclones will increase and their number will likely remain constant or decrease.[6]

Recent experience of extremes of summer heat in Europe, Asia, and North America has underscored the great threat to health when physiological thresholds are passed. Once the human body's capacity to cope with increased thermal stress is exceeded, risks of homeostatic failure, disease exacerbation, and death begin to rise rapidly. This is especially the case in older people, those with underlying cardiovascular or chronic respiratory disease, and those who are poor, uneducated, or isolated (and therefore less likely to have access to, or take, preventive action).[10 16] Such effects are exacerbated by changes in air quality: ground level ozone levels rise with temperature, threatening human health.[17] The greater absolute burden of adverse health impact from heatwaves will be in the general community, but workers in various heat exposed workplaces, both outdoors and indoors (if unventilated), are particularly vulnerable.[18]

Societies will be hard pressed to prepare for and cope with extreme weather events, especially when these occur on a large scale. The flooding in Pakistan in July 2010 left 160 000 $km^2$ (or 62 000 square miles, a fifth of the country's land mass) under water. 2010 also saw the hottest summer in Russia for 130 years, leading to forest and grassland fires burning a similar area, contributing to many deaths, and damaging grain crops.[19]

### Indirect risks

Indirect risks arise from changes and disruptions to ecological and biophysical systems, affecting food yields, the production of aeroallergens (spores and pollens), bacterial growth rates, the range and activity of disease vectors (such as mosquitoes), and water flows and quality.

Rising temperatures reduce the solubility of gases (such as oxygen) in water: oxygen concentration at saturation falls 10% with a 3°C increase. Such effects may reduce fish stock density. Ocean fishery harvests are also affected by the adverse impacts of acidification (caused by increased uptake of carbon dioxide from the atmosphere) on the vitality of the marine food web base.[20]

Crop and livestock yields are more sensitive to changes in climatic conditions than previously thought. Yields are impaired by relatively small changes in growing season temperatures.[21] Rising temperatures affect rice production.[22] Indeed, between 1980 and 2008, gains in crop yields due to factors such as technological advances may have been significantly offset by negative impacts of rising temperatures in many cropping regions of the world, often in association with changes in seasonal rainfall. Rice production in India, for example, peaked a decade ago, and the gains from the green revolution in South Asia are now over.[23] Such negative impacts seem likely to progress to regions beyond South Asia, including southern Europe, the American Midwest, and southern Australia,[8] with parts of Africa particularly vulnerable in the near future.[24 25]

Much attention has been paid to climate influence on food yields in relation to export earnings, livelihoods, and community incomes, but the ultimate manifestation of reduced yields is health impairment: hunger, under-nutrition, child stunting, susceptibility to infectious diseases, impaired adult health and strength, and premature death. In addition, climate induced falls in crop yield have potentially disastrous effects for the poor in terms of spiralling food prices. In 2011 the food price index of the Food and Agriculture Organization of the United Nations (FAO) matched its earlier peak in 2008, and has contributed to social unrest in the Middle East and elsewhere. Food prices are likely to stay high and volatile during the next few years because of factors including rising demand, and a likely increased frequency of extreme weather events.[26]

Changes in climatic conditions will affect many climate sensitive infectious diseases, via influences on pathogen maturation and multiplication, on vector organism density and behaviour (such as the mosquito), on the ecology and density of reservoir (intermediate) host species, and on aspects of human behaviour that amplify risks of infection (such as crowding and displacement). Thus, cases of campylobacteriosis, and infection with *Salmonella* Typhimurium and *Salmonella* Enteritidis rise

FAREED KHAN/AP/PA

**Extreme weather events can have profound psychological sequelae**

with temperature. Such risks may be offset in countries with sufficient resources, but this may not be the case elsewhere.[27]

Changes in the distribution and life cycle of vector organisms will also occur, as will those of their transmitted pathogens. Changes in Lyme disease, malaria, schistosomiasis, trypanosomiasis, onchocerciasis, and leishmaniasis are to be expected, as well as in dengue fever and infections by other arboviruses.[28 29] The geographical distribution and timing of such changes are difficult to predict. For example, a short term increase in temperature and rainfall associated with the 1997-98 El Niño caused *Plasmodium falciparum* malaria epidemics in Kenya,[30] but reduced malaria transmission in Tanzania.[31] Malarial zones have apparently extended to higher altitude in western Kenyan highlands[32 33]; the schistosomiasis water snail survival zone has extended north in eastern China[34]; tick borne encephalitis zones have expanded northwards in Sweden; and the ixodid tick, which transmits Lyme disease, has spread northward in eastern Canada.[11 35] Taken together, these observations suggest that such impacts of climate change may already be taking place.

Surface runoff and solid material transportation (for instance, of organic materials) result from heavy rainfall, which is likely to rise in frequency in temperate countries as climate change progresses. Increased water contamination (both particulate and microbial, including from sewerage effluent) is thus likely.[36] Gains in temperature and changes in rainfall and humidity may extend and intensify exposure to allergenic pollen and spores from plants such as ragweed.[37 38]

### Deferred and diffuse risks

Deferred and diffuse risks to health include those associated with rural to urban displacement,[39] and the mental health consequences of droughts in failing rural communities. A recent review from Australia suggests that, following a severe weather event, as many as one in five people will suffer debilitating effects of extreme stress, emotional injury, and despair.[40] The emotional and psychological toll can linger for months or even years, affecting community wellbeing and the capacity for people to work. Children in particular are vulnerable to pre-disaster anxiety and post-trauma illness. The failure of adults to act on climate change may lead to long term insecurity and anxiety in young people,[41] including chronic neurohormonal changes that affect long term disease processes.

### Risks associated with conflicts and environmental refugee flows

That weather and climate can affect the risk of conflict is evident from history.[42] Disease, starvation, drought, loss of habitat, loss of natural resources, and economic impacts are powerful drivers. Local wars in Africa in recent decades have peaked during very hot and dry years, in association with reduced food yields.[43] Further evidence comes from study of the El Niño-Southern Oscillation (ENSO), which affects weather in many regions including Africa, Asia, and the Americas. In the warmer (El Niño) phase, land temperatures may rise and rainfall decline, bringing droughts that last several years. A study of 175 countries and 234 conflicts during 1950-2004 estimated that in the large subset of countries known to be affected by El Niño events, the chance of civil war breaking out doubled during such warmer spells. The study's authors calculated that El Niño may have played a role in over a fifth of civil conflicts since 1950.[44] Such climatic drivers as these can also lead to migration, often to areas where resources are already strained, and the risk of conflict greater still.

