Future risk

Climate change and energy security – global challenges and implications

Centenary Future Risk Series: Report 3

1912–2012
A CENTURY OF
PROFESSIONALISM

CII

Contents

Foreword

This year the Chartered Insurance Institute celebrates its centenary year as a chartered professional body. To mark this achievement, we are publishing a series of reports, each of which explores some of the risks and opportunities that might face us in the decades to come, drawing on the assessment of commentators across various fields of expertise.

Whilst 'future gazing' doesn't always lead to accurate predictions, it is an important exercise for the insurance industry to undertake as understanding and assessing potential risks is at the heart of what we do. Indeed, central to the role of insurance is the ability to make informed, professional judgments about the relative risks of various hazards occurring over a particular period of time. By planning for the long-term and challenging assumptions about what the future might look like, the profession will be well placed to provide expertise and insight on the risks that lie ahead.

This report is the third within our series and focuses on future risks related to climate change and energy security. Five world leading experts in this area discuss the possible implications of global warming, how we can reduce the environmental impact of energy consumption and how we can adapt to climate risks. We conclude the report by reflecting on three possible future scenarios and their potential implications for the insurance sector.

David Williams,
Chair, CII Underwriting Faculty

1. Introduction

There are a multitude of interrelated risks associated with climate change and energy security, many of which were dramatically illustrated in 2011. The mega earthquake and tsunami that struck Japan demonstrated in a most tragic way the extent to which even developed nations with advanced infrastructure are vulnerable to extreme weather events. If scientific consensus is to be believed, global warming is likely to increase the prevalence and severity with which such events occur in the future. And, assuming that man-made greenhouse gas emissions are to blame for some proportion of climate change, increasing fossil fuel consumption in the years ahead is likely to warm the planet further creating a more conducive environment for natural catastrophes.

As well as the environmental risks associated with continued fossil fuel consumption there is also an obvious economic one related to limited and concentrated sources of supply. The political unrest emanating from the so called 'Arab Spring' of 2011 caused a sharp rise in the price of oil as a consequence of concerns that political instability would stem the flow of oil from the world's most abundant region. In turn, oil price inflation helped contribute to a decline in economic growth in countries particularly reliant on imported oil.[1] The Russian-Ukraine gas dispute of 2008 which threatened the energy supplies across much of Europe is another case in point.

In short then, many countries may need to diversify their energy sources, not just to help reduce the impact of energy consumption on the environment, but also to limit their economic vulnerability to potential supply-side shocks.

Making such a shift in energy usage and adapting to the amount of climate change that is already 'locked in' will not be easy.[2] Some of the decisions along the way will include difficult trade-offs which potentially necessitate sacrificing short-term economic growth for a sustainable long-term economic future – a difficult sell politically.[3] And these decisions are not made any easier by the uncertainty which surrounds climate change. Whilst consensus suggests that the earth is warming and that some of this is down to human beings, modelling the likely impacts of climate change on human activity and wellbeing is very difficult given the infinite number of variables involved and the complex interactions between them.

Crucially, the insurance and financial services industry must be one step ahead in order to provide comprehensive insight into the changing nature of these challenges, and to recommend credible courses of action in the face of them. With this in mind, our third report within the centenary series provides the views of five world leading experts and seeks to develop three possible future scenarios and their implications for the insurance industry.

1 To read a short analysis on the effect of an oil price rise on economic activity please read: The Economist (March 2012) "The new grease? How to assess the risks of a 2012 oil shock"

2 By 'locked in' we mean the amount of global warming that is likely to occur even with substantial efforts to shift to renewable sources of energy

3 There is a moral and political issue associated with demanding that certain countries reduce emissions just at a time when they are trying to catch-up with more advanced economies. One potential way of resolving this is to adopt a policy of "contraction and convergence". Under this framework, developing countries would be allowed to grow emissions while developed countries contract theirs until the figures converge. For a discussion of this see Meyer and Crichton (Jan 2005) "Weathering the Storm", article for Post Magazine, and CII Report (2009) "Coping with Climate Change"

Overall approach to the Future Risk series

In early February we published the first in the centenary series – ***Future Risk: Learning from History***. It set the scene for the entire CII Future Risk series by reflecting on some of the most dynamic trends of the past and their potential implications as well as discussing some initial findings from a global survey into the risk perceptions of members of the public from across the globe.

A central point made by the report was that in such a rapidly changing international environment, it is vitally important to question underlying assumptions about the world around us and re-evaluate prevailing wisdom. We qualified this statement by noting that whilst a healthy level of scepticism about prevailing wisdom and future forecasting is a good thing, it should not prevent us from developing some scenarios on the long-term to help us prepare for some of the opportunities and risks that lie ahead. Rather, it should ensure that we do not become overly confident and dependent upon any single narrative. In this context, the third in our series of reports looks at some possible environmental futures and their implications for the insurance sector and society as a whole. Crucially it also seeks to identify what role the industry can play in delivering a more environmentally secure world. Our next report in the series will look at future technological risks.

2. Executive summary

The report begins by presenting a number of specially commissioned essays on future environmental risks from leading experts in the field. The authors and their topics include:

- **Dr Fatih Birol** – The Chief Economist at the International Energy Agency discusses recent energy trends, likely projections for future energy usage and the potential impact of this on global warming.
- **Professor Sir John Beddington** – The Government's Chief Scientific Adviser considers the potential global implications of climate change including how it might interact with other future trends like continued population growth and sustained developing world poverty.
- **Dr Swenja Surminski** of the Grantham Research Institute discusses the potential impact of extreme weather events on developing countries and the role of insurance in reducing risks and spreading awareness of climate change.
- **Professor Lord Julian Hunt** of University College London (UCL) and **Dr Yulia Timoshkina** Honorary Research Fellow at UCL explore the relationship between climate change, natural hazards and the growth of megacities.
- **Professor David Crichton**, Hon. Visiting Professor at UCL and Chartered Insurance Practitioner discusses the role of insurance in adapting to climate risk with particular emphasis on how to cope with flooding across Europe.

These essays represent compellingly argued visions of the future which can provide the basis for the construction of three illustrative scenarios – all of which could have important **implications for the insurance sector and beyond.**

In our **upside scenario** there is some global warming, but the world is able to sufficiently shift to renewable forms of energy so that the effect of energy consumption is limited. Countries also take substantial adaptation measures to ensure that even the most vulnerable in society are well protected through appropriate infrastructure and warning systems. Insurers are able to support this – providing innovative solutions, even to those living in the most vulnerable areas. Insurers are also able to play a leading role in informing policymakers about the risks posed by natural hazards.

In our **central scenario** global warming is significantly greater due to limited efforts to shift towards renewable sources of energy. Compounding the problem, adaptation is not taken so seriously leaving some parts of the world particularly vulnerable to extreme weather events. There will be a few isolated incidences of insurance market failure as insurers are unable to pay some large claims following catastrophic weather events. And, with weather events posing an increasing risk to insurers' capital, some insurers choose to withdraw cover for certain individuals and firms.

In the **downside scenario** the earth warms considerably – little if any effort is made to switch from fossil fuels to renewable sources of energy. Irreversible tipping points are breached making adaptation essential but very costly. Unfortunately, few countries take adaption to climate risk seriously so they are powerless to protect their citizens. Vulnerable populations will flee particularly stricken regions with negative international economic and political consequences. Insurance market failure is common – insurers are often unable to cover claims from increasingly large losses stemming from catastrophic weather events. Multiple insolvencies are possible and those insurers that do remain are only able to provide cover against natural hazards to a minority of the population – even in the developed world.

In summary, our report shows that insurers have a key role to play in determining which environmental future the world faces. Over the coming decades the industry must embed itself deeper into the multitude of channels through which it can help ensure that adaptation is properly considered and mal-adaptation is consistently avoided. Innovation will be key to this – both in terms of developing new products that build in climate risk as well as through better forecasting of future environmental trends. And insurers need to continue to be innovative in the way that they engage with policymakers to ensure that their unique insights are fully utilised at the national and international level.

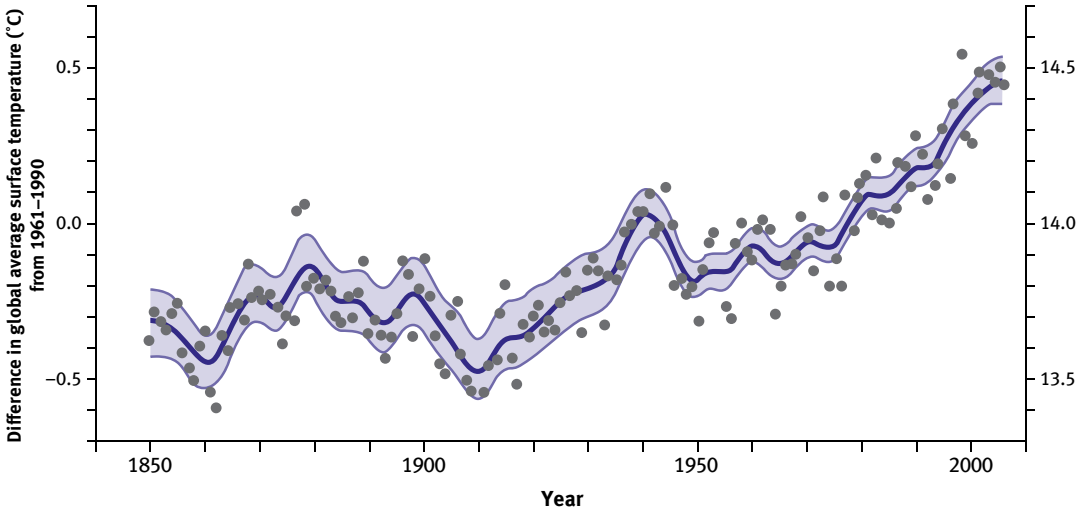
3. Past trends and possible futures: an overview

Our analysis of past trends from the first report within the centenary series identified a number of key risks posed by changing patterns of energy consumption and global warming.[4] In this opening section, we briefly revisit some of these risks and outline the kinds of insights that our expert authors provide. This short discussion and the essays that follow, act as the building blocks for some simple environmental scenarios set out later in this report.

Energy consumption can drive climate change

In our first report within the centenary series, we noted how global warming has been particularly pronounced in the last hundred years, coinciding with substantial increases in energy consumption and in particular greenhouse gas (GHG) emissions. There is a risk, we argued, that continuing rises in greenhouse gases will warm the planet further with implications for the environment and ultimately the health and wellbeing of populations.

Figure 1. Changes in temperature: 1850–2005



Source: Intergovernmental panel on climate change "Fourth Assessment Report: Climate Change" 2007

In our opening essay, **Dr Fatih Birol – Chief Economist of the International Energy Agency (IEA) reflects on the latest IEA** projections for future energy consumption and how this will impact on the earth's climate over the next few decades.

With reference to the IEA's central scenario, Birol describes a world where energy demand doubles between now and 2035 as a consequence of population growth and economic expansion, particularly in developing countries. Part of this rise in demand will be driven by an increasing desire for mobility (i.e. access to transport) and therefore oil, which is still predominantly supplied by countries in the Middle East and North Africa (MENA). As a consequence of such a large concentration of oil in the hands of just a few countries, continued tensions in the MENA region are likely to have significant implications on global oil supply and price. And whilst Birol foresees a potential "golden age" for natural gas which could help to offset this supply problem, he emphasises that "increased use of gas in itself (without carbon capture) will not provide the answer to climate change".

4 For an in-depth analysis of past environmental trends please read our first centenary report, ***Future Risk: Learning from history***, Centenary future risk series: report 1 (Feb 2012)

Birol warns that due to the projected increase in energy consumption, "the world is in real danger of missing the chance to reach its long-term target of limiting the global average temperature increase to 2 degrees". In response, Birol argues that there needs to be much greater focus on energy efficiency – including green technologies such as carbon capture and storage. Without significant progress in these areas before 2017, he believes that there will be an "extraordinary burden on other low carbon technologies to deliver lower emissions".

The impact of climate change

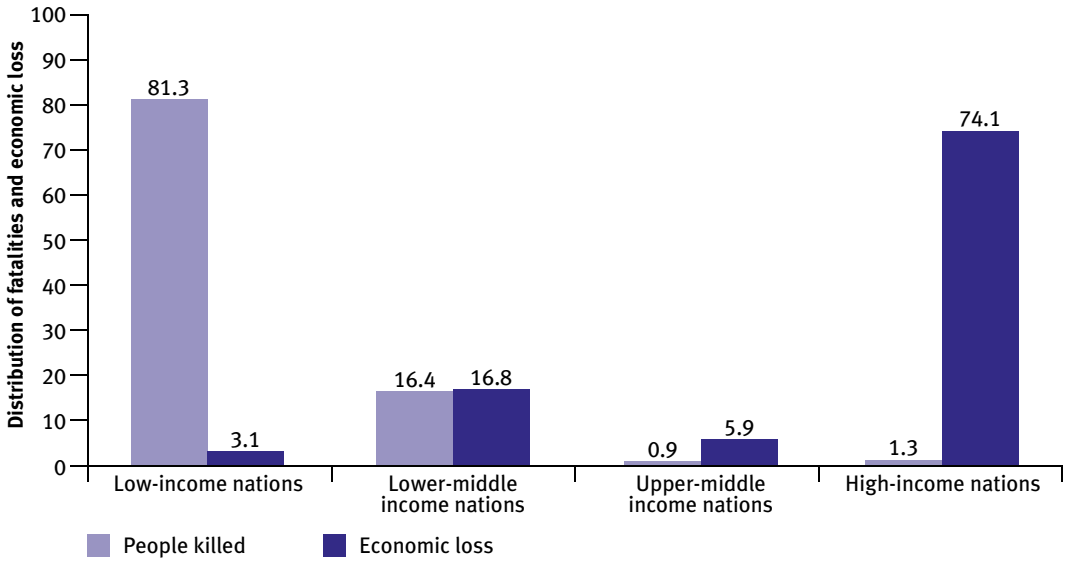
In our second essay, the Government's Chief Scientific Adviser, **Professor Sir John Beddington**, discusses the potential implications of a two degree warming of the climate. Possible negative consequences include; a rise in sea levels, increase in prevalence of heatwaves and an increase in the number of extreme weather events such as storms and droughts. There is also the possibility of breaching tipping points in the climate system which if crossed could result in irreversible climate change. Examples could include changes to large scale oceanic circulatory systems such as the Gulf Stream or significant thawing of ice sheets which could both have substantial implications for regional climates.

Beddington argues that the social and economic consequences of such events could be significant. For example, increased flooding could disrupt global agriculture and food production as well as destroy vital urban infrastructure. And in the most vulnerable areas of the world, Beddington believes that climate change could "exacerbate tensions" driven by already prevalent issues like food and water security, energy shortages and poor health.

In response to the threat of climate change, Beddington echoes Birol's call for immediate action. He argues that decarbonisation of the energy sector is "probably one of the greatest technological challenges of the twenty first century". However, he implies that such a shift in energy investment strategies is also an economic opportunity and Beddington refers to research by HSBC which suggests that the carbon market could be worth up to $2.2 trillion by 2020.

Clearly then, whilst to a certain extent climate change represents an economic opportunity, it is for the most part a dangerous risk that poses different problems in different regions of the world. This last point was highlighted in our first report within the Centenary series. We showed with past data that extreme weather events cause greater fatalities in poor urban areas than rich urban ones due to the difference in infrastructure between the two. Assuming that there is a link between climate change and increased catastrophic weather events, then global warming is likely to pose a particularly severe risk to life across the urban, developing world.

Figure 2. Distribution of fatalities and economic loss from cyclones per year



Source: The International Federation of Red Cross and Red Crescent Societies

Climate change and developing countries

In our third essay, **Dr Swenja Surminski** of the Grantham Research Institute (LSE) reflects on climate change and extreme weather events across lesser developed countries. She argues that these countries are most at risk from climate change – not just because of a lack of basic infrastructure and reliance on agriculture – but also because of many developing countries being located in hot tropical and subtropical environments. Like Beddington, she expects climate change in some parts of the developing world to exacerbate socioeconomic risk drivers such as poverty.

In assessing how governments can respond to the problem of climate change, Surminski asserts that aid is not always effective. Indeed she notes that there is often a 'moral hazard' at play – reliance on this form of assistance can sometimes deter governments from undertaking their own risk prevention activities due to the expectation of post disaster relief.