Climate change thus acts as a force multiplier, amplifying the negative health impacts of other environmental stressors (such as land degradation, soil nitrification, depletion of freshwater stocks, ocean acidification, and biodiversity loss). Populations with high pre-existing rates of climate sensitive diseases and conditions, such as child diarrhoea, malaria, under-nutrition, asthma, atherogenic cardiovascular disease, and extreme heat exposures in workplace settings, could suffer large absolute increments in adverse health impact with relatively small changes in climate.[45] Indeed, conservative extrapolation of estimates made for the year 2000 suggested that climate change is now causing some 200 000 premature deaths each year (from under-nutrition, diarrhoeal disease, malaria, and flooding), with over 90% of these occurring in low income countries (especially sub-Saharan Africa and South Asia), and 85% in children under 5 years of age.[46]

### The potential health co-benefits of taking mitigation action

Many more localised health co-benefits should flow from national and local actions to reduce the atmospheric concentrations of greenhouse gases, in addition to the long term protection of health at global level.[47] Local and regional air quality, for example, will improve from the reduction of fossil fuel combustion in the generation of power, thus lowering risks of respiratory and cardiovascular disease. An increase in the use of mass transit, cycling, and walking, as alternatives to more energy intensive private vehicles, will increase physical activity, reduce obesity, and stimulate social contacts. In high income countries, where the average daily intake of red meat is typically greater than nutritional requirements, a decrease in production and consumption of meat (especially from ruminant animals, including cattle, sheep, and goats) would confer health gains via reductions of cardiovascular and some cancer risks.

A further and fundamentally important set of health co-benefits would result from promoting reproductive rights for women, especially in low income countries. Improving access to family planning and health services for mothers and children will increase personal control over fertility and yield reductions in both maternal and child mortality, two of the key determinants in reducing the rate of growth in world population size—a basic determinant of total human impact on the global climate system.

## Adaptation and mitigation

Climate change poses a grave threat to human health and survival and urgent and substantial efforts to limit greenhouse gas emissions (that is, mitigation) are essential. Meanwhile, public health action is needed to manage those risks already with us, or that will result from the locked in, but as yet latent, warming from past emissions (estimated at ≥0.7°C). These adaptation strategies will range from near term ameliorative actions (such as early warning systems for impending weather extremes, enhanced infectious disease surveillance, and reinforced sea walls against storm surges) through to long term transformative actions, such as remodelling urban settlements to render them less vulnerable to climate change, demographic transition, and new modes of farming and strains of cultivars better able to cope with climate change.

The health sector should play a central role: to communicate the health risks of global heating, to collaborate with other (sometimes unfamiliar) partners, and to promote, lead and evaluate a range of adaptive strategies.[48] In doing so, particular attention must be paid to protecting the health and safety of the most vulnerable sectors of populations. Globally, effective and equitably shared adaptive responses will require increased financial contributions by high income countries to low income countries, and a freer flow of information and technologies between countries.

## What we need to do

Human induced climate change is a reality, and one which threatens our biosphere and the global economy. It also poses a grave threat to our health and survival, and an even greater risk to our children and grandchildren. Urgent action at national and international level is required to minimise emissions of greenhouse gases, while adaptive mechanisms are put in place to deal with those health consequences that are already unavoidable.

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# How the low carbon economy can improve health

Health professionals are uniquely placed to guide the climate change conversation towards policies that are good for the planet and for people, say **Andy Haines** and **Carlos Dora**

Wrong for so many reasons

The current global economy has generated enormous wealth but simultaneously created profound, and in many cases growing, inequalities. Furthermore, the global economy is based on unsustainable foundations, not only because of a dysfunctional global financial system but also because human activities are undermining the planetary life support systems that sustain human health and development.[1 2]

It has been proposed that there are nine planetary boundaries to the biophysical subsystems that provide the conditions for human civilisation to flourish: climate change, rate of biodiversity loss, ocean acidification, stratospheric ozone depletion, interference with nitrogen and phosphorus cycles, global freshwater use, changes in land use, chemical pollution, and atmospheric aerosol loading. If disrupted beyond certain limits these processes could cause unacceptable environmental damage.[3]

For some of these boundaries there is evidence of a threshold level that if exceeded could lead to non-linear, abrupt changes, with adverse, and in some cases potentially catastrophic, consequences for humanity. Thresholds have probably already been exceeded in three of these interlinked processes: climate change, rate of biodiversity loss, and the nitrogen cycle. For some others the boundaries are being approached and without decisive action they are likely to be exceeded in the foreseeable future. Despite scientific uncertainties it is clear that humanity can only flourish within finite ecological limits.

At the same time, as awareness of the global scale of the environmental challenges has become evident, concern is also growing about the burgeoning epidemic of non-communicable diseases in low and middle income countries. The recent UN High Level Meeting on Non-communicable Diseases concluded with a ringing endorsement of a range of policies to promote health, prevent non-communicable diseases, and scale up cost effective treatments.[4] However, there was little consideration of the critical links between the current non-communicable disease epidemic (including cardiovascular disease, chronic pulmonary diseases, and obesity related conditions) and environmental drivers, such as exposures to air pollution and urban environments that profoundly shape sedentary lifestyles. These drivers are in many cases related to processes that emit greenhouse gases to power economies and produce food.

Health and sustainability are indivisible at a global level, as improvements in health cannot be maintained without safeguarding the underlying systems on which human health and development depend. We outline some of the policies that can significantly improve both health and promote sustainability, with a particular focus on reducing greenhouse gas emissions to mitigate climate change. Some of these policies could also have added environmental benefits, by reducing biodiversity loss and land use change, for example.