In place of aid, Surminski focuses on the role that insurance can play in helping to adapt to the risks of climate change. Surminski argues that when properly designed "risk transfer can play a cost effective role in a country's efforts to increase its resilience, especially when compared to post disaster aid". Unfortunately, however, according to Surminski, few risk transfer schemes – including micro insurance in parts of Asia – have explicitly taken account of the impact of climate change on risk levels. She believes that this will need to be addressed to avoid mal-adaptation in the future.

Climate change and megacities

How climate change interacts with urban infrastructure will also be crucial to understanding its global impact. In our penultimate essay, **Professor Lord Julian Hunt** of University College London and **Dr Yulia Timoshkina,** Honorary Research Fellow at UCL argue that there are many reasons to focus on cities; at least 60 per cent of the world's population will live in cities by the end of this century, cities will drive global energy demand and their ever increasing size will significantly contribute to climate change whilst remaining prone to serious natural hazards of their own.

Lord Hunt and Dr Timoshkina's core proposition is that the increasing scale of cities affects the "operational, social and economic capacities to deal" with severe natural hazards linked to global warming. Hunt and Timoshkina argue that in rapidly growing cities, infrastructure systems lack resilience to natural hazards. With global warming likely to increase the prevalence of large scale, long lasting catastrophes, this is a particularly serious problem. If infrastructure is inadequate to withstand a disaster and citizens are not warned well in advance of an event, then lives will be put at risk. In such circumstances it may ultimately become necessary for populations to abandon some cities altogether.

Thankfully such a scenario is generally avoidable and the authors set out specific ways to improve the ability of cities to adapt to climate change. Measures include; better communications systems to forewarn endangered areas, greater investment in methods of evacuation and technical improvements in the design of shelters. And perhaps most importantly of all, Hunt and Timoshkina stress the need for community buy-in to whatever planning processes are put in place to make cities safer.

The role of insurance

In the last essay within this special report, **Professor David Crichton**, Honorary Visiting Professor at the AON Benfield Hazard Research Centre at UCL, also considers adaptation to climate risk with particular emphasis on the role of the insurance industry across Europe. He notes how increased flooding could have a major impact on property and society with particular emphasis on the most vulnerable – such as those with disability problems or dependent on medication making evacuation from disaster stricken areas difficult. Insurance can help by 1) responding to claims costs by adjusting premiums, 2) anticipating natural hazards through scientific modelling and 3) managing adaptation efforts through lobbying, educating and assisting authorities in improving climate change risk management.

Crichton argues that to be successful in the future, insurance companies need to be more active on the second and third types of adaptation. Measures could include, for example, greater industry engagement in land use planning and economic incentives such as insurance discounts for sustainable flood management. He notes examples in Germany and Switzerland of natural flood management techniques such as introducing forestry to reduce rain fall off. And perhaps one of Crichton's most compelling messages is about building in flood plains – which still takes place in England and Turkey and which has the potential to significantly increase risk to life and local business.

In short then, our expert authors identify a number of significant and interrelated risks associated with energy and climate change, which could have substantial implications for the health and wellbeing of people across the world. All of our authors highlight the importance of taking action now in order to improve our ability to both reduce the extent of global warming and to take measures to adapt our buildings and industries so that they are more resilient to some of its consequences. Action must not be deferred – what policymakers and business leaders do now will have important implications for our long-term future. In later chapters we will use this expert analysis to form the basis for some future environmental scenarios and how they might impact upon the insurance industry.

4. Future environmental risks: what the experts say

Energy and climate change – looking at future trends and risks

Dr Fatih Birol, Chief Economist and Director, Office of the Chief Economist, International Energy Agency, Paris, France

The world is perfectly on track for an unsustainable energy future and there are few signs that the urgently needed change in direction is underway. But, if energy is what really makes the world go round, why are things heading in the wrong direction? In 2011, events such as those at the Fukushima Daiichi nuclear power plant and the turmoil in parts of the Middle East and North Africa (MENA) cast doubts on the reliability of energy supply, while concerns about sovereign financial integrity have shifted the focus of government attention away from energy policy and limited their means of policy intervention, boding ill for agreed global climate change objectives. But they have not changed the one thing of which we can be certain: growing population and prosperity will, in the longer term, continue to push up the world's energy needs. What is less certain is how will those needs be met and what the consequences of our energy choices will be. The energy industry's ability to provide clean, affordable and secure energy to growing populations and economies is always complicated by the interplay of a number of different factors, most of which are hard to predict accurately. But today, the industry is facing a period of unprecedented uncertainty – over the economic outlook, over future policy direction – which is complicating investment decisions. The critical challenge is to meet the expected increase in demand in ways that are reliable, affordable and that do not compromise the environment that we leave for future generations.

> *"the one thing of which we can be certain: growing population and prosperity will, in the longer term, continue to push up the world's energy needs."*

Global energy trends

The International Energy Agency's (IEA) flagship publication the World Energy Outlook[5] provides a quantitative look at the risks and opportunities facing the global energy economy out to 2035. One of the key conclusions is that how we produce and use energy in the decades to come depends crucially on actions taken by governments around the world, the policy frameworks they put in place, and how the energy industry and energy consumers respond.

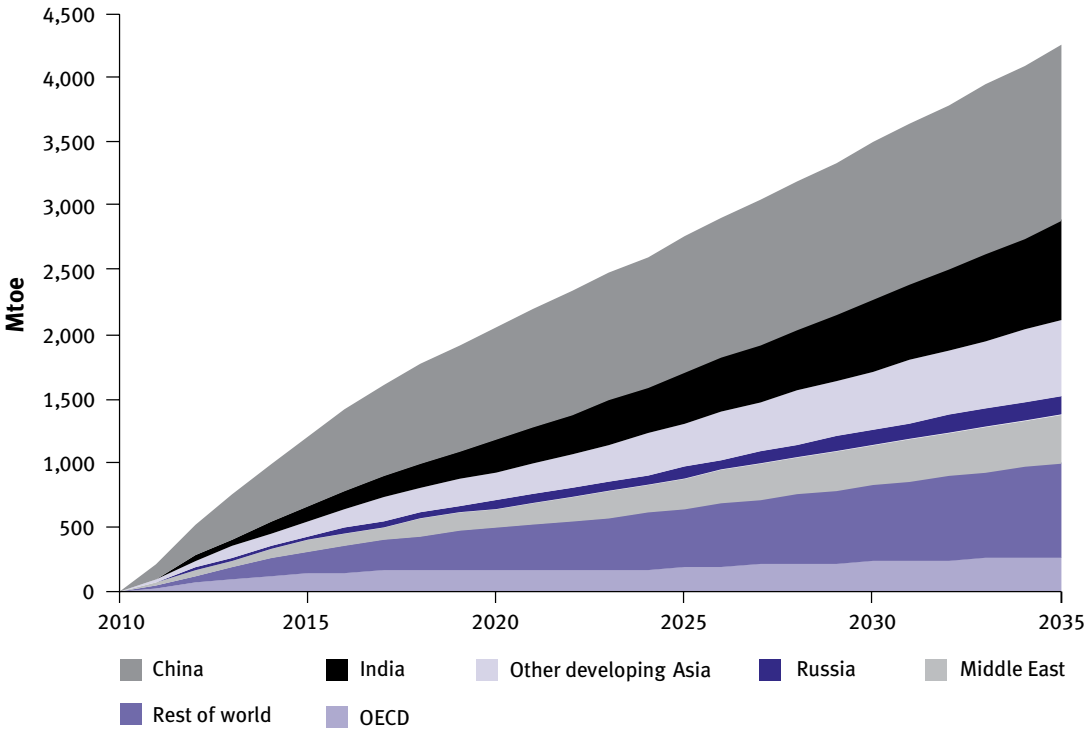
In the World Energy Outlook's central scenario (the New Policies Scenario), world primary energy demand is projected to increase by 40 per cent between 2009 and 2035. Although overall demand for energy is set to keep on rising, there are major differences in trends by region and by fuel type. In 2009, China overtook the United States to become the world's largest energy consumer – a historic re-ordering of the global energy hierarchy. Looking forward, the emerging economies will continue to be the primary drivers of growth in global energy demand. Over the next two and a half decades, countries outside of the OECD[6] are expected to account for 90 per cent of global population growth, 70 per cent of the increase in economic output and 90 per cent of the growth in energy demand. China and India alone are projected to account for around half the growth in global energy demand (see Figure 3). The dynamics of energy markets will, therefore, increasingly be determined by decisions taken in Beijing and New Delhi. By contrast, demand for energy scarcely grows in the countries of the OECD, with coal and oil demand projected to decline over the period.

5 The International Energy Agency's *World Energy Outlook 2011* was published on 9 November 2011. See the website www.worldenergyoutlook.org for more details

6 Organisation for Economic Co-operation and Development

"Over the next two and a half decades, countries outside of the OECD[7] are expected to account for 90 per cent of global population growth, 70 per cent of the increase in economic output and 90 per cent of the growth in energy demand."

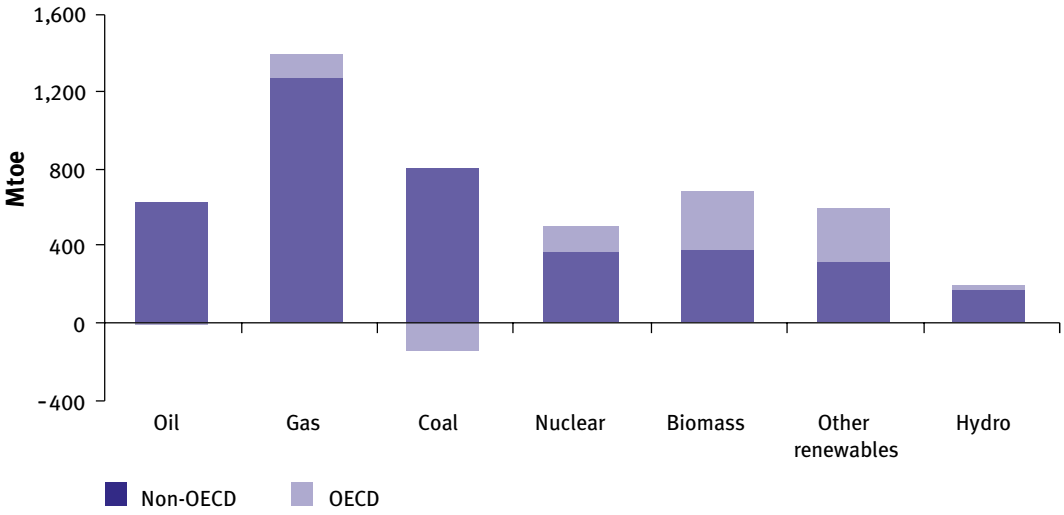
Figure 3. Growth in primary energy demand by region in the New Policies Scenario
(million tonnes of oil equivalent)



The age of fossil fuels is far from over, but their dominance declines. Fossil fuels – oil, coal and natural gas – are projected to remain the dominant sources of energy in 2035, despite a fall in their share of total energy demand from 81 per cent to 75 per cent. Of those fuels, demand for natural gas grows at the fastest rate (see Figure 4). Oil demand grows more slowly, reaching 99 million barrels per day (mb/d) by 2035. Of all the energy sources, the use of modern non-hydro renewables (excluding biomass) grows most rapidly compared to today, by almost 8 per cent per year, more than quadrupling its share of total energy use from less than 1 per cent today to more than 4 per cent by 2035. In the power sector, renewable energy technologies, led by hydropower and wind, account for half of the new capacity installed globally to meet increasing demand.

7 Organisation for Economic Co-operation and Development

Figure 4. Growth in world energy supply by fuel and region in the New Policies Scenario, 2009–2035
(million tonnes of oil equivalent)



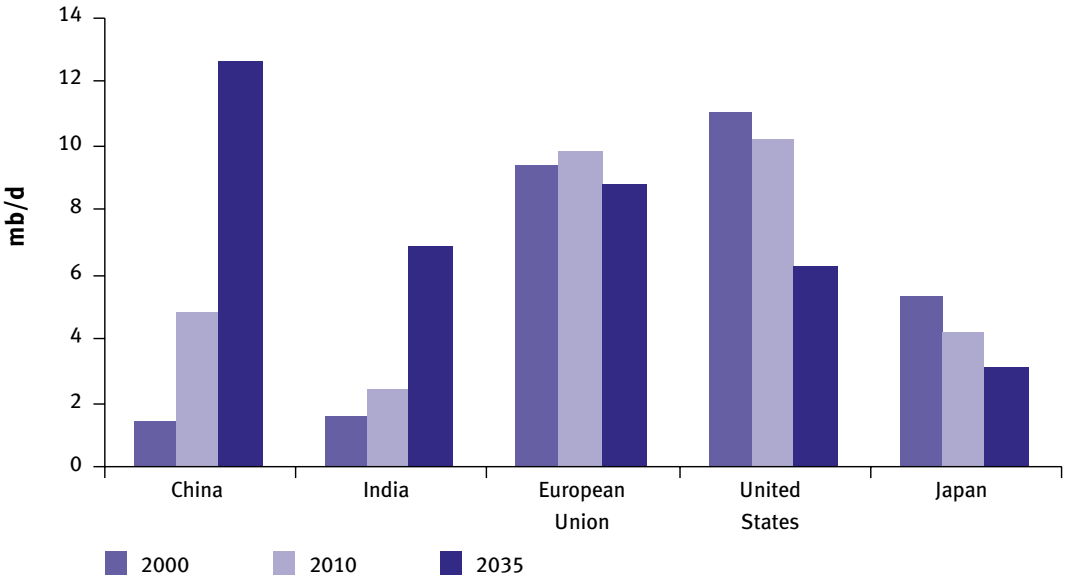
Ever-increasing demand for mobility will drive oil markets. Rising incomes in China, India and other non-OECD countries will result in the ownership of vehicles soaring – we expect the global passenger vehicle fleet to double to 1.7 billion by 2035. Thankfully, doubling the vehicle fleet does not mean an equivalent rise in oil demand because the increase is moderated by improved fuel economy, a gradual rise in alternative fuel vehicles powered by electricity or natural gas, and increased use of biofuels. But as long as there are only limited possibilities to substitute for oil as a transportation fuel, this relentless rise in demand for mobility will continue to be a major factor underpinning global oil markets.

> *"Rising incomes in China, India and other non-OECD countries will result in the ownership of vehicles soaring – we expect the global passenger vehicle fleet to double to 1.7 billion by 2035."*

Looking at the supply side, the cost of bringing oil to market is expected to rise as oil companies are forced to turn to more difficult and costly sources to replace lost capacity and meet rising demand. New sources of oil are coming from the deep offshore, or the 'light tight oil' that is now being developed in the United States, because of advanced drilling techniques and hydraulic fracturing. These technologies also bring new risks – in particular environmental risks – that the industry has to address. But the world still relies on the Middle East and North Africa for the bulk of its additional supply – the expected growth in output from this region to 2035 is equal to 90 per cent of the growth in global oil demand. The supply picture is therefore vulnerable to any shortfall in investment in this region.

While the critical nature of the Middle East and North Africa region for oil supply will continue, the focus in terms of global demand for oil imports will change. The United States is currently the largest oil-importing country in the world. But, a combination of increased transport efficiency and increased domestic oil supply promise a drastic reduction in the United States' oil imports (see Figure 5). By 2015, oil imports to the European Union are projected to surpass those to the United States, and by around 2020 China becomes the largest single oil importing country. The European Union is already the largest importer of natural gas in the world and gas imports to China and other fast-growing Asian economies are also rising rapidly. These changing patterns of global trade imply shifting concerns about the cost of imports and about oil and gas security, and a further sea-change in the geopolitics of energy.

Figure 5. Net imports of oil in selected countries in the New Policies Scenario (million barrels per day)



There are good reasons both on the demand and the supply sides to foresee a bright future, even a golden age, for natural gas. We expect that global demand for natural gas is set to catch up with that of coal by 2035, with most of the additional demand coming from countries outside the OECD, notably China, India and countries across the Middle East. Natural gas is a particularly attractive fuel for countries that are seeking to satisfy rapid energy demand growth in fast-growing cities. On the supply side, unconventional gas now accounts for half of the estimated resource base and it is more widely dispersed geographically than conventional resources, a fact that has positive implications for energy security. Unconventional production is expected to rise to account for one-fifth of total output by 2035, although the pace of unconventional development varies considerably by region with the United States, China and Australia taking the lead. Natural gas is the cleanest of the fossil fuels and so can play an important role in the transition to a low-carbon energy future. However, increased use of gas in itself (without carbon capture and storage) does not provide the answer to the challenge of climate change.