MITCHELL KANASHKEVICH/CORBIS

**Inefficient cooking stoves and open fires: bad for people and the planet**

## Addressing climate change

In order to avert dangerous climate change (that is, climate change that leads to major abrupt or irreversible changes in the climate system or a component of the system) many climate scientists consider that it is necessary to keep global mean temperature increases to no more than 2°C above pre-industrial levels. It will nonetheless be difficult, if not impossible, to hold temperature increases below this level given current trajectories of greenhouse gas emissions.[5] Decisive action is needed to cut global emissions by at least 50% by 2050. This figure implies a cut of at least 80% for a developed country such as the UK,[6] which has benefited historically from access to affordable fossil fuels. The Contraction and Convergence (C&C) position,[7] in which countries aim for a similar per capita emission cap, seems the most promising approach to addressing the profound inequities in greenhouse gas emissions that currently exist.

According to one measure, the benefits over time of approaches to move the world on to a low carbon path could be around $2.5 trillion (£1.6 trillion; €1.9 trillion) annually.[8] Despite

TIM GRAHAM/GETTY IMAGES

**Table 1 | Win-win transport strategies to maximise health and climate gains[22]**

| Strategy | Key pathways |
|---|---|
| Land use systems that increase density and diversity of uses | Increases proximity of destinations, reducing need for car travel and reducing vehicle kilometres travelled (VKT)Improves access by walking, cycling, and rapid transit/public transport |
| Investment in and provision of transport network space for pedestrian and cycle infrastructure | Improves access by walking and cyclingEncourages shift from car use to walking and cycling, reducing VKT |
| Investment in and provision of transport network space for rapid transit/public transport infrastructure | Improves access to rapid transit/public transportEncourages shift from car use to rapid transit/public transport, reducing VKT |
| Engineering and speed reduction measures to moderate the leading hazards of motorised transport | Reduced speeds improve safety of walking and cyclingIncreased separation of vehicles from walkers and cyclists improves safety of walking and cyclingEncourage walking and cycling by reducing real and perceived road dangersTechnological improvements reduce production of hazards from vehicles (greenhouse gases, air pollutants, noise) |

the evidence that technologies and policies for reducing greenhouse gas emissions are likely to be some of the main drivers of a sustainable economy, and that the cost of mitigation is likely to be lower than the cost of the damage caused by climate change, in practice progress has been too little, too late. The Kyoto Protocol expires in 2012 and the challenge is to reach an agreement that results in sufficient reductions in greenhouse gas emissions at the UN Framework Convention on Climate Change negotiations.

### The benefits to health of a low carbon economy

Health has been a missing dimension in climate policies. It is not widely appreciated that there are many benefits to health that are likely to accrue from a low carbon economy. (The term "low carbon economy" is used for simplicity; although not all greenhouse gases contain carbon, neither are greenhouse gases the only climate change pollutants—black carbon, for example). These collateral benefits (often called co-benefits) have frequently been overlooked by policy makers and constitute an added rationale for deep cuts in greenhouse gas emissions. Co-benefits should make deep cuts in greenhouse gases more attractive because they offer the promise of accelerated progress towards both public health and climate goals.[9]

Low carbon strategies can directly or indirectly affect health by acting upon health exposures and risks related to ambient (outdoor) air pollution from electricity production, primarily from coal; indoor air pollution in homes reliant on coal and biomass fuels; transport related air pollution and the spread of sedentary lifestyles; and agriculture and nutrition, particularly as a result of increased consumption of animal products and changes in land use.

### Electricity production

A shift away from the combustion of coal for electricity generation will reduce both carbon dioxide emissions (the major greenhouse gas) and fine particulate air pollution. A number of studies have estimated the health benefits from low carbon electricity generation. It has, for example, been estimated that in the case of India around 90 000 premature deaths annually could be avoided as a result of reduced atmospheric concentrations of fine particles from reduced coal combustion.[10] In high income nations the health co-benefits would be comparatively less because of existing air pollution legislation, but still worthwhile.

### Indoor air pollution

WHO estimates that in 2004 over half the cases of pneumonia in children were related to exposure to indoor smoke from the combustion of biomass or coal in inefficient cook stoves or open fires.[11] Indoor air pollution also causes chronic obstructive pulmonary disease, particularly in women. Black carbon and other greenhouse pollutants are released from inefficient biomass combustion. Thus improved efficiency cook stoves or the use of biogas, for example, can greatly reduce indoor air pollution as well as helping to mitigate climate change. One study has suggested that in India around two million premature deaths, particularly in women and children, could be averted by introducing 150 million improved efficiency cook stoves over a decade, with a concomitant reduction of between 0.5 to 1.0 billion tonnes of $CO_2$ equivalent greenhouse pollutants.[12]

Improved insulation and building design can substantially reduce greenhouse gas emissions as well as protect dwellers from thermal stress. Adequate ventilation needs to be built into energy efficient building projects, to avoid dampness, mould, radon, and other indoor pollutants.[13] Improved ventilation may enhance quality of life in asthma[14] and reduce transmission of some respiratory diseases in healthcare settings. Screens on windows and doors protect from vector borne diseases like malaria and reduce energy consumption from air conditioning and related greenhouse gases.[15] Some important untapped opportunities for health advances and greenhouse gas reductions lie in the use of clean and low carbon solutions in slum improvements, where 40% of the increase in urban populations will take place by the year 2050.[16]

### Transport

Major increases in greenhouse gas emissions are projected from the transport sector without decisive policies to address the growth in emissions. Motorised transport is responsible for the vast majority of the deaths from road traffic injuries (1.3 million a year)[11] and makes a substantial contribution to urban air pollution (also responsible for around 1.3 million deaths a year).[17] Reliance on private motorised transport can also be a major contributor to sedentary lifestyles, associated with obesity and with 3.2 million noncommunicable disease deaths a year.[11] Increased active travel could reduce greenhouse gas emissions and the disease burden from ischaemic heart disease, cerebrovascular disease, depression, Alzheimer's disease, diabetes, and breast and colon cancer.[18]

Longitudinal studies in Copenhagen[19] and Shanghai[20] have shown that all cause mortality was 30-40% less among those who cycled to work compared to those who did not use active transport or get equivalent amounts of leisure time exercise, even after the increased risk of road injuries to cyclists and confounders were considered. A systematic review of interventions to promote physical activity found that urban planning interventions in land use and transport were among the most effective—and better than other health promotion approaches focused on individuals (see also table 1).[21]

### Agriculture and nutrition

The demand for animal products is projected to increase in the coming decades, particularly in middle income nations. Food and agriculture