> *"Natural gas is a particularly attractive fuel for countries that are seeking to satisfy rapid energy demand growth in fast-growing cities."*

Coal was the big winner of the energy race over the last decade, but the future is less certain. Coal accounted for nearly half of the increase in global energy use over the last decade, with the bulk of this increase meeting demand for electricity in emerging economies. The international coal market is very sensitive to developments in China, which accounts for almost half of global production and demand, and increasingly also to India, which is expected to overtake the United States as the world's second-largest coal consumer in the 2020s. Widespread deployment of more efficient coal fired power plants and carbon capture and storage (CCS) technology could boost the long-term prospects for coal, but there are still considerable hurdles.

An expansion of nuclear power post-Fukushima is still on the cards as there has been no change of policy in the key countries driving the expansion of the nuclear industry, such as China, India, Russia and Korea. What is more, renewables are set to come of age, underpinned by continued government subsidies. The subsidy cost per unit of renewable energy declines as costs are reduced and in some cases renewable technologies becoming competitive without support. But in most cases, renewable energy requires continued subsidies: the global cost of subsidies is expected to rise from $66 billion in 2010 to $250 billion by 2035 as supply grows from renewable sources. This delivers lasting benefits, such as a more diverse electricity mix and a reduction in emissions of greenhouse gases. The European Union and China are expected to take the lead in pushing the introduction of green technologies.

> *"Global investment in energy supply infrastructure of $38 trillion is required over the period to 2035, and almost two-thirds of the total is in countries outside of the OECD."*

Global investment in energy supply infrastructure of $38 trillion is required over the period to 2035, and almost two-thirds of the total is in countries outside of the OECD. Oil and gas collectively account for almost $20 trillion, as both the need for upstream investment and the associated cost rise in the medium- and long-term. The power sector claims most of the remainder, with over 40 per cent of this being for transmission and distribution networks.

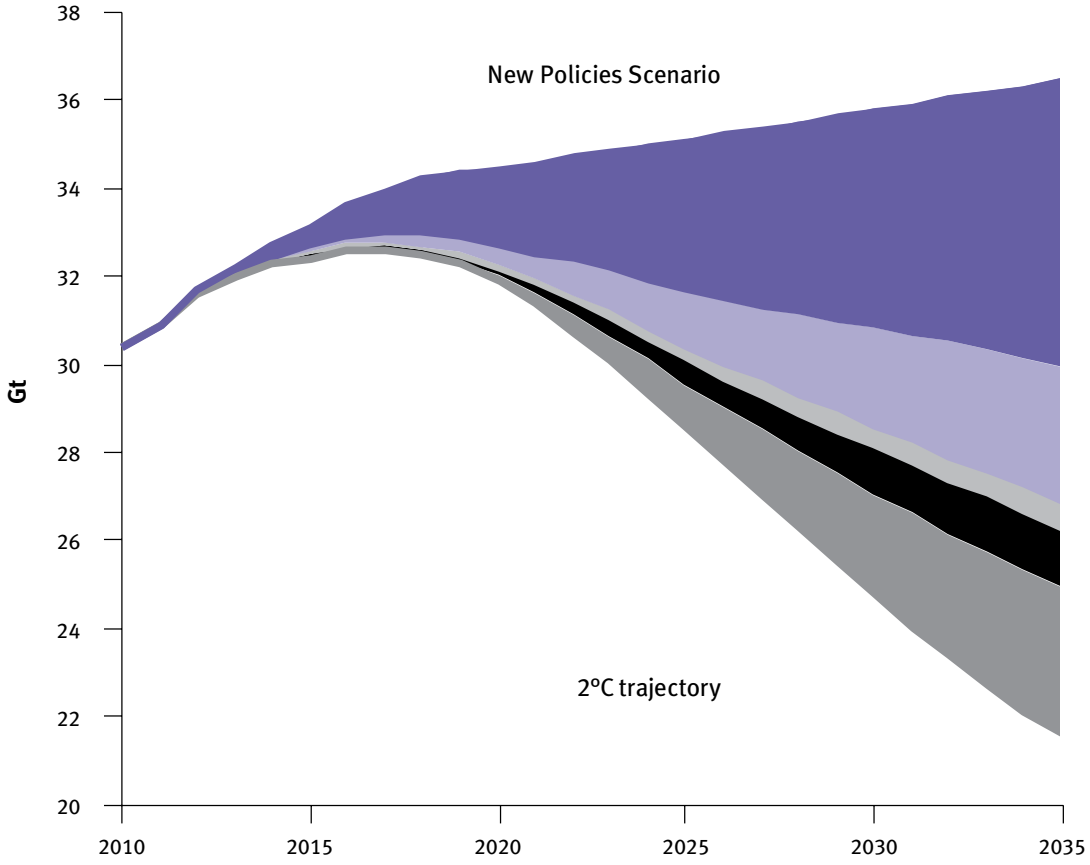
Global climate outlook

Overall, there is much more to be done to put the world on the path towards a more reliable and sustainable energy future. According to our analysis in the World Energy Outlook, the world is in real danger of missing the chance to reach its long-term target of limiting the global average temperature increase to 2 degrees Celsius. If stringent additional action is not forthcoming by 2017, then the world's existing capital stock – its power plants, buildings, factories and so on – will generate all of the CO_2 emissions permitted up to 2035 under a 2 degree Celsius scenario, leaving no room for additional power plants, factories and other infrastructure unless they are zero-carbon, which would be extremely costly.

> *"A much greater focus on energy efficiency is vital – a real transformation in the way that we produce and use energy. Green technologies, nuclear power and technologies such as carbon capture and storage all have important roles to play as well."*

The most important contribution to reaching global climate change objectives comes from the energy that we do not consume (see Figure 6). A much greater focus on energy efficiency is vital – a real transformation in the way that we produce and use energy. Green technologies, nuclear power and technologies such as carbon capture and storage all have important roles to play as well. If there is a substantial global shift away from nuclear power, or if carbon capture and storage technology is not widely deployed already in the 2020s, this would make it harder and more expensive to combat climate change and put an extraordinary burden on other low-carbon technologies to deliver lower emissions.

Figure 6: World energy-related CO_2 emissions in the 2 degrees Celsius climate scenario relative to the New Policies Scenario (gigatonnes)



	Abatement 2020	2035
Efficiency	72%	44%
Renewables	17%	21%
Biofuels	2%	4%
Nuclear	5%	9%
CCS	3%	22%
Total (Gt CO_2)	**2.5**	**14.8**

Note: The central scenario in World Energy Outlook 2011 is the New Policies Scenario. The 2°C trajectory scenario (called the 450 Scenario in the World Energy Outlook) works back from the international goal of limiting the long-term increase in the mean global temperature to 2°C above pre-industrial levels, in order to trace a plausible pathway to this goal.

Risks to the global energy economy

So what does this analysis tell us? In short, it says that, despite the prospect of greater reliance on low-carbon energy sources and more efficient energy using technologies, the pace of change that is implied by our central scenario will not be anywhere near fast enough to alleviate threats to our global energy security and to avert irreversible climate change. Short-term economic and geopolitical risks are not expected to change the long-term picture of increasing global demand for energy. Developing countries outside of the OECD are, and will continue to be, responsible for much of the change in the global energy landscape. Many oil- and gas-importing regions will see a significant increase in their import dependence, with a growing share of those imports coming from the Middle East and North Africa. Coal has played a much larger role in supporting the economic growth in developing countries than many people realise, and the extent to which this continues to be true in the future will be a critical question. Natural gas has a potentially golden future but key to its outlook is the need for governments and industry to be determined in their enforcement of best practice production of unconventional gas, so minimising the environmental risks. The climate trajectory of the central scenario is consistent with a long-term increase in the average global temperature of 3.5 degrees Celsius, rather than the 2 degrees Celsius targeted. Action to increase energy efficiency is the most important single step to tackling climate change, but not enough is being done. Alongside this, government support for renewable energy must be protected and expanded, even in the context of a challenging economic climate.

“Action to increase energy efficiency is the most important single step to tackling climate change, but not enough is being done. Alongside this, government support for renewable energy must be protected and expanded, even in the context of a challenging economic climate.”

It is therefore clear that policymakers and industry leaders must redouble their efforts to overcome the energy challenges that they share, tackling these risks and minimising the possibility that the next global crisis is an energy one. At the heart of policymaking will be the difficult task of balancing the sometimes conflicting goals of energy security, climate protection, energy access and economic competitiveness, while providing the energy industry with the long-term and stable framework that it needs to confidently move ahead with the huge investments that can transform our energy future.

Author's biography

Dr Fatih Birol is the Chief Economist and Director of the Office of the Chief Economist of the International Energy Agency. He oversees the annual World Energy Outlook which is the flagship publication of the IEA and is recognised as the most authoritative source for energy analysis and projections. He is also the founder and chair of the IEA Energy Business Council which brings together leaders of some of the world's largest energy companies and policymakers to seek solutions to global energy challenges.

Dr Birol has been named by Forbes Magazine as among the most powerful people in terms of influence on the world's energy scene. He is a member of the UN Secretary-General's 'High-level Group on Sustainable Energy for All' and the Chairman of the World Economic Forum's (Davos) Energy Advisory Board. Throughout his career, he has been awarded from many governments and institutions for his outstanding contribution to the profession.

Climate Change: implications for the UK and the rest of the world

Professor Sir John Beddington, Government's Chief Scientific Adviser

Scientific evidence suggests that our climate is changing, mainly as a result of human activity. Over the course of the last century global average temperature increased by 0.74ºC.[8] Each of the last three decades has, on average, been warmer than the preceding one, and each has set a new and statistically significant record; with the 2000s the warmest decade of all.[9] Continuing this warming trend has profound implications for our societies and economies.

Greenhouse gases trap the energy we receive from the Sun and re-radiate it back to earth, warming our atmosphere. This natural greenhouse effect keeps the earth's atmosphere warm enough to sustain life, but the higher the concentration of greenhouse gases in the atmosphere, the more energy is trapped and the more our atmosphere warms. Since the industrial revolution, through the burning of fossil fuels, agricultural practices and land use changes, the levels of greenhouse gases in the earth's atmosphere have risen. Ice core records show atmospheric concentrations of carbon dioxide (CO_2) are at their highest level for 800,000 years[10] and the rate of emissions continues; with 2011 seeing a record rise in global CO_2 emissions from fossil fuel combustion.[11] How much our climate changes in the future depends on whether this rate of emissions can be constrained and reversed.

We are already committed to a certain amount of climate change: Even if global greenhouse gas emissions were to dramatically reduce tomorrow the warming trend will continue for several decades as the climate system slowly responds to past and current emissions. How severe the changes to our climate are over longer timescales depends on how effectively mitigation action is taken by the global community.

> *"Even if global greenhouse gas emissions were to dramatically reduce tomorrow the warming trend will continue for several decades as the climate system slowly responds to past and current emissions."*

Scenarios describing potential global emissions trajectories for different economic, demographic and technological futures are widely used in assessments of possible future climate change.[12] Climate projections for a range of scenarios tends to show broadly consistent levels of warming out to the middle of this century between scenarios in which emissions are constrained and those in which they are not, due to the dominant role of past emissions. Around the middle of the century warming trajectories start to diverge: Scenarios in which emissions are constrained show a slowing down and gradual levelling off of global warming, whereas high emissions trajectories show the mean annual global temperature continuing to increase, well beyond 2ºC of warming.

Like any assessment of the future, projections of the future impacts of climate change will always be uncertain to some degree. This is in part due to uncertainty over the level of future greenhouse gas emissions, but also limitations to our scientific understanding of some aspects of climate change, and to the extent to which we are able to represent a system as complex as the climate system in climate models. This uncertainty over the future is not something which should paralyse decision-making. The uncertainty is not **whether** the world will experience climate change but **how** its impacts will be felt, and a world which has warmed by more than 2ºC is likely to experience some very significant impacts.

8 Trenberth, K. E., Jones, P. D., Ambenje, P., Bojariu, R., Easterling, D., Klein Tank, A., Parker, D., Rahimzadeh, F., Renwick, J. A., Rusticucci, M., Soden, B. & Zhai, P. (2007) Observations: Surface and Atmospheric Climate Change In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press

9 Arndt, D. S., Baringer, M. O. and Johnson, M. R. Eds. (2010) State of the Climate in 2009. Bull. Amer.Meteor. Soc., **91** (7), S1–S224

10 Luthi, D. et al (2008) High-resolution carbon dioxide record 650,000 – 800,000 before present Nature **453**: 379-382

11 International Energy Agency (2012) http://www.iea.org/newsroomandevents/news/2012/may/name,27216,en.html [last accessed 06/05/12]

12 Such as those from the IPCC's Special Report on Emissions Scenarios (SRES)

> *The uncertainty is not whether the world will experience climate change but how its impacts will be felt, and a world which has warmed by more than 2°C is likely to experience some very significant impacts.*

There is wide acceptance in the scientific community that there are also likely to be 'tipping points' in the climate system which, if crossed, could result in long-term or irreversible changes to our climate. The warmer our climate gets, the greater the likelihood of passing a 'tipping point'; be it accelerated (and/or irreversible) melting of the Greenland or West Antarctic Ice Sheets, which could significantly increase sea levels, or changes to large-scale atmospheric and oceanic circulatory systems, such as the Gulf Stream, which could potentially fundamentally alter regional climates.

The Copenhagen Accord[13] recognises a need to keep global average temperature increase to within 2°C compared to pre-industrial temperatures, with the aim of avoiding the most serious impacts of climate change. Scientific analysis shows a gap between the emissions reductions pledged by 2020 under the Accord and the global emissions cuts needed to stay within 2°C warming. This gap, and the need for greater ambition, was recognised at the most recent United Nations Framework Convention (UNFCCC) conference negotiations in Durban.

Even in the currently rather unlikely scenario that international actions lead to a world which has only warmed by 2°C we can expect a range of impacts, many of which will be negative. Rising temperatures will affect weather and precipitation patterns, sea level will rise, heatwaves will increase, and there is the potential for an increase in extreme events, such as droughts, flooding and storm surges. These impacts will not be geographically uniform; different regions will be affected in different ways. Climate models show, for example, the potential for enhanced levels of precipitation in some areas of the world, whereas others are more likely to experience a reduction in precipitation. These kinds of changes have serious implications, both direct implications for local populations and livelihoods, but also indirect implications for populations in other regions, given the highly globalised world we live in.

> *Rising temperatures will affect weather and precipitation patterns, sea level will rise, heatwaves will increase, and there is the potential for an increase in extreme events, such as droughts, flooding and storm surges.*

While scientists have high levels of confidence in some of the large scale impacts of climate change, it is more difficult to assess the impacts at regional and local levels. Moreover, the level of severity of many impacts of climate change will depend on the context in which they occur and the capacity of those affected to adapt. Making decisions in the absence of certainty requires us to assess the range of potential outcomes and options. Even when there is significant uncertainty there can still be 'no regrets' actions which can be taken.

In January this year the Department for Environment, Food and Rural Affairs published the UK's first Climate Change Risk Assessment.[14] This ground-breaking analysis looks at risks posed by climate change across UK regions and sectors out to the end of this century; identifying key risks – in the absence of any action – to the increased chance of flooding; water scarcity; threats to wildlife, and; while warmer winters may reduce cold-related deaths, hotter summers are likely to increase health risks.

13 http://unfccc.int/documentation/documents/advanced_search/items/3594.php?rec=j&priref=600005735#beg [last accessed 09/02/12]
14 http://www.defra.gov.uk/environment/climate/government/risk-assessment/

For the majority of the risks identified the severity of impact increases with time in scenarios where emissions are not constrained. For example, annual damage to UK properties due to flooding from rivers and the sea currently totals around £1.3 billion. For England and Wales alone, the figure is projected to rise to between £2 billion and £12 billion above current levels by the 2080s in the absence of any adaptation.[15] The Climate Change Risk Assessment also suggests that there may be opportunities; for example, for businesses to make the most of potential services related to climate change adaptation. However, the net effect of climate change for the UK is thought to be negative, if no action is taken.

> *"climate change, while a discrete challenge, is likely to act as a 'risk multiplier', interacting with other trends, exacerbating existing tensions and insecurity, and making it even more difficult to address poverty, disease, food and water insecurity."*

To augment the evidence base for the Climate Change Risk Assessment a Foresight study[16] looked at the indirect risks to the UK as a result of climate change impacts overseas. This study concluded that climate change, while a discrete challenge, is likely to act as a 'risk multiplier', interacting with other trends, exacerbating existing tensions and insecurity, and making it even more difficult to address poverty, disease, food and water insecurity.

Even without climate change the earth's resources are already stretched. Seven billion people currently inhabit our planet and this figure is set to grow to 8 billion by 2025 and 9 billion by 2050.[17] With this growing population comes growing demand for food, water and energy. Around one in five people globally still have no access to electricity[18] and areas of the world are experiencing food and water insecurity: almost one billion still suffer from hunger (and another billion suffer from 'hidden hunger'; long-term deficiencies of key micronutrients) and 1.2 billion live under conditions of physical water scarcity in river basins where water resources development has exceeded sustainable limits.[19]

Over the next few decades it is highly likely that the world will continue to experience rapid population growth, significant demographic shifts, increased globalisation, greater global inequality, resource scarcity (including water insecurity) and shifts in economic power. Areas of the world currently optimised for 20th Century climatic conditions will need to adapt to the challenges that a new climate will bring, while meeting the demands of a growing population.

> *"Areas of the world currently optimised for 20th Century climatic conditions will need to adapt to the challenges that a new climate will bring, while meeting the demands of a growing population."*

The substantial uncertainty and complexity that arises in assessing the physical effects of future climate change also applies to any consideration of the political, security, economic, and social impacts, and the interactions of the latter with wider global drivers of change. Impacts are contextual and are likely to differ across sectors, regions, countries and populations.

15 http://www.defra.gov.uk/environment/climate/government/risk-assessment/ [Evidence report, page x]

16 Foresight International Dimensions of Climate Change (2011) Final Project Report, Government Office for Science, London Available at: http://www.bis.gov.uk/foresight/our-work/projects/published-projects/international-dimensions-of-climate-change [last accessed 09/02/12]

17 UN Department of Economic and Social Affairs (DESA) Population Division (2011) World Population Prospects The 2010 Revision: Highlights and Advance Tables, United Nations, New York Available at: http://esa.un.org/wpp/Documentation/pdf/WPP2010_Highlights.pdf [last accessed 10/02/12]

18 World Energy Outlook 2011 Executive Summary, International Energy Agency Available at: http://www.iea.org/weo/docs/weo2011/executive_summary.pdf [last accessed 09/02/12]

19 United Nations (2008) The Millennium Development Goals Report 2008, United Nations, New York Available at:http://www.un.org/millenniumgoals/pdf/The%20Millennium%20Development%20Goals%20Report%202008.pdf [last accessed 10/02/12]

The Foresight International Dimensions of Climate Change study identified a range of risks to the UK from climate change impacts overseas. These include potential disruption to vital infrastructure serving global markets, due to the increasing risk of flooding and other extreme weather events to, for example, communications networks and data centres; disruption to global agricultural and food production and disruption to supply chains, through impacts on infrastructure and transport networks and the extraction of vital raw materials. Short supply of resources and increases in commodity prices driven by climate change could lead to more protectionist trade measures. Because many global infrastructure networks are interdependent there is also a risk of 'cascade failure' where damage to one network has negative implications for others (for example, transportation is heavily reliant upon communications infrastructure, which is itself reliant on power networks).[20]

> *"Climate change impacts could exacerbate tensions driven by issues such as food, water and energy shortages, demographics and poor health."*

In the most vulnerable areas of the world, governance at the state level is already overstretched, and there will be a limited capacity to adapt to climate change. Climate change impacts could exacerbate tensions driven by issues such as food, water and energy shortages, demographics and poor health; and where there is limited resilience or capacity to respond there is the potential for heightened regional tensions and wider effects on international security and stability.[21]

Population growth, economic growth and urbanisation are likely to increase the level of human and economic exposure. For example, over half a billion people live in low elevation coastal zones, areas at particular risk from rising sea levels and flooding, and which also contain significant economic assets and activities (for example, 35 per cent of the world's oil refineries, 11 per cent of airports and all seaborne trade).[22]

Alongside the potential negative impacts, for more moderate levels of climate change at least, there are also potential benefits. For example, some crop types are able to benefit physiologically from higher temperatures and atmospheric concentrations of CO_2 in the atmosphere (but this will only occur if plant growth is not limited by other factors, including water and nutrient availability).[23] Other potential benefits, strongly influenced by location and existing conditions, include the expansion of areas suitable for crop production, longer growing seasons, and, for some regions, potential increases in rainfall.[24]

By the second half of the century, however, without effective mitigation action, more extreme warming is expected to have an overwhelmingly negative impact globally, through changes in precipitation patterns, more frequent droughts, increased stress in crop, animal and fish production systems in response to extremes in temperature, and the reduced reliability of water availability in some regions.[25]

It is vital for policymakers, in industry as well as Government, to develop strategies to mitigate the risks posed by climate change, to plan for unavoidable consequences, and to understand better how such consequences may increase other pressures. In many cases, action taken now, or in the near future, will address future problems for significantly less resource than action at a later date, often by simply accounting for climate change when considering the legacy of new development.

20 Foresight International Dimensions of Climate Change (2011) Final Project Report, Government Office for Science, London

21 ibid

22 ibid

23 Foresight International Dimensions of Climate Change (2011) Physical Resources and Commodities and Climate Change, Government Office for Science, London Available at: http://www.bis.gov.uk/foresight/our-work/projects/published-projects/international-dimensions-of-climate-change/reports-and-publications [last accessed 14/02/12]

24 ibid

25 ibid

> *In many cases, action taken now, or in the near future, will address future problems for significantly less resource than action at a later date, often by simply accounting for climate change when considering the legacy of new development.*

That climate change is taking place, and projected to continue for at least several decades even with ambitious efforts to reduce emissions, is well supported by the evidence. Uncertainties in specific areas of climate science, along with the inherent uncertainty of considering the future over several decades, particularly beyond mid-century, do not diminish the need to take action now. Rather, they imply the need to develop plans and policies which are resilient to future uncertainties by taking a risk-based approach.

There are also obvious business opportunities which may be generated because of the need to reduce emissions or adapt to climate change. UK business has significant strengths which could help other countries to mitigate and adapt to climate change. They include low-carbon technologies, coastal engineering, finance and insurance expertise, and climate and weather science. There will be growing demand for these skills as the world adapts to climate change.

Business and financial services are key sectors of the UK economy and significant financial investment will be needed for effective climate change mitigation and adaptation. Investment opportunities include a wide range of green technologies, particularly in the energy sector, such as wind power, and carbon capture and storage. HSBC, in a 2010 report, considered four scenarios of future low carbon market growth based on policy implementations, with its most likely scenario estimating a $2.2 trillion global low carbon market by 2020.[26]

Mitigating against the most severe impacts of climate change, and building resilience to those impacts which are unavoidable, are significant challenges. We must look to science and engineering to deliver the fundamental changes that climate policy demands. The decarbonisation of our energy sector is probably one of the greatest technological challenges of the twenty-first century, bringing with it real opportunities for UK prosperity and global sustainable growth. Our success in achieving change must also be based on individual behaviour and societal acceptance – understanding the interplay between these factors and new technology will be important to climate policy delivery in a number of areas.

Author's biography

Sir John Beddington was appointed as Government Chief Scientific Adviser (GCSA) on 1 January 2008. Since being in post, the GCSA has led on providing scientific advice to Government during the 2009 swine flu outbreak, the 2010 volcanic ash incident, and the emergency at the Fukushima nuclear power plant in 2011. Throughout 2008 and 2009 Sir John raised the concept of the "Perfect Storm" of food, energy and water security in the context of climate change, raising this as a priority in the UK and internationally. Prior to his appointment as GCSA, he was Professor of Applied Population Biology and headed the main departments of environmental science and technology at Imperial College. In June 2010 he was awarded a knighthood in the Queen's Birthday Honours.

26 HSBC (2010) Sizing the climate economy Available at: http://www.research.hsbc.com/midas/Res/RDV?ao=20&key=wU4BbdyRmz&n=276049.PDF [last accessed 09/02/12]

Climate change and extreme weather events in developing countries

Dr Swenja Surminski (Centre for Climate Change Economics and Policy/Grantham Research Institute, London School of Economics, London, UK)

Introduction

Fatalities and injuries, property damage, economic and social disruption – the impact of extreme weather events can be widespread and long-lasting. In addition to direct local consequences there can be disruption on a global scale, through our ever-growing connectedness, affecting travel, trade, supply-chains and communication, in some cases even geopolitical stability. 2011 provided plenty of evidence – severe droughts in East Africa, floods in Australia and Thailand, landslide and flash floods in Brazil and Italy, just to name a few. And the costs appear to be rising, reaching an estimated $US 150bn in 2010, the fifth-highest level since 1980.[27]

There is broad agreement amongst experts that the observed global trend in rising losses from extreme weather events is mainly caused by wealth and population increases, i.e. more assets and people located in harm's way.

But over the coming few decades, climate change is also expected to alter the global landscape of natural catastrophe risk. The scale and speed of the changes is deeply uncertain, due to the complex interplay between human induced climatic changes, natural climate variability and socio-economic factors such as population trends and economic development. Some regions could see increases in weather-related extreme events and others declines.

Climate science has become more visible and important, but the challenge of communicating latest findings on climate change remains complex. Society looks for evidence and guidance, but often the science predictions are less than clear, with a large degree of uncertainty attached to the findings. This can lead to inaction – for fear of getting it wrong. Or it can lead to denial – with so-called climate sceptics arguing that not having complete certainty implies not knowing anything. But scientific evidence suggests that both inaction and denial now would leave future generations with huge economic costs and potentially irreversible and catastrophic consequences.

> *"The challenge of climate change will not be resolved simply by waiting for better climate data and new models – the uncertainty attached to both scientific findings and socio-economic trends needs to be properly communicated by scientists and accepted by decision makers."*

The challenge of climate change will not be resolved simply by waiting for better climate data and new models – the uncertainty attached to both scientific findings and socio-economic trends needs to be properly communicated by scientists and accepted by decision makers. This challenge applies to both the need to reduce emissions (mitigation) and to prepare for those climatic changes already in the system due to historic emissions (adaptation).

27 Munich Re: TOPICS GEO Natural catastrophes 2010, published in 2011

Communicating climate science and making it accessible to policy makers, businesses and the wider society is imperative. This becomes evident in the case of extreme weather events: Not considering potential impacts can lead to costly mal-adaptation, such as inadequate flood defence structures or insufficient building restrictions in coastal areas.

A particular challenge with regards to predicting the impact of climate change on natural disasters is that they are very rare, and therefore only limited data exists. This explains the limited confidence that scientists display when projecting potential future changes of climate extremes. In general terms scientific confidence levels about weather extremes are driven by a range of factors, such as the quantity and quality of data, the knowledge about complex underlying processes, the reliability of simulation models and also the type of hazard and the specific location or region investigated.[28] This explains why we may know more about some hazards and some areas and less about others.

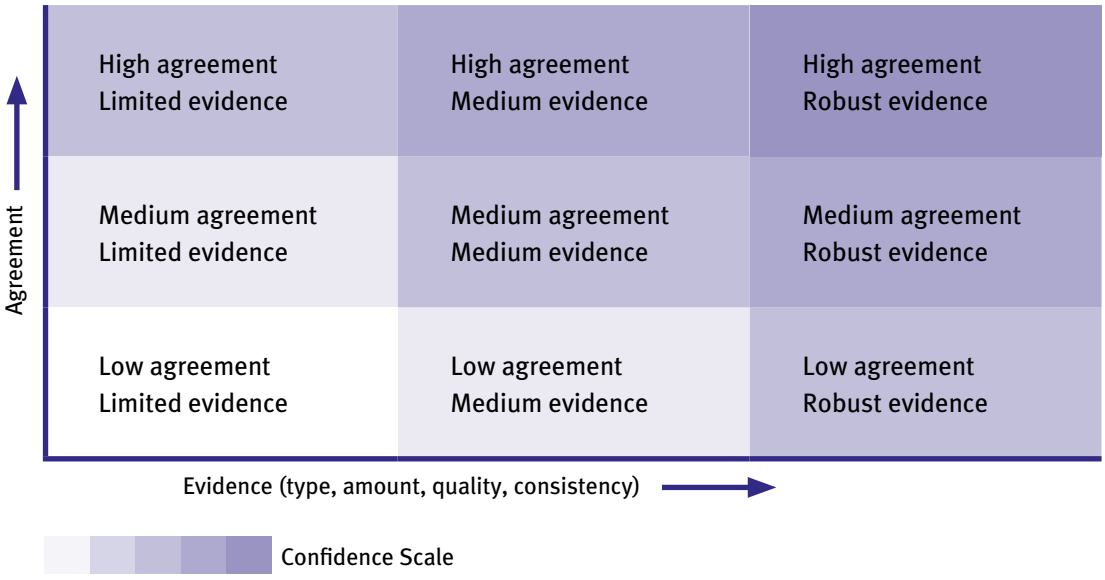
The IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation

The most recent effort to communicate science findings about extreme events and climate change is the International Panel on Climate Change (IPCC) Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.[29] The IPCC, the UN's scientific intergovernmental body set up to provide scientific assessments of the risk of climate change, tasked more than 200 leading scientists and experts from around the world to assess existing knowledge about the effects of climate change on extreme weather events. A summary of the report was launched in November 2011, and the full publication is expected for February 2012.

The report assesses the role of climate change in altering frequency and severity of extreme events and investigates risk management and resilience options. The findings are characterised by the confidence in their validity – expressed in an "uncertainty language", based on the evaluation of the underlying scientific evidence and agreement (from "low agreement/low evidence" to "high agreement/high confidence"), and on quantified measures of uncertainty expressed as probabilities (ranging from "virtually certain 99–100 per cent probability" to "exceptionally unlikely 0–1 per cent probability").

The confidence levels depend on the quality and quantity of the available data. It is, therefore, important to recognise that "low confidence" in a finding does not give the all-clear. It simply suggests that we do not know enough and that we could easily misjudge the potential impacts.

Figure 7: Evaluation of underlying scientific evidence: Confidence levels



28 IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, 2012

29 IPCC, 2011

The report describes as "virtually certain" a global increase in warm temperature extremes and a global decrease in cold extremes in the 21st century, with longer, more frequent and stronger heatwaves "very likely" for most land areas. Sea level rise contributing to rising extreme coastal high water levels is also "very likely". An increase in the frequency of heavy precipitation for many regions is "likely".

> *"The report describes as "virtually certain" a global increase in warm temperature extremes and a global decrease in cold extremes in the 21st century, with longer, more frequent and stronger heatwaves "very likely" for most land areas."*

For other extreme weather events the picture emerging is more complex: While an increase in the average maximum wind speed of typhoons and hurricanes is "likely", it is also "likely" that the number of these extreme tropical cyclones will decrease or stay unchanged.

The report assigns "medium confidence levels" to the intensification of droughts and explains the limited confidence by lack of observational data and the inability of models to recognise all factors contributing to droughts. Similarly, there is "low confidence" in global changes in magnitude and severity of river floods – with the report referring to limited evidence and complexity of changes at regional scale.

Where does this leave decision makers who are looking for guidance in terms of public policies, investment decisions or infrastructure planning?

There is clear evidence that we have to reduce greenhouse gas emissions and increase our climate resilience – but by how much and by when is less clear. New approaches to decision making under uncertainty are addressing this challenge – usually by focusing on measures and strategies that are deemed beneficial under different climatic scenarios ('low regrets' such as warning systems, education, and building regulation) and by allowing enough flexibility within a policy or an infrastructure plan to take into account changing evidence and adjusting protection levels. An example for this is the Thames Estuary 2100 plan, which has developed a flood protection strategy for London taking into account the potential impacts of climate change over the next 100 years.

> *"New approaches to decision making under uncertainty are addressing this challenge – usually by focusing on measures and strategies that are deemed beneficial under different climatic scenarios."*

Recognising the possible impact of climatic changes on the frequency and severity of the hazards is important. But it is of similar importance to recognise how this interplays with other risk drivers.