THE ASAHI SHIMBUN PREMIUM/GETTY IMAGES

**Prime suspects**

contribute 10-12% of global greenhouse gas emissions, with major additional contributions from deforestation and other land use change. A large proportion of emissions is attributed to rearing animals. Ruminants contribute a disproportionate share because they emit methane, a potent greenhouse gas. Also, pastureland used for livestock grazing and forage crops occupies 26% of the Earth's terrestrial surface and livestock feed crops occupy around 30% of arable land.[23] The increased reliance upon grain commodities for both livestock feed and the increase in crops grown to make biofuels, along with shifting patterns of rainfall and drought, have contributed to sharp increases in commodity prices, threatening the nutrition of the world's poorest populations.[24] At the same time, people in many low and middle income countries are eating more meat and dairy products, often in unhealthy diets that increasingly mirror those in some developed economies. This is despite the clear evidence, in health terms, that excessive saturated fat consumption from meat and dairy products can substantially increase ischaemic heart disease and stroke. In addition, large bowel cancer has been linked to high levels of processed meat consumption. One study suggested that as a result of decreases in saturated fat intake, reducing animal product consumption by 30% could reduce the ischaemic heart disease burden by around 15% in high consuming societies such as the UK and São Paulo, Brazil.[25]

### Why health should be taken into account in climate change mitigation strategies

Too often, those greenhouse gas mitigation strategies that have been championed by the mitigation experts themselves (including the Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report[26]), emphasise technology heavy solutions that are not necessarily optimal for health or health equity.[27] The IPCC, for example, focuses most of its attention on transport mitigation on improved fuels and vehicles, including biofuels. These strategies can reduce the levels of fine particulates and other traffic related pollutants, as well greenhouse gas emissions, but do not yield the benefits for traffic injuries, noise, or physical activity that can result from shifts away from car travel to efficient public and non-motorised transport.[28] Furthermore, increasing car use can quickly offset benefits from improved engines and fuels.[29]

Similarly, the IPCC largely overlooks the problems for both health and climate change of a continuously expanding livestock production sector, for discussion of technology intensive approaches to livestock production and carbon sequestration. The grave omissions of what might, in some cases, be the most effective measures—for mitigation as well as health—illustrate why such strategies should be subject to closer analysis relevant to health, such as health impact assessment and cost-benefit analysis including all relevant health issues. Such analysis would also alert policy makers to where adverse health effects could occur, as in the case of some biofuels or diesel.

Many of the policies mentioned above are also highly cost beneficial for health and poverty reduction. For example, the benefit-cost ratio of replacing polluting and leaky biomass stoves with liquefied petroleum gas (LPG) stoves has been estimated at 4:1. These positive outcomes in terms of fuel, time, health, and climate are likely to be even greater with newer, more advanced biomass stove technologies that rely on renewable fuels and can greatly reduce the emissions of climate and health damaging pollutants.[30] For every dollar investment in active transport, there is up to $30 return. A systematic review of the economic benefits of cycling interventions, including economic benefits of health impacts from more physical activity, found a median benefit-cost ratio of 5:1, with a range of −0.4 to 32.5.[31]

Although there are many synergies between health and a low carbon economy, health is not yet central to the low carbon economy discourse. Why should policies to reduce greenhouse gases consider health?

Firstly, because the external costs to health as well as the expected gains produced by these policies need to be considered in decision making processes so as to achieve the most benefits to society. Excluding health costs may lead to policy choices that are not optimal to society. For example, when costs to society exceed those for an individual road user, the levels of road use will be higher than socially optimal.[32] Secondly, because individuals and policy makers are making decisions, such as those to promote a sustainable low carbon economy, based on partial information. This lack of due diligence may lead to risks that could have been avoided. Thirdly, health professionals should be the voice of population groups, like children, who may lose out in certain policy decisions, but who have no voice in decision making. Finally, the health sector has evidence that can guide other sectoral policy decisions in the direction of reducing health and social inequities.

The health sector has a unique contribution to make to climate policies by providing tools and expertise for health impact assessments and economic analyses, and by developing health monitoring and evaluation of mitigation policies. Health professionals can promote greater accountability, and generate the evidence to aid the selection of policies that will improve health and reduce greenhouse gas emissions.

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# Politics and policies

The geopolitical consequences of climate change are real and imminent, says **Hinrich Thölken**, and an issue for Europe

The onset of climate change means that for the first time in modern human history our physical environment is no longer stable. Yet our rules for peaceful coexistence on an increasingly crowded planet have always assumed a stable environment. Geographical borders, watercourses, and coastlines have been understood as constants, but this seems no longer true.

Climate change requires us then to rethink some basic principles of geopolitical importance. We may need to revisit the laws of the sea and laws concerning natural resources. We may have to rethink the concept of national sovereignty. Adapting our geopolitics to a changing environment is a task for foreign policy.

In human history conflicts arise over access to resources and territories. Climate change will affect both. We will increasingly be short of such vital resources as fresh water, food, and clean energy. Rising sea levels and increased frequency of extreme weather events will render whole stretches of territory uninhabitable or no longer economically viable. Low lying coastal areas and islands may simply disappear.

We have no rules to clarify what will happen to the economic zones of islands and territories that have sunk into the sea. Arguments over single rocks and sand banks have erupted in the past, so it's likely that the disappearance of such territories will lead to tensions and conflicts. Borders that follow coastlines, riverbeds, and river deltas will start shifting. Loss of territory may trigger migration and exacerbate tensions. We are currently unprepared for such problems; the situation requires preventive and far sighted foreign policy to come up with solutions. Here are three suggestions.

### High level policy forums

Firstly, high level foreign policy forums need to engage with the problem. When the United Kingdom took the topic of climate change to the United Nations Security Council in 2007 it met strong opposition. There was a debate, but no written statement could be agreed on. Germany had been explicit in its campaign for a seat on the Security Council that climate change would be one of the major topics for its time there, and reintroduced the topic in July 2011. During the July debate, the Security Council accepted a presidential statement that climate change posed a threat to peace and security. The UN secretary general was asked to include the subject of climate change in his report to the Security Council.

En route to this result it was felt strongly that not all UN members, and not all Security Council members, agreed on the fundamental importance of climate change as a risk to peace and stability. Negotiations for the presidential statement were tough. Some argued that it was wrong to introduce a subject that wasn't part of the Security Council's original brief; others argued that its introduction might wrest control of the topic from the UN Framework Convention on Climate Change. We found it interesting that as a collective the Group of 77 nations (G-77) opposed discussion of climate change within the Security Council, but that many individual G-77 members strongly supported the initiative and even congratulated us after the successful outcome of the debate.

Is also necessary to rethink how we handle climate change within Europe and the European Union. At the European level so far, climate change has been predominantly the domain of environment ministers, with foreign ministers only occasionally involved. However, in July 2011 Germany and the UK introduced the topic in a joint initiative to the Foreign Affairs Council, which brought to the attention of ministers the diplomatic challenges of climate change.

### Convince the politicians

Secondly, we must work harder to make politicians worldwide understand what needs to happen. Successful climate policy means that we have to adopt low carbon energy production and transport. We need to find low carbon ways to produce food, minimising the generation of greenhouse gases. Known resources of fossil fuels can be exploited only to a very limited extent, as they would produce a carbon load that would by far exceed acceptable limits. Peak oil is no longer a relevant issue; rather peak $CO_2$ emissions is what we should be looking at.

If all known resources of fossil fuels were exploited and burned it would lead to 100 times more $CO_2$ emissions than we can allow ourselves, if we want to stay within the two degree limit on global temperature increase over pre-industrial levels. That means more than 90% of all known oil, gas, and coal reserves have to stay in the ground. Imagine what this means to economies dependent on producing and selling fossil fuels. To believe that such a shift in geopolitical paradigms could take place without major disturbances of international relations is naïve.

So we are trying to reach a new balance of interests. We need to find a balance between the interests of industrialised countries and developing countries, between exporters and importers of fossil fuels, between technologically advanced and less advanced economies, and between vulnerable and more robust regions. Climate change

TIM GRAHAM/GETTY IMAGES

**More than 90% of all known oil, gas, and coal reserves should stay in the ground**

is a global factor with massive economic, legal, energy, and financial implications, and it will be one of the key determining factors of international relations.

The view that climate negotiations are nothing less than global economic conferences aiming at redistributing resources is gaining more and more credibility. Climate change may easily become the 21st century's biggest foreign policy challenge, comparable with the challenge of the cold war in the second half of the 20th century. Climate change could endanger human rights. It could endanger human lives by cutting off millions from food and drinking water. In the end, climate change could do as much harm as tanks and guns.

**Involve the public**

The third suggestion is for dialogue with the public. Politicians and government representatives need to tell people that climate change is a topic not only for scientists and experts but for everybody. Politicians themselves need to increase their level of scientific literacy. Climate change is a difficult subject, but people have the right and the capacity to know what is at stake and what their choices are. Our experience in Germany is that consumers are willing to make a choice for the environment and for the protection of the climate. Many people have, for example, chosen electricity that is produced by renewable energy sources, energy-saving light bulbs, food that is produced in an ecologically sound way, and so on. Consumers seem willing to pay more for products with a positive ecological label. A key to the necessary transformation of our economy is giving people a choice and at the same time providing them with ample information.

There are enormous challenges ahead, but they are not insurmountable. In Europe we are uniquely placed to play a pivotal role in international climate diplomacy, and the decisions we make will be influential in determining how others act. National foreign services have demonstrated an ability to show leadership and to engage with and broker agreements on some of the most challenging issues. They can and should be a major force in addressing the threats to security and growth posed by climate change.

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# Climate change and resource security

Climate change is a key issue for the future of the militaries of the UK and the US, says **Neil Morisetti**, both in how they are run and what they have to do

There is a growing recognition that we face a number of new threats to global stability and national security. In particular, there are risks to secure, sustainable, and affordable supplies of key natural resources (food, water, and energy), essential for economic prosperity and wellbeing. The 2010 UK Strategic Defence and Security Review and the US Quadrennial Defence Review both highlighted the effects of climate change as one of these risks.

It is unlikely that climate change will be a direct cause of conflict. However, the impact of the second and third order consequences—loss of land or livelihood—has the potential to increase the risks of global instability and conflict in those parts of the world already experiencing other stresses, such as food or water shortages, health issues, or demographic challenges. Countries in this part of the world (centred on the equatorial belt) have experienced conflict in the past, both intrastate and interstate, frequently as a result of a lack of capacity in their government to look after the needs of their citizens. Because of this, climate change is widely recognised as a threat multiplier.

**Not somebody else's problem**

At a time when countries such as the United Kingdom, the wider European Union, and the United States face many other challenges, not least as a result of the global economic downturn, it is tempting to see this as somebody else's problem (especially when the direct impact of climate change in these countries is unlikely to be felt until much later in the 21st century). However, by virtue of the globalised world that we live in, events many miles away can impact on the interests and security of our nations. A recent example of this is the impact felt by European and US companies as a result of the floods in Thailand. Whether it be auto parts or computer chips, both are manufactured in Thailand for subsequent use in the assembly of cars or computers in third party countries; the floods disrupted supplies and production lines had to be slowed. At the same time the loss of rice crops has resulted in shortages and price increases of this staple food product.

The problem is compounded in a "just enough, just in time" world where factory warehouses are on the high seas, on global

DIRK WIERSMA/SPL

**Factory warehouse on the move**

trade routes passing through the parts of the world where climate change will have the greatest impact, and are therefore vulnerable to disruption. All nations are, to a greater or lesser extent, trading nations. In the case of the UK more than 90% of goods imported travel along these supply lines. Of particular concern for many countries is the risk to secure, sustainable, and affordable supplies of energy, key for economic growth and prosperity. This is not only an issue for Europe and America: 75% of China's oil comes from the Middle East via the Strait of Malacca. It is, therefore, in all our interests to address the risks posed by climate change.

### Time for a strategic view

New threats and challenges frequently require governments, societies, and international institutions to adapt. Addressing climate change is no different. To tackle climate change nations will need to take a strategic approach; one which looks beyond the normal political and planning horizons, and one which involves all of government, as well as public and private collaboration, and international action. We should not focus only on the threats but also identify the opportunities, including that of economic growth.

The armed forces have a part to play in this process, both nationally and internationally, not least because we are part of society. We can contribute in several areas.