Population growth, uncoordinated urbanisation often in exposed costal locations, and environmental degradation alone are significant risk drivers, particularly in developing countries. Adding climate change to the equation creates an even more dramatic picture and underlines the urgency for action. The IPCC report reflects on this and provides an assessment of the current evidence on vulnerability and exposure trends and risk management. It states with "high confidence" that "the severity of the impacts of climate extremes depends strongly on the level of the exposure and vulnerability to these extremes".[30]

30 IPCC, 2011

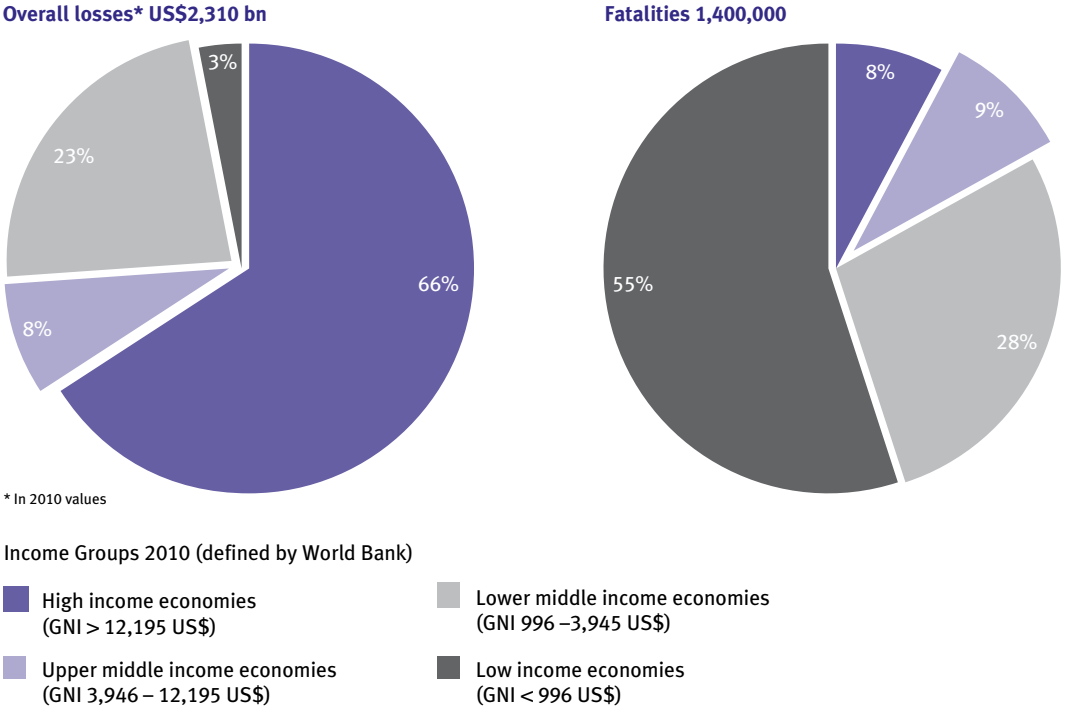
Developing countries most at risk

Developing countries are most at risk from changes in extreme events, due to a combination of factors such as geography – with many being located in already hot tropical and sub-tropical regions, sensitivity of the economies to weather because of the relative dominance of agriculture, and lack of resources to prepare for disasters and increase resilience levels.[31]

While total economic losses from natural disaster are higher in developed countries, the relative size of economic impacts (economic losses expressed as a proportion of Gross Domestic Product) and the number of fatalities are higher in developing countries. Estimates from the global reinsurer Munich Re show that between 1980 and 2010, weather catastrophes have caused almost 1,200,000 fatalities and led to direct damages amounting to US$610 billion in low and lower middle income countries (Figure 8). These disasters put at risk past development gains by damaging natural capital and infrastructure, undermining economic development and setting back poverty reduction efforts.[32]

> *"...between 1980 and 2010, weather catastrophes have caused almost 1,200,000 fatalities and led to direct damages amounting to US$610 billion in low and lower middle income countries."*

Figure 8[33]: Fatalities and overall losses from global weather catastrophes by World Bank (as of 2010) income group between 1980 and 2010.



Source: the Munich Re NatCatSERVICE database, April 2011)

31 Milner, A. and Dietz, S.: Adaptation to climate change and economic growth in developing countries, CCCEP Working Paper, 2011

32 World Bank 2009. World Development Report 2010: Development and Climate Change

33 Ranger, Surminski, Silver (2011): Open questions about how to address 'loss and damage' from climate change in the most vulnerable countries: a response to the Cancún Adaptation Framework. Policy Paper, Centre for Climate Change Economics and Policy Grantham Research Institute on Climate Change and the Environment, London. http://www.cccep.ac.uk/Publications/Policy/docs/PP_Cancun-Adaptation-Framework-response.pdf

Climate change is expected to undermine the resilience of poorer countries by exacerbating socio-economic risk drivers such as unplanned urbanisation, poverty and environmental degradation. Reductions in agricultural productivity, water scarcity and increasing incidence of disease already reduce the ability of developing countries to absorb disaster losses and recover after an extreme event.[34]

This is why a closer integration of disaster risk management and climate adaptation is so important. Disaster risk management is generally divided into ex-ante (before the occurrence of a disaster – such as warning systems, education, defence structures and insurance) and ex-post categories (applied after an event, such as disaster aid and reconstruction support). The key challenge with ex-post measures is that they do not prevent the impact, and are reactive. History shows that reliance on aid can create 'charity hazard' – where governments do not undertake risk prevention activities in the expectation that should a disaster occur they would receive aid payments.

> *"History shows that reliance on aid can create 'charity hazard' – where governments do not undertake risk prevention activities in the expectation that should a disaster occur they would receive aid payments."*

The IPCC report assesses existing approaches to managing extreme events. It states with 'high confidence' that effective disaster risk management is usually based on a portfolio of measures to reduce and transfer risk, informed by the specific local circumstances. These measures can also provide additional benefits, such as improving general human well-being and conserving biodiversity. The report also signals the opportunity of using 'post disaster recovery' for improving resilience levels, for example, by improved building techniques. But disaster risk management can also lead to long-term mal-adaptation and an increase in exposure, for example, by triggering development in exposed areas through the provision of defence measures, which may become unable to cope with climatic changes. The IPCC argues with 'high agreement, medium evidence' that adaptation and disaster risk reduction action are most effective when they "offer development benefits in the relatively near-term, as well as reductions in vulnerability over the longer-term."[35]

> *"...risk management can also lead to long-term mal-adaptation and an increase in exposure, for example, by triggering development in exposed areas through the provision of defence measures, which may become unable to cope."*

34 Warner, K., Ranger, N., Surminski, S., Arnold, M., Linnerooth-Bayer, J., Michel-Kerjan, E., Kovacs, P. and Herweijer, C. 2009a. Adaptation to Climate Change: Linking Disaster Risk Reduction and Insurance. A paper prepared for the United Nations International Strategy on Disaster Reduction (UNISDR). http://www.preventionweb.net/files/9654_linkingdrrinsurance.pdf

35 IPCC, 2011

A role for insurance?

Managing current and future risks is particularly challenging for developing countries, as they often lack resources and expertise. International efforts to respond to this challenge have intensified over the last few years. The United Nations Framework Convention on Climate Change (UNFCCC) has now recognised the importance of assisting vulnerable countries with the management of climate risks. The Cancùn Adaptation Framework, an outcome of the 16th session of the Conference of Parties to the UNFCCC, highlights the need to strengthen international cooperation and expertise to understand and reduce loss and damage associated with the adverse effects of climate change and a new work programme on 'Loss and Damage' has been initiated under the UNFCCC. This considers a wide range of adaptation and risk management measures. One particular focus of this work stream is the proposal to create a climate insurance facility to provide cover against extreme weather events. This constitutes a recognition that risk transfer is still in its infancy in most developing countries. Most developing countries experience very low insurance penetration rates due to a range of factors such as high transaction costs, lack of financial literacy and lack of access to affordable products in remote rural areas.[36]

While risk transfer is no 'magic solution' for all climate risks faced by developing countries, there is evidence that it can play a cost-effective role in a country's efforts to increase its resilience, especially when compared to ex-post disaster aid. If applied correctly, risk transfer has the potential to be an important part of a country's adaptation and economic development plan. This is also underlined by the IPCC report which states that "risk sharing and transfer mechanism at local, national, regional and global scales can increase resilience to climate extremes."[37] At the same time there is evidence that a poorly designed risk transfer can create moral hazard and reduce incentives for risk reduction.[38]

> *"...there is evidence that it can play a cost-effective role in a country's efforts to increase its resilience, especially when compared to ex-post disaster aid."*

The rising losses from extreme weather events pose a significant challenge to the insurance industry. In response, insurers have increased their efforts to understand current and future risk trends and work in partnership with other stakeholders to increase resilience levels.[39] There is growing literature on the implications that climate change can have on insurance and how the provision of insurance could support the fight against climate change. Some of these impacts are already observable, while others are predicted to occur in the future, with the scale dependent on location and type of insurance.

As insurance is still in its infancy in the developing world, less attention has been given to the role of risk transfer in supporting climate activities in those countries. But over the last decade more risk transfer schemes have been developed in poor countries, often run as pilot-projects between the private sector and public authorities.

36 H. Ibarra,/ J. Skees: Innovation in risk transfer for natural hazards impacting agriculture, Environmental Hazards 7 (2007) 62–69

37 IPCC 2011

38 Ranger, Surminski, Silver (2011)

39 Individual companies as well as sector initiatives such as Munich Climate Insurance Initiative MCII, ClimateWise and UNEPFI's Insurance Working Group, as well as industry organisations such as the Chartered Insurance Institute, the Geneva Association and national trade bodies, have started to publicly address this issue through statements, research and events

The recently published Compendium of Disaster Risk Transfer Initiatives in the Developing World[40] offers a snapshot of current risk transfer activities in low- and middle-income countries.[41] The Compendium documents 123 existing initiatives in middle-income and lower-income countries that involve the transfer of financial risk associated with the occurrence of natural hazards. There appears to be potential in many places and a growing recognition of the possible roles for risk transfer. Closer examination shows that the schemes are hugely diverse, often created to meet very specific needs in a particular community, with a wide range of stakeholders being involved, and differing levels of risk transfer being provided. While agricultural insurance is the most common form in all countries, a particular geographical preference for other types of insurance is noticeable – such as micro-insurance against natural disasters in Asia. This may reflect local tradition and possibly also cultural differences, while other factors, such as links to micro-finance schemes, may influence this.

> *"...risk transfer schemes that do not recognise future risks may even lead to mal-adaptation and may not achieve economic viability."*

Only one of the disaster risk transfer schemes captured in the Compendium appears to have explicitly taken into account the impact of climate change on risk levels. Not surprisingly, the large majority of risk transfer schemes focus on today's weather risks. This can capture a lot of experience and knowledge suitable for adaptation efforts, as resilience to today's weather is a step towards adaptation to a changing climate. But risk transfer schemes that do not recognise future risks may even lead to mal-adaptation and may not achieve economic viability.

Conclusion

Every extreme weather event reminds us of the importance of risk reduction and an increase in societal resilience. The IPCC report highlights the risks and challenges posed by climate change, but also indicates suitable options for risk management and resilience increase. Embracing scientific uncertainty is important, with decision makers relying on clear and transparent communication from scientists.

Low-income countries are particularly at risk, with extreme events posing significant threats to their endeavour to sustainable development. Expected impacts of climate change on the natural catastrophe landscape underline the urgency of action. Comprehensive risk reduction, aligned with climate adaptation measures can help developing countries manage the risks they face. Insurance risk transfer can be a useful component in this strategy, if correctly designed and implemented.

> *"Comprehensive risk reduction, aligned with climate adaptation measures can help developing countries manage the risks they face. Insurance risk transfer can be a useful component in this strategy, if correctly designed and implemented."*

The need to align disaster risk management and climate adaptation has been embraced by experts for some time, but progress on the ground is still limited and slow. The IPCC report should be a useful reminder not to wait for the next disaster to strike, but to take precautionary action.

40 ClimateWise (2011) "Compendium of Disaster Risk Transfer Initiatives in the Developing World"

41 Surminski & Oramas-Dorta: Building effective and sustainable risk transfer initiatives in low- and middle-income economies: what can we learn from existing insurance schemes? CCCEP Policy Paper, 2011

Author's biography

Swenja joined the Grantham Research Institute and the Centre for Climate Change Economics and Policy at the London School of Economics in September 2010. She works as a Senior Research Fellow on a range of topics including the role of insurance in climate adaptation and mitigation; linking adaptation and disaster risk reduction in developing countries; private sector adaptation; and the economics and governance of natural disaster management.

Prior to joining the LSE she spent 10 years working in the international insurance industry, as climate change adviser at the Association of British Insurers, for Marsh Risk Management division in London, and for the Geoscience Team at Munich Re in Munich. Swenja has been a member of a range of governmental and non-governmental steering groups and task forces, including the Management Committee of the ClimateWise initiative, the European Insurance Industry Climate Change Taskforce, and the London Climate Change Partnership Steering Group. She has been advising on climate change risks at UN, EU and UK level and is the author of several papers on these topics.

In 2010, Swenja founded an independent climate insurance consultancy, advising industry and policy makers.

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Growing challenges of megacities and climate change

Professor Lord Julian Hunt[1,2], Dr Yulia Timoshkina[1,2]

[1] University College London, University of Cambridge

[2] Advisory Committee on Protection of the Sea, Jan 2012

1. Introduction

Since the second UN Habitat Conference in 1996, scientists, engineers, planners and policymakers have begun to realise the importance of the interactions between cities and the wider global environment. The importance of urban regions in driving economic growth, and efficient use of energy and natural-resources has never been greater for several reasons: first, cities are popular: over half the world's population lives in cities, and every week one million people move to cities.

Second, the higher standard of living within cities leads to increasing demands for greater energy and resources per person, though there are wide variations, by a factor of five or more between the most energy efficient cities in Asia and the most inefficient ones in North America.

Third, ever larger cities have substantial environmental consequences; they are the main contributors to pollution and global climate change. As cities and clusters of cities, or conurbations, grow ever larger their energy use and pollution emissions increase approximately in proportion to the surface area. As a result, though cities take up only two per cent of the Earth's land mass, they are responsible for about 57 to 75 per cent of the heat-trapping greenhouse gases (GHG) that are released into our atmosphere. Cities also alter the adjoining rural environment, and the rivers and coasts that are so crucial to the livelihoods of many.

Fourth, cities are prone to serious risks. For example, in the USA, extreme winds have endangered the lives of those living in large cities where people cannot escape because of the size of the metropolis.

> *"...though cities take up only two per cent of the Earth's land mass, they are responsible for about 57 to 75 per cent of the heat-trapping greenhouse gases (GHG) that are released into our atmosphere."*

These trends demonstrate that the sustainable future of the planet will be determined in large cities. This paper outlines some specific challenges and practical policies to address them.

2. Climatic and Environmental Trends Affecting Urban Areas

The Intergovernmental Panel on Climate Change has recently reviewed how increasing extremes of high- and low-temperature, drought and flood are likely to have greater impacts with climate change, in different regions of the world. These impacts, especially in urban areas, will grow faster than most current plans allow for. The latest projections for climate change (for example by the International Energy Agency), based on likely estimates of expanding emissions of GHG by developed and developing countries, indicate that the future rise in average global temperature by the end of the century will lie between 3° and 4°C. There is a steady trend of rising surface temperature over land areas of the world, whereas the trend for the entire global land and sea surface fluctuates because of significant decadal variations of ocean surface temperatures. The global temperature rise will be significantly greater than the 2°C target, which is still considered to be the goal of international policy at UN climate conferences and by the UK Government.

Such a rise in temperature will cause an increase in the variability of weather and seasonal climate in certain parts of the world. For example, there are likely to be longer periods of extreme heat and cold, and stagnant weather conditions which can effectively close down large areas of wind power or prolong the serious effects of volcanic eruptions on aviation.

> *"In central London, for example, the urban heat island effect currently adds up to a further 5°C to 6°C to summer night temperatures and will intensify in the future."*

In cities, observational studies of the decadal warming trend worldwide show that the trend is greater in urban areas than in the surrounding regions. In the evening and night-time the stored heat in the buildings is transferred to the air and is carried away by the wind. In central London, for example, the urban heat island effect currently adds up to a further 5ºC to 6º C to summer night temperatures and will intensify in the future. The location of the maximum varies with the wind direction; it is not always in the centre. In Asian cities, high levels of gaseous and particulate pollution, which include dust from desert areas, can also trap heat during the day, leading to even higher urban temperatures and air pollution. The local climate varies across urban areas, with cool spots like parks, rivers and buildings, while local hot-spots occur at airports and city centres. These factors need to be considered in urban planning and in policies for the health of the population. Pollutants can be carried hundreds and even thousands of kilometres downwind of urban areas, as with the aerosols of eastern Asia. The winds associated with nearby coasts and mountains, as in Los Angeles and Phoenix, can transport pollutants 30 km away from the centre and then sweep the pollutants back again to build up the concentrations even further.