### What we can contribute—understanding

Firstly, the armed forces can help in developing an understanding of the risks and how they will impact on both global stability and individual nations' interests. There is a need to improve our collective knowledge of how people in affected areas react to the loss of land or livelihood. Will they migrate or are they trapped? If they move will it be within their country or to another state? Will this migration be manageable or put further pressure on already stretched authorities? In the case of loss of livelihood, are there sufficient alternative and legitimate sources of income available, or are those affected susceptible to recruitment into serious crime or even paid terrorism?

Understanding these behaviours and the risks they pose is necessary to ensure that the threat of climate change is included in national security strategies and risk registers, and that it informs the priories for action, both adaptation and mitigation. Developing capacity in vulnerable countries, for example, is a key element of reducing the risk of conflict, as highlighted in the UK government's 2011 Building Stability Overseas Strategy, signed by the secretaries of state for Defence, Foreign Affairs, and International Development.

AKHTAR SOOMRO/REUTERS

**The military's prodigious energy requirements: fuel for NATO forces in Afghanistan**

### Humanitarian assistance and disaster relief

Secondly, analysis of risks and impacts can be used to establish likely future missions for the armed forces. One example is the provision of humanitarian assistance and disaster relief, something the armed forces frequently find themselves tasked to do. During the hurricane season the crew of the Royal Navy ship operating in the Caribbean is trained to perform such a role and is often called upon to do so. In the future, with the increased likelihood of extreme weather events, especially in the Indian Ocean and South East Asia, it may be necessary to have the same skills available in all deployed ships.

Both the Strategic Defence and Security Review and the Quadrennial Defence Review recognised that the military must retain the ability to provide conflict resolution but that there would also be greater involvement in the area of conflict prevention. That is not to say that the military will try to usurp the role of others, but will rather undertake complementary activity, such as developing the capacity of a country's coastguard to police its exclusive economic zone. The ability to work with other government departments, NGOs, and other organisations, is key to effectively delivering such activity, and these skills will need to be developed in advance, building on the experience gained in post-conflict stabilisation operations.

### Energy: from commodity to capability

Finally, the armed forces need to make sure both that the mission can be delivered and that it can operate in a sustainable fashion. We must ensure that there are sufficient units available, such as helicopters for humanitarian assistance and disaster relief, and that they are capable of operating in harsher environments with potential water and energy shortages.

Fundamental to achieving this is addressing the use of energy. Energy has always been a critical enabler for the armed forces, whether it be fodder in Napoleon's time or diesel today. Like any other organisation the armed forces need an energy plan that recognises the requirement of obtaining secure, affordable, and sustainable supplies in order to deliver their outputs. At the same time they need to recognise that the manner in which they deliver that plan must address the requirement to reduce $CO_2$ emissions, especially but not exclusively with regard to utility energy. Such an approach will address the challenges faced by the military when operating at great distance from their home bases, for example Iraq or Afghanistan. By changing behaviour, optimising existing equipment, and where appropriate using alternatives to fossil fuels (such as solar and wind) not only is it possible to reduce the cost and risk incurred in the supply chain but it will also help improve operational effectiveness. In the longer term it will be necessary to treat energy as a capability, rather than a commodity, and factor in the full costs throughout the projected life of the equipment. This can best be described as sustainable operational capability.

The military will always need a hard edged war fighting capability and will continue to use fossil fuels in the foreseeable future, but the choices that are made in delivering these capabilities must recognise the potential impact on the environment and on global stability.

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# What needs to be done

Finding the necessary political will to act is the biggest challenge facing climate policy, says **Tom Burke**

If we are to meet the challenge of generating political will, the climate conversation must involve everyone, from all professions and all walks of life. Political will is built into the base of society; it is not something that you can manufacture in the headlines or leave to those politicians we increasingly distrust.

Our analysis of the climate issue is unusually clear. We know exactly what we need to do—construct a carbon neutral global energy system by the middle of the century.

We know how to do it—all the technologies and engineering knowledge we need to get there by that time are already available. We know we can afford it—the International Energy Agency estimated last year that the net cost of doing so might add only a couple of trillion dollars to what we will be investing in energy anyway over the next 25 years. That is a few tens of billions of dollars a year—I used to think that was a lot of money until the bankers taught me otherwise.

What we do not know is how to put the technology and capital together in a timely manner. Doing that will require political will. Political will is built by making clear the connection between what is happening to the climate and all the other interests and preoccupations that concern us in our daily lives. Health and security are two of the most important of those preoccupations. One of the bigger barriers to building the necessary political will is the tendency of the climate conversation to fall too quickly into the elephant trap of mind numbing detail and impenetrable acronyms. Far too often the climate narrative is framed in a way that excludes rather than includes most people.

Unless we correct this fault we will not build the necessary political will to take up those technologies and to use that capital, however good our analysis is and however hard we try. So I want to steer clear of the detail and begin by looking at the very big picture of the political challenge that climate change presents. We need to identify just how different this problem is from any other that humanity has ever faced. It is different in at least three ways.

### We're all in this together

Firstly, it is a problem that is more truly global than any other. The livelihood of literally every person in every nation will be affected by a changing climate. Far too many people lead lives constrained by poverty, violence, ignorance, and ill health. But they share the planet with others who lead lives that are affluent, peaceful, educated, and healthy. Everyone, for better or worse, will live with the consequences of climate change.

This characteristic creates an entanglement of interests unprecedented in history, and unprecedented in any of the efforts diplomacy has ever had to meet. And, although there might be hard power consequences of a failure of climate policy, there are no hard power solutions to the problem.

The problem cannot be solved by one nation imposing its will on another. Therefore, solving the problem requires an intensity and persistence of cooperation between nations not yet seen.

Cooperation between governments is never one dimensional. This means climate policy success is ultimately predicated on the continuance of a global system where cooperation takes precedence over competition.

PANOS

**Rich or poor: all will live with the consequences of climate change**

### Policy failure is not an option

The second difference is that policy failure is not an option. The development of public policy is typically empirical. Human beings learn by doing. Policy measures are adopted, monitored for effectiveness, reviewed to take account of changing circumstances, and revised as necessary. Economic, social, or political goals that are not achieved today can be pursued again tomorrow. This is not true for climate change.

The long lifetime of carbon dioxide in the atmosphere—many centuries—means that we are committed irrevocably and, in policy terms, indefinitely, to whatever climate is generated by the carbon burden in the atmosphere at the point of stabilisation—that is, the point at which the amount of carbon we add to the atmosphere is balanced by the amount natural processes remove.

If we fail to stabilise greenhouse gas concentrations at a level compatible with the temperature rising by less than 2°C we cannot try again later to achieve this goal. This conflicts with the automatic reflex of all politicians when faced with a truly difficult problem: prevarication. And we cannot afford prevarication with this issue.

### The clock is ticking

Thirdly, there is a specific timeframe within which action must be taken. The build up of carbon in the atmosphere is cumulative and effectively irreversible. Most governments now accept that a 2°C rise in global average temperatures marks the boundary between manageable and unmanageable climate change.

To remain within this boundary condition, global carbon emissions must peak within the period 2015-20 and decline rapidly thereafter. Climate change will lead to a complete transformation of the prospects for humanity. This is true whether climate policy succeeds or fails.

If climate policy succeeds the transformation will take place over the next 30 years. If it fails, the transformation that is already under way will accelerate gradually and become dramatic in the 30 years after that. The choice is whether events or people drive that transformation. If people


AFP/GETTY IMAGES

**Battling for the future**

make the choice, then over the next 30 years the way energy is used will be transformed. This transformation will bring with it a wide range of co-benefits in terms both of economic efficiency and human wellbeing. Food and water security will be maintained. However, the pattern of economic winners and losers will be significantly disrupted.

If events drive the transformation then the global average temperature will rise inexorably and, for all practical purposes, irreversibly. Food and water security will be undermined and ever larger numbers of people will be displaced, exposed to conflict and disease, and subject to deeper climate induced poverty.

### Failure threatens prosperity

In those circumstances preserving political support for the international institutions that have sustained the prosperity and security of billions of people over half a century will become progressively more difficult. The health and defence professions will be the first responders picking up the consequences of that failure.

The international negotiations on climate change did not fail in Copenhagen through faults in the process—though faults there were—but because world leaders lacked the political will. As we saw with the formation of the coalition after the last UK election, when the political will is there, processes can be adapted, worked around, or simply ignored.

Building that political will is about the conversations that occur in the capitals of the key countries—not the conversations that go on in the negotiating rooms. International treaties are the output of political agreements, not the input to them.

The mismatch between the intensity and urgency of the effort required and the perceived remoteness of the threat to everyday life is the major obstacle to our success.

Governments everywhere are both distracted and constrained by the current fiscal crisis. They are faced with large and deeply entrenched economic interests, some of which are openly antagonistic to the measures needed to prevent dangerous climate change.

The additional costs of making the transition to a carbon constrained economy are inevitably resisted by both businesses and consumers. But more importantly, the scale, urgency, and nature of the policy measures required are a poor fit with the core political projects of both the left and the right. For the right, the prospects of higher taxes, more regulation, constraints on personal choice, and a more interventionist government are very hard to swallow. It is no accident that in politics almost all climate deniers are from the right.

For the left, the need to put growth at risk, to dislocate existing patterns of employment, and to shift public expenditure from entitlements to investment in a low carbon infrastructure are equally difficult. This means that we cannot rely on our existing political parties to offer voters a clear vision of the choices we must make to preserve our prosperity and security.

To deal with the problem of climate change we need a much deeper political analysis than we have had to date. This analysis needs to address the tension between markets and planning and the tension between entitlements and investment. So far, we have not begun to do that. My own very strong feeling is that what it's really going to take politically to solve this problem is an insurgency of those under 40 against those over 40. We need to shift the axis of politics from a battle between the left and the right to a battle between those who care about the future and those who want to stay in the past.

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TB has worked on climate change issues at senior level in government, business, and the NGO community for 25 years. He has a particular interest in the geopolitics of climate change. This article reflects his conclusions on the political challenges facing the world as we build on the success of the Durban round of negotiations at the end of 2011.

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# Contraction and convergence

Together they could solve the twin problems of climate change and inequity, argues **Robin Stott**

"Philosophers have only interpreted the world; the point is to change it." Karl Marx, 1845

Much is now known about anthropogenically induced climate change, its impacts on the planet's species, and the need for urgent action to avoid catastrophe.[1 2] The consequences differ for rich and poor populations.[3] In poor countries, life expectancy may be only 40 years (Swaziland and Mozambique), infant mortality as high as 180 in 1000 (Angola), and the lifetime risk of dying in childbirth 1 in 16 (sub-Saharan Africa). In rich countries, life expectancy can exceed 82 years, infant mortality can be as low as 4 in 1000, and the lifetime risk of dying in childbirth is less than 1 in 3000. But, having reaped the health benefits of wealth, these countries now face the diseases of excess. In the United States 30% of the population is obese, for example, and in urban Samoa a staggering 70%, and with obesity comes an increasing prevalence of diabetes, cardiovascular disease, musculoskeletal problems,[4] and rocketing healthcare costs. And despite their affluence, over 10% of many rich populations are on antidepressants.[5]

Despite these different disease patterns, most early deaths and many disabilities are preventable. We know what to do: improve the conditions in which people are born, grow, live, work, and age. This improvement entails tackling the structural drivers of these conditions: inequities in power, money, and resources.[6] Fortunately, many of the measures needed to improve global health are the same as those needed to make the required 80% reduction in global greenhouse gas emissions. What is good for tackling climate change is good for health, and responding to climate change is not a distraction from the business of protecting health.

Protection of public health is the duty to society of health professionals. Their actions are rooted in the ethical obligation to create the best possible circumstances that enable humanity to flourish and be healthy. Many influential health professional bodies and individuals now recognise that if climate change is tackled in a fair and just way, the health of all will be transformed.[7] Solutions are available that health professionals must vigorously promote, particularly as the global response to date has been woefully inadequate: despite numerous global meetings committed to their reduction, carbon dioxide emissions have risen by 45% since 1990.[8]

EVAN SCHNEIDER/AP/PA

**Future proofing: Nobel prizewinner Wangari Maathai plants another tree**

### What needs to be done?

Many local initiatives are responding to the challenge. In 1991 Germany, for example, introduced a feed-in tariff, an amount of money paid by the government or utility provider for energy produced by a renewable energy producer. Consequently, 20% of Germany's energy is renewable and about 340 000 people work in the renewable energy sector, which has a turnover of €8.7bn (£7.3bn; $11.6bn) and in 2005 there was a reduction in $CO_2$ emissions of 38 million tonnes attributable to German legislation.[9] UK retailer Marks and Spencer is well on the way to becoming the world's most sustainable major retailer, achieving by 2015 all the 180 sustainability goals set out in its Plan A.[10] Wangari Maathai received the 2004 Nobel peace prize for her role in inspiring 80 000 women in her native Kenya to plant 30 million indigenous trees; a project giving many Kenyan women purpose, companionship, and a source of income, as well as capturing carbon dioxide.