> *"As the Paris heatwave of 2003 demonstrated, local variations in the urban environment are very important, and can even determine the local pattern of mortality."*

As air pollutants are transported across the city, some gases increase in concentration, while others undergo chemical transformations. As the Paris heatwave of 2003 demonstrated, local variations in the urban environment are very important, and can even determine the local pattern of mortality. Overall, mortality associated with air pollution is greater in larger cities, as shown by the statistics issued by the World Health Organisation.

These and other hazards may become more serious and even change their nature as a result of combinations of effects resulting from climate change and other geophysical phenomena. This combination of risk is a challenge to scientific research, where more collaboration between different specialisms is needed. For example, there could be increased impact of tsunamis on coastal cities caused by the increase in sea-levels, and even tsunamis on arctic coastlines as the sea-ice melts. The greatest hazards for urban areas in Asia are associated with intense rainfall events (with new records as high as 150 miles per hour) which can rapidly flood and immobilise medium size cities. But some kinds of extreme events are apparently not worsening in frequency and intensity, such as tornadoes and tropical cyclones, although there are theoretical reasons why worsening is to be expected in future in certain regions and in certain periods of atmospheric activity. Combinations of hazards can have cumulative effects on human health, such as occurs in Asia where high urban temperatures, together with dust storms from nearby deserts, worsen the impacts of high concentrations of air pollution.

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3. Environmental Risks and Increasing Urbanisation

Cities have evolved means to shelter people, but as climate change affects the nature and magnitude of meteorological and hydrological hazards, there is an issue over whether they will continue to be able to do so. These dangers, which vary with climatic regions and geography, are intensified by the presence of large and immobile populations, as well as through the effects on buildings, infrastructure, industry and power plants.

> *Many types of natural hazards have specific impacts on urban areas, which can arrive singly or in interaction with others... Current risk models generally underestimate these deadly combinations.*

Many types of natural hazards have specific impacts on urban areas, which can arrive singly or in interaction with others. Some countries are exposed to geophysical as well as climatic hazards such as volcanoes, earthquakes and tsunamis, occasionally at the same time, as occurred on the east coast of Japan in 2011. Current risk models generally underestimate these deadly combinations. Another long-term hazard for large urbanised areas in dry regions is reduced water supply either caused by reduced precipitation locally or regionally or by depleting the water table.

The increasing scale of cities affects the operational, social and economic capacities to deal with hazards. Some hazards, both climatic and environmental, as well as those caused by industrial accidents and criminals, are localised over distances much less than the overall size of the city. In this case the resources and sheer scale of a megacity provides the communities affected with relatively greater resilience.

But the impacts on conurbations may be overwhelming when the hazards are extended across the whole city, such as with fluvial flooding, large earthquakes, heatwaves or tropical cyclones. With climate change some of these hazards could last longer. In such circumstances the damage can be widespread (like waterborne or airborne debris) across the conurbation.

4. Current practices to adapt and mitigate natural hazards

There are two main kinds of policy for reducing the impact of climate change; *mitigation* (reducing net emissions of carbon dioxide and other greenhouse gases to reduce global warming and ocean acidification) and *adaptation* (increased capability to withstand the effects of climate change). The former policies are generally enacted over global and regional scales, while the latter are generally more local.

Mitigation policies

Emissions of greenhouse gases lead to a cumulative build-up in the atmosphere that affects the climate of the planet. Integrated and flexible global carbon management to effect change is necessary. This requires a joint collaborative approach at global and national levels. The most prominent policy instrument is the Kyoto Protocol to the UN Framework Convention on Climate Change, initially adopted in 1997. Despite the agreements, which stated that richer developed countries should reduce their GHG emissions to below their 1990 levels, the fact remains that global emissions have continued to rise. However, this rise is less pronounced than it would have been had no mitigation measures been taken, given the rise in emissions caused by the substantial growth of the global economy over the past two decades.

Improvements in technology and energy efficiency are limiting certain cities' GHG emissions. Examples include developments in non-fossil fuel sources of power and more efficient use of transportation systems in urban areas. But according to the UK Climate Change Committee the necessary policies for the UK are not being introduced fast enough or strongly enough to achieve the national target to reduce emissions by 80 per cent by 2050, or to adapt to climate risks.

> *"It is intended that an agreement [to reduce GHG emissions] will be in place by 2015 for implementation by 2020. However, even if these efforts are successful, global emissions will still not start to fall before the middle of this century."*

The latest international climate agreement brokered by the UNFCCC at Durban in December 2011, set a target for limiting GHG emissions across all countries of the world including industrialising and developing countries. It is intended that an agreement will be in place by 2015 for implementation by 2020. However, even if these efforts are successful, global emissions will still not start to fall before the middle of this century.

In industrialising countries with rapid economic growth and increasing emissions, such as Brazil, India and China, measures similar to those introduced in developed countries, should begin to curtail emissions by mid-century, when population levels of some regions and countries will level out. In many countries, energy policies are also motivated by other national policy objectives such as reducing reliance on fossil fuels and improving energy security.

Another vital component of 'mitigation' policy is to ensure that the global area of forest cover remains intact so as to continue to absorb a significant proportion (about 15 per cent) of the Carbon Dioxide emitted by the human activities of fossil fuel combustion, including the expansion of agriculture, which can still involve deforestation.

Adaptation policies

Compared to climate change mitigation, climate change adaptation policy development is much less developed. Although the Bali Action Plan and Copenhagen Agreement of 2007 and 2009 respectively put adaptation on an equal footing with mitigation, no substantial international funding of vulnerable countries has yet been agreed. However, effective adaptation measures have been implemented in some countries and in some vulnerable regions as outlined later in this essay.

Regional and local policies

Mitigation policies

> *Recent research...has shown that the majority of the top 60 UK cities by population size have agreed carbon reduction plans and targets.*

Cities now recognise the need to deal urgently with these threats to their sustainability. The mayors of 400 European cities, for example, pledged in February 2009 to make "drastic" cuts in CO_2 emissions by 2020. Recent research, funded by the Royal Institution of Chartered Surveyors Education Trust, has shown that the majority of the top 60 UK cities by population size have agreed carbon reduction plans and targets. City of London aims to reduce London's CO_2 emissions by 60 per cent by 2025 and proposes:

- Stimulating uptake of electric vehicles and encouragement of walking and cycling.
- Developing London smart grid, which enables decarbonising energy supplies and the increasing electrification of heat and transport.
- Recycling of waste and more efficient water use.

Cities need to make overall plans to transform their physical infrastructure, their planning for future development and their systems of energy, water, and transportation. There should be other benefits as they become healthier, greener and more resource efficient.

Adaptation policies

Given projected current climatic trends, national Governments and urban authorities are being forced to introduce policies for adapting communities, industries and agriculture to the likely consequences of global warming.

> *Taking precautionary measures now, may be necessary to avoid having to take more drastic action later which, at its most extreme, could mean people having to abandon the city altogether.*

With computer models and remote sensing data, it is possible to plan how to reduce effects of climate change and minimise environmental risks in urban areas that are developing rapidly. In future it will become possible to give greater forewarning about impending hazards given the presence of more reliable projections of atmospheric and ocean conditions – some countries are already considering the use of electromagnetic ionospheric data to detect early signs of earthquakes. The consequences of hazards and impacts need to be considered individually and collectively in order to decide short-term responses and long-term policies. Integrated planning can help deal with several types of hazard simultaneously. Taking precautionary measures now, may be necessary to avoid having to take more drastic action later which, at its most extreme, could mean people having to abandon the city altogether. Indeed some coastal communities and island states, such as the Maldives, are preparing for such a possible fate during this century as sea level rises.

Construction of new dykes and dams is considered the most traditional structural measures to cope with increasing flood impacts and/or inundation-related risks. For example, in Holland, following a major review of their plans to prevent future flooding, the Government has decided to raise its dykes by several metres to allow for the anticipated rise in sea level and in increased storm surges over the next century – which corresponds to the worst case scenario of significant melting of polar ice-caps.

> *...recent experience has emphasised how the magnitude of the impact depends not only on the nature and strength of the hazard, but also how well the community has adapted to reduce the impact of the hazard and to recover afterwards.*

There is not enough work on raising the awareness of communities in order to accept the risk of flooding and be prepared for it. Recent experience has emphasised how the magnitude of the impact depends not only on the nature and strength of the hazard, but also how well the community has adapted to reduce the impact of the hazard and to recover afterwards (i.e. its resilience or lack of vulnerability). Because one hazard can lead to another, such as rain causing massive land-slides and water pollution, the forward planning and the operational management depend on the type of critical event expected. In order to achieve this aim, there needs to be better systems in place to warn the endangered population well in advance, providing advice about primary events and possible follow-on effects.

Hazard warnings are an essential prerequisite to improve the resilience of urban centres. If hazard warnings are not well in advance, inhabitants will not be able to leave endangered areas of cities, because transportation is unlikely to be available. However, there are some large cities on islands like Mumbai and Hong Kong where it is effectively impossible for such evacuation to be achieved. In some cases, the hazards may be some distance from the conurbation, as in Japan in 2011 when a severe earthquake was followed first by an exceptional tsunami and then by the release of substantial radio activity from a damaged nuclear power station. This combination overwhelmed local communities near the disaster. It also affected the whole conurbation of Tokyo 300 km away.

With mobile phones and social media, valuable messages and pictures about hazards and impacts can now be received and transmitted by people located in critical situations. These informal messages are now a valuable part of public warnings. Advances in detailed satellite images and communication systems unaffected by local power cuts can also greatly assist urban resilience.

Warnings can now be communicated more effectively both through technology. Improvements in this area are likely to increase in pace and scale over the decades to come as internet penetration and smart phone use accelerates.

Communities need to be informed and consulted about administrative and technical policy proposals in order that they are appropriate in the local context. Public and even international pressure is forcing some major cities to be more open about environmental information. However, many public and private bodies continue to restrict information and cynically, reduce the measurements of critical processes. Generally though mass communications are improving community's preparedness for disasters. And these possibilities are only just beginning to be explored.

Medical, social and economic impacts are of increasing concern to policymakers, since they determine whether communities can recover before the next hazard event occurs. Failure to do so may threaten their position as holder of political office. Insurance companies now assess vulnerability risk as much in terms of the social capacity of communities, as by the physical impacts of extreme events and preventive measures that may have been taken.

Dealing with the potential consequences of climate change and shifts in the frequency and severity of natural disasters requires a range of technical, economic and administrative policies. Especially for building infrastructure and for managing disasters, integrated approaches have been shown to be more effective socially and economically, e.g. by combining warning and response services.

Conclusions

Experts and policymakers need to improve their understanding of how complex hazards affect urban areas and impact upon society as a whole. Crucial to achieving this aim is a better understanding how hazards relate to the social and economic drivers determining urbanisation and how the physical infrastructure and its operations develop (see for example Peter Head's work in China as Director of Arup). The risks will also be affected by how climate change alters extreme natural hazards and how they impinge on urban areas.

Planning of urban development, as well as the practical policies regarding their management, can reduce the impacts of natural and artificial hazards. Better systems are being established for warning the endangered population well in advance of hazards occurring, and also for providing advice about responding to the likely consequences as they evolve following the initial event (e.g. diseases from compromised water systems as a result of flooding). In addition, policymakers should be aware of the latest research about emerging techniques.

Secondly, there needs to be much greater investment in evacuation arrangements and security measures such as refuges for people above the level of any likely floods, which are built to repel flying debris in high winds. In the largest evacuation plan anywhere, a second city is available for people escaping from Naples in the event of a major eruption of Mount Vesuvius.

There has been little study so far about how megacities may impact upon climates, environments and natural hazards in surrounding regions .

International experience has shown that where hazards have reocurred, many communities have put into practice lessons from previous events, but when there has been little or no experience, there has been limited success in effective preparation. There needs to be more social science research about improving the efficacy of preparing communities as well as of local and national government against uncommon hazards. International conferences (e.g. Kobe in 2005) and national legislation are establishing general approaches along these lines.

> *"Structural engineers, planners and social scientists need to consider more urgently the design of appropriate shelters in urban and also in rural areas. But for technical solutions to be successful, they have to be supported by communities."*

Technical developments are also urgently needed, as this paper has pointed out. Structural engineers, planners and social scientists need to consider more urgently the design of appropriate shelters in urban and also in rural areas. But for technical solutions to be successful, they have to be supported by communities. For example, in Bangladesh cyclone shelters were not used until people were allowed to bring their livestock with them. Estimates of the likelihood and impacts of extreme events in growing conurbations are needed to plan and justify the investment needed for such precautionary measures.

Clearly developing optimum policies for dealing with natural and artificial hazards and their impacts in expanding urban areas is extremely complex, and requires research and data about all the climatic, environmental, engineering and societal aspects involved. Exceptional levels of collaboration between specialists will be necessary to use these results and develop new approaches for the planning and operation of megacities in different parts of the world.

Authors' biographies

Professor Lord Julian Hunt,
Professor Julian Hunt's current position is emeritus Professor of Climate Modelling in the Department of Earth Sciences, at University College London. He is a Fellow of Trinity College Cambridge. He was Director-General and Chief Executive of the Meteorological Office from 1992–1997. He was created a Baron in the House of Lords (with the title Lord Hunt of Chesterton) in May 2000.

Professor Hunt held several visiting research appointments in USA, Europe and Asia. He was elected a Fellow of the Royal Society in 1989 and was awarded the L.F. Richardson Prize of the European Geophysical Society in 2001. He is an honorary Fellow of the Royal Meteorological Society.

Professor Hunt's has applied his studies of environmental science to policy issues of risk (in collaboration with the Lighthill Risk network), especially to integrated approaches to dealing with natural disasters and the effects of climate change. He chaired the Royal Society Committee on Natural Disaster Reduction in the 1990's.

He has been a consultant to several UK and international companies and to government departments on environmental fluid mechanics and pollution.

He and his colleagues at Cambridge formed a company, Cambridge Environmental Research Consultants Ltd (CERC) which developed environmental software and is working with Cerc and other collaborators on the environmental and security challenges of megacities.

Dr Yulia Timoshkina
Dr Yulia Timoshkina is an Honorary Research Fellow in the Department of Mathematics, at University College London. She graduated with a PhD in Engineering for Sustainable Development, from the Department of Engineering at the University of Cambridge. Between 2007 and 2009 she worked as a Research Associate at the Centre for Energy Studies, University of Cambridge. In 2010 Dr Timoshkina joined the British Civil Service's Department of Energy and Climate Change as a Policy Advisor. Currently she works as a Strategy Advisor at Gazprom.

At the Department of Mathematics Dr Timoshkina's professional interests include design of urban systems and infrastructure; she has applied her background in engineering to policy issues dealing with integrated natural resources management, and responses to natural disasters.

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Climate change and insurance adaptation

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Introduction

Insurance is the biggest industry in the world with a global annual income of $4.3 trillion ($4,300,000,000,000) and $24.6 trillion in managed funds. Insurers are experts in risk management and arguably have the best catastrophe hazard maps, models and data, yet they are rarely consulted by governments or academics about such issues. There is an enormous potential for insurers to provide economic incentives, data and modelling skills to help to manage risks more sustainably by encouraging adaptation to climate change.

> *"There is an enormous potential for insurers to provide economic incentives, data and modelling skills to help to manage risks more sustainably by encouraging adaptation to climate change."*

Predicted climate change impacts include more severe and frequent disasters from heatwaves, diseases, storms, and floods.[42] In recent decades the number of reported hydrological disasters has increased by 7.4 per cent per year, on average.[43] Hydrological disasters can have a big human impact. See Table.

Table: Global Losses for 2011

	Dead or missing	Insured Loss ($m)
Floods	5,093	16,262
Storms	3,301	41,152

Source: Swiss Re. Sigma 2/2012.