Iran has reduced its fertility rate from an average of 6.54 in 1986 to 1.8 in 2008, through

policies enabling 80% of women to get secondary education, and easy access to family planning.[11]

Individuals, communities, and governments have created environments where these initiatives can take root and flourish. These locally created environments are isolated, however, as most of the world continues to set economic growth as the marker of progress—the precise cause of our current predicament.

Any solution has to refashion the prevailing global environment and create the circumstances for new so called virtuous projects to thrive. Virtuous projects need three ingredients to enable small scale local activity and yet to be global in reach.

Firstly, a scientifically assessed and globally binding commitment to cap and reduce carbon emissions is needed.

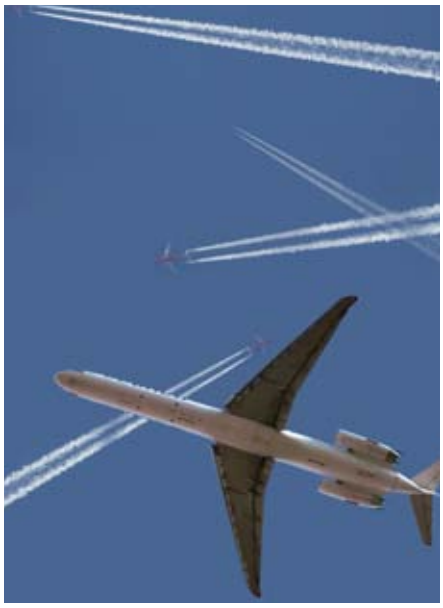
Secondly, a mechanism is needed to ensure that resources are transferred to those countries where both living standards and fossil fuel use have been low. These resources must be sufficient to cover the $110 per person per year that Jeffrey Sachs concludes is the minimum to enable low income countries to reach the Millennium Development Goals.[12-14] The attainment of these goals is essential for health; providing universal access to female education and reproductive health services is a well tested route to stabilising population numbers.[12]

And thirdly, an approach to development is needed that gives financial power to individuals and local communities, and provides the incentive to make low carbon choices.

## Contraction and convergence

The most feasible present framework that embraces these principles is contraction and convergence (C&C).[15] C&C is based on the science of limits and the logic of global rights. The global total of permitted emissions is calculated so as to achieve the objective of limiting and stabilising atmospheric carbon concentrations below the level beyond which runaway climate change becomes unavoidable (presently thought to be about 400 parts per million). This calculated amount of carbon (the global carbon budget) provides the quantum from which an inclusive, global, equal rights per capita entitlement of carbon is derived; an entitlement that will go to each adult. Emissions trading can then take place within the context of this scientifically calculated carbon budget and the rights based mechanism for distribution.

The implementation of a framework founded on these principles will require tough negotiation, particularly around the speed of convergence to an equal per capita entitlement of carbon dioxide emissions, which can be no more than one and a half tonnes per person by 2050 (assuming a global population of 9 billion). Calculation of the initial carbon budget takes account of the present capacity of the global sinks: the oceans, soils, forests, and other flora that absorb $CO_2$. If these sinks diminish, C&C enables the necessary recalculation; the contraction and convergence framework has the capacity to be modified in relation to evolving risks.



**Time to come down to earth**

## How will C&C work?

The equal per capita entitlement of carbon emissions can be pre-distributed as carbon coupons to consumers who could then negotiate the sale of these coupons. Under-consumers (generally the poor) will have coupons to sell to over-consumers (generally the rich). Market forces will work for the poor as well as to reduce carbon emissions; a key feature of the scheme. Putting the poor in control is a crucial development goal, as evidenced by the recent moves by donor agencies such as the International Red Cross to simply give cash to the poor. Recent publications testify to the efficacy of this approach.[16 17]

Equal entitlement under C&C has the added advantage that, in the early stages of the implementation of the framework, rapidly industrialising countries such as China, India, and Brazil (which are still relatively low per capita emitters of carbon) will be beneficiaries.

Credits (entitlements) will be issued by the global institution that oversees global sustainable development and agrees and implements C&C. C&C envisages that a greater portion of these entitlements are delivered to individuals or small collectives. This commitment can be written into the global agreements. So also can the proportion of the entitlements that would be held by the country level group to cover communal facilities such as schools and hospitals. For instance, in the UK, the proportion of carbon emitted by collective rather than individual actions is around 40%, an indication of the proportion of entitlements that the UK would hold centrally.

The widespread uptake of microcredit and the penetration of electronic communication, especially mobile phone technology, provides a route for implementing C&C in poorer countries. And although C&C encourages low carbon solutions, it does not seek to define those solutions for any particular group. The agency of individuals and communities to use resources as they think best makes C&C nonintrusive and is one of the socially attractive properties of the scheme.

No other framework quantifies allowable carbon emissions against an atmospheric $CO_2$ concentration. No other framework allocates entitlements of this amount in a way which is to the advantage of underprivileged people in both the countries that are yet to industrialise and the rapidly industrialising countries. These unique features account for the significant level of global support for C&C, support which will be essential to getting the framework implemented.[15 18] During the implementation of C&C, a period of no more than a few years, a low carbon development fund of at least $150bn must immediately be established. Much of the money could be raised by a tax on airline tickets and imposition of a $5 tax on each of the 20 billion barrels of oil used by OECD countries each year, or through the introduction of a financial transaction tax as advocated by Nobel prize winning economist James Tobin.[19 20]

Time is of the essence. This is well understood by health professionals. After any serious trauma, a patient's chances of recovery are much greater if treatment is started within one hour of the event: the so called golden hour. Our traumatised globe is nearing the end of its golden hour. For the sake of present and future generations, we have to move quickly for our interventions to successfully heal the globe. An agreement to implement C&C cannot be delayed.

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