Outlook

According to the PRUDENCE research project[44], involving computer modelling by nine leading European universities, the outlook is for an increase in hazards:

- Heatwaves: increased frequency, intensity and duration especially over the continental interior of Europe
- Precipitation: heavy winter precipitation in central and northern Europe and decreases in the South
- Increases in heavy summer rainfall in NE Europe. In June 2010, France had its heaviest rainfall since 1827
- Longer droughts will happen in Mediterranean countries
- Extreme wind speeds increase between latitude 45°N and 55°N. (that is North of Milan and South of Carlisle). Seven of the top 40 most costly insurance losses since 1970 have been European storms in this latitude, costing more than $40bn in total.[45]

42 World Health Organisation, "Climate change and human health – risks and responses." WHO in collaboration with UNEP and WMO, Geneva, 2003

43 Scheuren, J M, Le Polain De Waroux, O, Below, R, Guha-Sapir, D, and Ponserre, S, Annual Disaster Statistical Review The Numbers and Trends 2007, Center for Research on the Epidemiology of Disasters (CRED), Brussels. 2008

44 Prediction of Regional Scenarios and Uncertainties for Defining European Climate Change Risks and Effects ("PRUDENCE") See http://prudence.dmi.dk/ accessed 8 May 2012.

45 Source: Swiss Re. Sigma 2/2012

- More North Sea storms, leading to increases in storm surge along the North Sea coast. There has already been an unprecedented 5 metre storm surge in Denmark during the Anatole storm in 1999 which recorded a barometric pressure of only 953MB. (As Anatole was mainly over Denmark and Sweden it did not make it to the top 40 because Scandinavian buildings are more resilient.)

The most authoritative source on climate change is the Intergovernmental Panel on Climate Change (IPCC). Their Fourth Assessment report[46] states:

- "World leaders have not yet accepted their countries would have to adapt to the likely consequences."
- "Mitigation has got all the attention, but we cannot mitigate out of this problem."

> *"It will no longer be sufficient to base premiums on historic claims experience."*

Increasing uncertainty about future natural disasters will increase the demand for, and the cost of, insurance, and will require insurers to adapt to changing circumstances. It will no longer be sufficient to base premiums on historic claims experience.

Insurance adaptation

There are three types of insurance response to the challenges of climate change:

1. React: respond to claims costs by adjusting premiums or withdrawing cover.
2. Anticipate: use scientific modelling and mapping techniques to predict future disasters. Collect data to assess future costs.
3. Manage: enter into a dialogue with the authorities and other stakeholders to lobby, educate, inform and assist the authorities and the public to manage risks better.

Most insurers seem to still be at the passive, reactive, stage,

The Flood and Water Management Act 2010 in England was intended to reduce flood risks in England. However, the legislation continues to promote only traditional structural solutions to flood risks, to enable continued building in the flood plain. In other words it will make things worse.[47] It seems short-sighted to complain to government about inadequate spending on flood walls while they continue to allow new building in the flood plain. Even if flood walls work (and often they don't) they simply transfer the risk onto future generations, along with the maintenance and repair costs.[48] Also they cannot prevent surface water flood losses.[49] Indeed there are examples of cases where they increased the losses by preventing water from draining away after the flood.

In June 2010, storms hit the south-east of France[50] and the large amounts of heavy rain led to localised flash flooding. 400 mm of rain fell in less than 2 days in Provence, producing the worst floods in France since 1827. In future, surface water flood losses are predicted to occur much more frequently than "classic" cases of river flooding, thanks to climate change, dam failures[51] and EU Directives. For example:

46 M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. Van Der Linden and C.E. Hanson, Eds. "Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change." Cambridge University Press, Cambridge, UK, 976pp

47 Crichton, D. 2012. "CII Thinkpiece 73: Is it Possible to Have Sustainable Flood Insurance without Sustainable Flood Risk Management?" Chartered Insurance Institute, London

48 Etkin, D. (2004) "Risk Transference and Related Trends: Driving Forces towards more Mega-Disasters". Environmental Hazards, vol. 1, pp. 69-75

49 "Flash Floods." Topics 01 2010. Munich Re, Munich. 2010 http://www.munichre.com/en/reinsurance/magazine/publications/default.aspx Accessed 28.5.2010

50 Climate: Observations, Projections and Impacts. France. Met Office Hadley Centre. 2011. http://www.metoffice.gov.uk/media/pdf/t/r/UK.pdf Accessed 7.5.12

51 Babtie Group and the Centre for Ecology and Hydrology, 2002. "Climate Change Impacts on the Safety of British Reservoirs" defra, London

- The Water Framework Directive[52] forbids modifying rivers or lakes to cope with increased rainfall (except in Scotland, thanks to the writer's lobbying).
- The Habitats Directive[53] can be used as an excuse to avoid the clearance of weeds and silt from watercourses, leading to blockages. (In Scotland local authorities have an overriding statutory duty to do this work.)

> *"...the non-Lloyds market in the UK even objected to sensible Parliamentary proposals to require dam owners to take out liability insurance, a risk which is usually underwritten by their competitors, Lloyds."*

Heavy rain, failure to clean watercourses, or to maintain drains or dams can produce overland flows which can happen on any sloping ground, not just near rivers or coasts. Not only has the insurance industry done nothing substantial to reduce such risks, the non-Lloyds market in the UK even objected to sensible parliamentary proposals to require dam owners to take out liability insurance, a risk which is usually underwritten by their competitors, Lloyds.

There is still no provision in England for funding the much more cost effective approach of working with nature using non-structural 'Sustainable Flood Management' methods. Contrast the methods used by Germany which is working with France on the Moselle catchment to introduce forestry to reduce rainfall run off[54] and with Belgium, Luxembourg and The Netherlands on the Rhine to restore meanders where the river has been canalised in the past.[55] (see image)

Image: INTERREG Rhine Meuse Activities Programme (IRMA). Restoring meanders in the Rhine in Germany to reduce flood risk in the Netherlands.

Source: IRMA Secretariat, The Netherlands

52 Water Framework Directive, 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000. Official Journal (OJ L 327) on 22 December 2000 Available at: http://forum.europa.eu.int/Public/irc/env/wfd.library?1=/

53 EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) ('The Habitats Directive')

54 Commissions Internationales pour la Protection de la Moselle et de la Sarre « Plan d'action contre les inondations dans le bassin de la Moselle et de la Sarre Bilan 2001-2005 » Secrétariat der CIPMS (French and German language versions only). Trier 2006

55 INTERREG Rhine Meuse Activities Programme (IRMA). See European Commission Press Release Reference: IP/01/1822 Date: 13/12/2001 Brussels. Also http://www.irma-sponge.org/ accessed 9.5.12

Countries such as Japan,[56] Germany, France, Holland and Scotland are concentrating on managing hazard and exposure through strict land use planning and a programme of cleaning drains and watercourses.[57, 58] They recognise the value of sustainable flood management techniques which include economic incentives such as insurance penalties and discounts, but this needs support from the insurance industry.

“They recognise the value of sustainable flood management techniques which include economic incentives such as insurance penalties and discounts, but this needs support from the insurance industry.”

Germany and Switzerland have been working with Scotland and the writer on the very cost effective natural flood management techniques developed under the SAFER project.[59]

The writer has been working with NGOs to lobby governments and to develop natural flood management techniques. Where are insurers in all this?

Insurance policies are renewable annually and underwriters can readily react to protect their shareholders, increasing premiums or withdrawing cover as a last resort if necessary. Mortgage lenders are more vulnerable: they issue mortgages for many years and if insurance is withdrawn they may have no alternative but to foreclose and lose money. Society is the most vulnerable of all. At the end of the day, climate change will have its biggest impact in its effects on social cohesion and resilience.

Social resilience

“Even if people are fully insured, the intangible impacts can be significant.[60] Evacuation of residents disrupts communities and the stressful effects of anxiety and insecurity may remain long after the physical damage has been repaired.”

Disaster impacts can be particularly severe on some of the most vulnerable people in our society, and these are the people who can find it harder to recover from them when they happen.[61] Disasters tend to widen existing inequalities unless social resilience can be addressed. If not addressed, the differential social impacts may lead directly to increased costs for the economy in terms of healthcare and social care. It is more difficult to measure social and emotional costs suffered when a disaster disrupts business, destroys homes and livelihoods, and disturbs family life. Even if people are fully insured, the intangible impacts can be significant. Evacuation of residents disrupts communities and the stressful effects of anxiety and insecurity may remain long after the physical damage has been repaired.

56 Crichton, D. 2008, “Flood Management in Japan and Britain. A comparison.” at http://www.ilankelman.org/crichton/2008japanbritain.pdf

57 Crichton, D, “Towards a Comparison of Public and Private Insurance Responses to Flooding Risks.” Dicke, W, and Meijerink, S (eds). International Journal of Water Resources Development, Delft, Netherlands. Vol 24, Number 4, Pp 583-592

58 Crichton, D. “UK and Global Insurance Responses to Flood Hazard.” Water International Vol 27, 1. Pp 119-131

59 ‘SAFER’ is an acronym for Strategies and Actions/Implementations for Flood Emergency Risk Management http://www.forestry.gov.uk/newsrele.nsf/AllByUNID/9C46CB11A10DA97B80256E9100606E12 accessed 6.5.12

60 Werritty, A, Houston, D, Ball, T, Tavendale A, and Black, A. “Exploring the Social Impacts of Flood Risk and Flooding in Scotland”; Scottish Government, Edinburgh, 2007

61 O’Neill, J, and O’Neill, M, 2012. Social justice and the future of flood insurance. Joseph Rowntree Foundation

Insurers have been warning of problems for years.[62] As repossessions increase or properties remain unsold, developers have come to realise that there may be problems selling properties in flood hazard zones, because without insurance the purchaser will not be able to obtain a mortgage. There are alternatives for the developer but these are just as much a cause for concern:

- Flood plain land can be used for "public" buildings such as schools and hospitals. However, hospitals are difficult to evacuate, especially intensive care units, where evacuation could put lives at risk. Hospitals are also important resources during flood events where waterborne pathogens can cause widespread illness. An unpublished insurance survey revealed that at least 89 hospitals in England are at a high risk of flooding and 70 per cent of them have no flood defences. There are also 2,374 schools at high risk in England. During the tsunami in Japan in 2011, patients in intensive care in hospital were simply left to die as there was no time to evacuate them safely.
- Housing can be sold to a housing association and let to social tenants. Social tenants tend to be older, poorer and are more likely to include single parent families with young children.

In other words, the most vulnerable people in the community will increasingly be forced to live in the most hazardous areas.[63]

> *"...the most vulnerable people in the community will increasingly be forced to live in the most hazardous areas."*

Health, age and disability problems

Storms and floods not only cause damage to property, they can also threaten lives, especially those with impaired senses, mobility, or dependence on electrical equipment, or those living on their own. Local authority Emergency Planning Officers (EPOs) should be building databases of such people to target them for special assistance in the event of a disaster or evacuation. A particular issue can arise with regard to loss or damage to items of great sentimental value such as photographs. The writer has been helping EPOs to do this, but insurers could do so much to provide advice, assist with making digital copies of photographs, and using their help lines pro-actively.

Other vulnerable people

In addition to the old, the sick, children, the disabled, and the poor, other vulnerable sections of society include:

- People dependent on prescription medication or medical equipment.
- Ethnic groups where women may be forced to stay in flooded homes for social or religious reasons when their male relatives are away.
- Immigrants who cannot speak English, do not understand evacuation instructions, and have no friends nearby to help them.
- Schools and homes for handicapped people.
- Residents in dam break inundation areas where urgent evacuation may be necessary.[64]

62 Davies, R "Flooding in Britain: Review of Causes, Damage and Control Measures" 56pp. Insurance Technical Bureau report ITB-R83/106, British Insurance Association, London 1983

63 Crichton, D. "The Future of Flood Management in the UK." Insurance Research and Practice No 1. Chartered Insurance Institute, London, 2007

64 Crichton, D. 2007 "Best laid plans" Public Private Partnership Journal Issue 58, pp 103–106

The Meaning of "Risk"

The "Crichton Risk Triangle"[65], was designed for use by the insurance industry for catastrophe modelling (see Figure) and is a useful way to explain the concept of "risk".

Figure: The "Crichton Risk Triangle" (©Crichton, 1999)

In this definition, risk is a function of hazard, exposure and vulnerability and is represented by the area of the triangle. If any one side of the triangle can be reduced then risk is reduced. The concept can be used for any type of risk.

Hazard

In the case of flooding, "Hazard" represents the frequency and severity of rainfall events or storms. Climate change predictions indicate an increasing hazard over which society has little immediate control other than to clean watercourses, provide adequate drainage,[66] and adopt natural flood management practices.[67] Insurers can help by encouraging the authorities to follow best practice from around the world, and in particular by explaining the critical importance of maintaining drains and watercourses. In Scotland, insurers have the added advantage of being able to take legal action against authorities which fail to maintain watercourses, and while insurers do not seem to be aware of this, the possibility ensures that local authorities would listen to their advice, if given.

Exposure

This represents the density and value of property located in flood hazard areas.

After 39 people were killed in floods in Turkey in November 2006, Tansel Unal, the Head of the Chamber of Construction Engineers in Diyarbakir, blamed the high toll on faulty building practices in the region, notably on settlements built in river basins.

> *"Nowhere (else) in the world, is construction authorised in river basins,"* he said.[68] *"Negligence and badly planned urbanisation are the real cause of high death tolls, be they due to floods or earthquakes."*

65 Crichton, D. "The Risk Triangle", Natural Disaster Management, Ingleton, J., (ed), Tudor Rose London, 1999

66 Lindholm, O G, Schilling, W, Crichton, D, 2007. "Urban water management before the court: flooding in Freidrikstad, Norway." Pp204–209, Journal of Water Law, Volume 17, Issue 5

67 WWF. "Slowing the Flow." 16pp. WWF Scotland, Dunkeld, 2007

68 Agence France-Presse, "Twelve more killed in Turkish floods, toll hits 39" 02/11/2006 14:59 Diyarbakir, Turkey; AFP, 2006

This is not quite correct: there are still two other places in Europe which authorise construction in river basins and other flood risk areas. One is England; the other is the Republic of Ireland. It is perhaps no coincidence that these are both countries with unusually high levels of flood insurance penetration.

> *"Insurers can help by using the premium mechanism to discourage building or buying properties in flood hazard areas, but even more important is a regular frank dialogue between insurers and local planners as in Scotland, to avoid problems arising in the first place."*

Insurers can help by using the premium mechanism to discourage building or buying properties in flood hazard areas, but even more important is a regular frank dialogue between insurers and local planners as in Scotland, to avoid problems arising in the first place. Such liaison should not be limited to dialogue between insurers and planners. In Scotland it extends to emergency planning officers, building control officers, utilities, fire and rescue services, police, property developers, land owners, environmental NGOs and the Scottish Environment Protection Agency, all working together to reduce flood risk. Discussions have included the latest legal and research developments, best practice in other parts of the world and the latest insurance strategies.

Measuring Risk

To measure risk, it requires an understanding of the three components of risk as set out in the "Crichton Risk Triangle":

- Hazard: for example accurate flood maps, which include not only fluvial and coastal flood but also pluvial, groundwater, and dam break inundation hazard zones.
- Exposure: the number, value, and types of properties in flood hazard areas.
- Vulnerability: the resilience of people and properties and the consequent health and financial costs of flooding.

One problem is assessing the costs of flooding claims. In the UK, the insurance industry has access to the National Flood Insurance Claims Database, established by the writer in 1995. This is the biggest flood damage database in the world, with details of the costs of flood damage by up to 28 different factors, including age, value, and type of building, by flood depth, time of year, and velocity.[69] As a result, insurance companies have for many years been able to model flood disasters in the UK to a higher resolution and accuracy than government or academia.

> *"...insurance companies have for many years been able to model flood disasters in the UK to a higher resolution and accuracy than government or academia."*

69 Black, A, and Evans, S. "Flood damage in the UK: New insights for the insurance industry." University of Dundee, Dundee, 1999

The Review[70] by Sir Michael Pitt into the flooding in England in 2007 made 92 recommendations and highlighted the vulnerability of electricity and water supply plant. In such cases there is of course an important role for civil engineers in designing structural flood defences to reduce vulnerability as a short-term measure until more sustainable solutions are found. There is also the question of direct risks to life. A good example is the centre of Paris. This had a catastrophic 100 year return period flood[71] in 1910, but despite that, since then, 154km of underground railway has been constructed in the city and 600,000 underground car park spaces have been built near the river with basement depths up to 10 levels. 90 per cent of the flood plain is urbanised in the City of Paris and the three surrounding départements: the Val de Marne, the Seine-Saint-Denis and the Hauts dé-Seine. As a consequence, a major flood today would cause many losses in this area and about 17 billion euros of damage (excluding infrastructure). About 1 million inhabitants, three hospitals, and more than 100,000 companies, factories and networks would be impacted for several months.[72]

Building in flood hazard areas increases the risks to life and sometimes the use of mass concrete structural defences may be the only short-term solution, but it may not be considered acceptable to build a three metre high flood wall through the centre of Paris. A major international research programme is under way to find ways to make European cities more resilient.[73] No insurance companies are involved.

> *"...adaptation and resilience is not taught in most architecture schools and there is only one architecture textbook in the world on how to adapt buildings for climate change.[74] Professional indemnity insurers could encourage the retraining of architects in real world problems."*

Many cities have a legacy of critical infrastructure in flood hazard areas. There is an important role for architects and civil engineers in designing to reduce vulnerability especially for critical infrastructure[75] but adaptation and resilience is not taught in most architecture schools and there is only one architecture textbook in the world on how to adapt buildings for climate change. Professional indemnity insurers could encourage the retraining of architects in real world problems.

Civil engineers and architects may find an increasing demand for flood resilient building designs, such as buildings on stilts and floating houses. This is likely to be forced on property owners by the insurance industry, if not by building regulations. A research report[76] was produced by Lloyds and the risk consultants RMS, which demonstrated that flood resilient building designs can be more cost effective than traditional flood defences.

70 Pitt, M. "Lessons from the 2007 Floods." Independent Review. The Stationery Office, London

71 Mellot, P. "Paris inonde" 208pp (French language version only.) Editions de Lodi, Paris, 2003

72 Proceedings of Colloque Franco-anglais, Paris, Septembre 2004 « Les Grandes Tempêtes et Inondations en Europe Du Nord » Association Française Pour La Prévention Des Catastrophes Naturelles, Paris (French language only)

73 http://resilient-cities.iclei.org/ accessed 11.5.12

74 Roaf, S. Crichton, D, and Nicol, F., 2009. "Adapting Buildings and Cities for Climate Change." (Second edition) 384pp. Architectural Press, Oxford. ISBN 978 1 85617 720 7

75 Crichton, D (2002). "UK and Global Insurance Responses to Flood Hazard." Water International Vol 27, 1. Pp 119-131

76 Lloyds 3600 Risk Project and RMS Ltd. "Coastal communities and climate change: maintaining future insurability" 24pp. Risk Management Solutions and Lloyd's underwriters, London. 2008

Conclusions

Greenhouse gases such as carbon dioxide remain in the atmosphere for as long as 100 years, so even if greenhouse gas emissions stopped tomorrow, we are committed to ongoing climate change for 100 years to come. Insurers can easily adapt to climate change by adjusting pricing and acceptance strategies, but they should not ignore the impact of climate change on social resilience. In the longer term, a breakdown in social cohesion and a rise in social problems could threaten the wider economic health of the country and the security of the whole financial sector.

The buildings we construct now can be expected to last for 60 years or more, so efforts should be concentrated on new building not only to construct low carbon buildings, but to make sure they will not be damaged by the next major flood or storm. Insurers and mortgage lenders are well placed to ensure this. It is in their interests to do so.

The writer has often been the only person from the insurance industry attending international disaster management and climate adaptation conferences. With some notable exceptions there is little sign as yet of insurance companies seeking to do more than just complain. If insurers want to be consulted, they need to participate.

Author's biography

David Crichton MA (Hons), FCII, Chartered Insurance Practitioner, is an experienced practitioner and academic researcher specialising in the insurance aspects of climate change and natural disasters, particularly flooding. He is an Honorary Visiting Professor at the AON Benfield Hazard Research Centre at University College London. This is the leading hazard research centre in Europe, specialising in natural disasters and insurance. He is also an Honorary Visiting Professor at the Middlesex University Flood Hazard Research Centre, London; and an Honorary Research Fellow at the University of Dundee, the home of the first UNESCO water research centre in Europe and the British Flood Insurance Claims Database (probably the biggest such database in the world).

5. The three scenarios

In the previous section, a number of distinguished authors identified significant and interrelated environmental risks, which could have severe implications for long-term human wellbeing. By pulling together some of their key conclusions, it is possible to outline a few simple scenarios to reflect on how climate change might affect the world in the decades ahead.

Before setting out these narratives a few words of caution are necessary regarding some of the core underlying assumptions made. All three scenarios assume that there is a significant link between human GHG emissions and global warming. They also assume that global warming will increase the likelihood of extreme weather events. Crucially, both assumptions may not actually hold in reality and the extent to which there is a relationship between emissions and global warming and between global warming and extreme weather events is far from certain.

For example, regarding the first assumption, whilst conventional wisdom suggests that there is such a phenomenon as anthropogenic climate change, we cannot be 100 per cent certain that this is the case, only that it is very likely (given the available data) that some proportion of global warming has been caused by human beings. For example, the IPCC estimates that there is approximately a 5 per cent chance that recent global warming is purely the result of internal variability and not human activity. The IPCC argue that the "widespread nature of the warming reduces the possibility that the warming could have [solely] resulted from internal variability" though it does not eliminate this possibility entirely.

The extent to which global warming is related to extreme weather events is also uncertain. In our first report within the centenary Future Risk series we noted how there appeared to be substantial increases in extreme weather events towards the end of the last century coinciding with sustained periods of global warming. However, we noted that the relationship may not be as simple as it seems. Some of the recorded increase in disaster frequency is actually likely to be the result of improvements made in reporting techniques rather than purely due to an actual increase in catastrophic weather events.[77] And, earlier in this report Dr Surminski referred to an IPCC forecast that suggested that certain types of extreme weather events might actually decline in frequency over the coming decades.

In summary then, the below scenarios are deliberately simple and necessarily exclude many possible permutations and interaction effects that could lead to futures completely different to the ones envisaged here. Therefore, rather than being used as concrete forecasts for future planning, these scenarios should instead help guide decision makers into considering how they might react as different possible futures unfold.

Existing scenarios

It is worth noting that there are already a number of existing scenarios which describe in varying degrees of detail the potential impacts of climate change on the wellbeing of populations. At the global level, these include scenarios developed by the IPCC (2000), the Millennium Ecosystem Assessment (2005) and the Global Environment Outlook (2007). At the European level these include SCENES (2008) VISIONS (2000) and PRECLUDE (2007) amongst others. For an in-depth discussion about the relative strengths and weaknesses of these existing scenarios and of scenario planning in general, it is worthwhile reading a very useful paper by Kok et al (2011) on behalf of The CLIMSAVE Project – a project developing its own scenarios for assessing climate change impacts, adaptation and vulnerability.[78]

77 See CII (Feb 2012) Future Risk: Learning from history

78 Kok et al (June 2011) "Report on the new methodology for scenario analysis, including guidelines for its implementation, and based on an analysis of past scenario exercises" Report for CLIMSAVE see: http://www.climsave.eu/climsave/doc/Report_on_the_Scenario_Methodology.pdf [last accessed, 7 June 2012]

Scenario 1

Upside

In our most optimistic scenario energy consumption drives global warming, but because of a substantial increase in the use of renewal technologies and improved energy efficiency before 2017, the temperature does not exceed the internationally agreed target of 2°C by 2035. Countries also take care to preserve forests which absorb a significant proportion of the remaining CO_2. As a result of these measures, there is a relatively small increase in surface temperature (small by comparison to the other scenarios), with limited implications for the global environment.

Nevertheless, the two degree rise will have some weather implications such as an increasing prevalence of drought in some areas and flooding in others. The two degree rise will also increase the likelihood of extreme weather events, but not to the extent as in the other scenarios. Passing irreversible tipping points is also avoided.

The world will still remain relatively dependent on oil for transportation, so political instability in key producer countries has the potential to disrupt the price and supply of this type of energy. However, due to greater diversification of energy sources, including greater prevalence of transport powered by electricity, the resulting socioeconomic impact of supply shocks is limited.[79]

Global warming still, therefore, poses a threat to populations and economies even in the good scenario. However, in this scenario, not only is global warming less pronounced due to effective mitigation, but countries also take appropriate measures to adapt to the threats it poses. For example, countries are able to make the kinds of investments in infrastructure necessary to improve the resilience of buildings, sustainable urban planning ensures that property is not built on flood plains and secure shelters are provided to ensure easy access to safe relief in the event of an extreme hazard occurring. And crucially, improvements are made in the forecasting of natural disasters and to methods of communications meaning that vulnerable groups are warned early enough to be able to successfully take action or ultimately evacuate before an event occurs.

Role of the insurance industry

The insurance industry plays a key role in this scenario by providing economic incentives for the construction and maintenance of resilient property and infrastructure, by raising awareness of climate risks through pricing strategies and knowledge sharing, and by playing a lead role in advising governments about natural hazards and climate change.

In the developing world, there is also significant penetration of new products like microinsurance which help to protect households and vulnerable industries like farmers from weather related events. And new financial instruments like catastrophe bonds and insurance linked securities are used to help spread the risk of an extreme weather event so that the industry can more easily cope with significant losses stemming from disasters.

Overall then, climate change still poses a risk but because of effective efforts to control GHG emissions and adapt to the climate change that is already 'locked in', risks to human wellbeing and economic activity are substantially limited. Indeed, in some countries, investment in sustainable technologies helps provide some economic stimulus in its own right.

79 In the UK for example, it has been estimated that the Arab Spring of 2011 increased household bills by up to 20%. In a report for the Department of Energy and Climate Change, Oxford Economics estimates that switching to renewable energy sources could, in their best case scenario, reduce the price impact of shocks in supply of fossil fuels by up to 50% by 2050. Oxford Economics (Dec 2011) "Fossil fuel price shocks and a low carbon economy"

Scenario 2

Central

In the central scenario, increased energy consumption and raised GHG emissions again cause an increase in global warming. However, this time, there is a less substantial shift from traditional, fossil fuels to renewable technologies and greater energy efficiency by 2017. The earth's temperature therefore exceeds the two degree target before 2035. As a consequence, the resulting environmental impact is more significant than in the upside scenario.

As a consequence of increased global warming, there is likely to be a sustained increase in the prevalence of drought in already arid areas and flooding in areas with already high levels of precipitation. The rise in global temperature will also significantly increase the prevalence of extreme weather events and there is a risk that irreversible tipping points in the global climate will be breached. Exacerbating the situation, there is little diversification in the supply of energy, with many still reliant on oil produced in the Middle East for transport. The relatively poor environmental situation is therefore interspersed with significant shocks to the supply and price of oil with implications for inflation in the price of global goods and services.

Global warming therefore poses a real threat to populations and economies worldwide due to a failure in mitigation. Unfortunately, compounding the problems with mitigation, governments and industries do not invest as heavily in adaptation in relation to the degree of climate risk that they face. Some improvements are made to buildings, flood defences, shelters and early warning systems but there remain vulnerable regions not helped by the fact that some urban planners still construct buildings on flood plains and other highly exposed areas. People living in low income countries will face the harshest affects of climate change helping to intensify existing poverty traps. And the most vulnerable within developed economies, such as the elderly and the disabled, will also face a harsher world characterised by homes that are ill equipped for hotter summers and colder winters.

Role of the insurance industry

In our central scenario, the insurance industry provides some economic incentives for the construction and maintenance of resilient buildings and infrastructure through effective pricing strategies but it is unable to act as a catalyst for changing some bad planning practises like building on flood plains or neglecting sustainable flood defences.

In the developing world there is only limited penetration of microinsurance to protect households and businesses against the adverse affects of weather related events. There are also only a few examples of insurers spreading climate risk away from the sector to capital markets through new financial instruments.[80]

There is some evidence of insurance market failure. Market failure can be characterised by lack of capital, lack of cover, inability to pay claims or failure to contract (people who need insurance failing to seek it).[81] In our central scenario, insurance failure is mostly related to the latter of these – lack of cover and failure to contract. We assume that insurers remain sufficiently well capitalised to absorb losses emanating from catastrophic weather events though this is made possible by insurers removing cover from particularly high risk businesses and individuals.[82] There is also likely to be failure to contract as household and business awareness of climate risk remains lower than in our upside scenario.

Overall then, in the absence of sufficient mitigation and adaptation, climate change poses a significant risk to the livelihoods of many of the world's most vulnerable people in the developed and developing world. In many cases insurance can help protect individuals and businesses, but providing cover becomes impossible for a significant proportion of the world's population and there is still a relatively low level of global awareness about climate risks.

80 CII (2009) "Coping with climate change: risks and opportunities for insurers" Chapter 5, Market failure and climate change

81 Ibid

82 In our "Coping with climate change" report it is noted that there have been only occasional instances of insurance market failure stemming from a catastrophic weather event. Examples include fifteen insurance insolvencies following Hurricane Katrina in 2005. In response the industry withdrew private windstorm cover from the state

Scenario 3

Downside

In the downside scenario, there is a significant increase in global energy consumption with no real attempt made to switch to renewable energy sources or more energy efficient technologies. Coal, oil and natural gas (without carbon capture) therefore remain the predominant global sources of energy. As a consequence, the earth's surface temperature misses the international target of 2°C by a significant margin and the environmental impact along the way is substantial.

Not only is there sustained drought in already arid areas, flooding in already wet regions and an increase in catastrophic weather events, but the world is also likely to cross a number of key tipping points which could change local climates irreversibly, increasing the difficulty and cost of any adaptation efforts. For example, Siberian Permafrost which stores much of the earth's carbon may rapidly thaw releasing over 30 billion tonnes of carbon a year by 2040 (this compares to 10 billion tonnes a year currently released through fossil fuel usage).[83]

Unfortunately in this pessimistic scenario, little concerted effort is made to adapt to climate risk before the tipping points are breached. With little improvements made to infrastructure, populations are significantly more vulnerable to weather events which are, given such substantial global warming, likely to occur on a more regular basis. Many of the world's citizens in developed and developing countries are unable to adequately protect themselves in the face of regular and severe natural hazards, though the effect is most severe in low income urban areas that have the least resilient buildings and infrastructure. Indeed the situation is so bad in some regions that whole cities have to be abandoned altogether with significant repercussions for social cohesion and economic activity.

In this scenario political risk is rife for two reasons in particular. Firstly, disasters will not just prolong poverty traps and political instability within countries but also across continents. For example, the abandoning of disaster stricken cities or regions is likely to lead to a substantial increase in the flow of refugees which could have a potentially destabilising effect on neighbouring countries and beyond.[84] Secondly, since economic growth continues to depend so heavily on fossil fuels and in particular oil, political tension over who controls supply is likely to be particularly high, increasing the chances of geopolitical intervention and conflict.

Role of the insurance industry

In the downside scenario, insurers help contribute to the poor outlook by failing to take full advantage of their position as risk specialists. Whilst the sector provides some limited economic incentives for the development and maintenance of resilient buildings and sustainable infrastructure, insurers make little effort to spread awareness or engage with policymakers.

In developing countries, microinsurance makes no headway. Insurance schemes are not able to achieve sufficient scale to keep costs low making the schemes unaffordable for the vast majority of the populations they seek to serve. And the schemes that do exist, fail to build in provisions for future climate risk so they actually help to contribute to mal-adaptation rather than raising awareness and reducing risk.

83 Nina Chestney (March 2012) "Global warming close to becoming irreversible-scientists", story for Reuters News, last accessed 29 May from: http://www.reuters.com/article/2012/03/26/us-climate-thresholds-idUSBRE82P0UJ20120326

84 Kristian Skrede Gledistch and Idean Salehyan (Spring 2006) "Refugees and the Spread of Civil War" International Organization 60, pp. 335–366

At our most pessimistic, insurance market failure is widespread and takes different forms. Due to increasingly regular and severe weather related events, insurers are likely to take increasingly substantial capital hits. Insolvencies related to extreme weather events therefore become more prevalent though the industry will survive by withdrawing cover for the most risk affected areas. However, given the extent of worldwide climate risk, even in developed countries which have relatively more resilient infrastructure, large swathes of the population will remain uninsurable.

Overall then as a consequence of little effort to keep global temperatures in check, or to deliver more resilient infrastructure through effective adaptation, the world faces a bleak future. Climate change continues unabated, wreaking havoc on human wellbeing and economic activity and potentially creating a downward spiral of poverty traps and political violence. The insurance industry is characterised by market failure with many providers withdrawing cover in the face of catastrophe risk.

6. Conclusion

Climate change is one of the greatest risks facing the world today. Whilst the exact implications are uncertain due to the difficulty of modelling the effects of temperature rises on economic activity, global society, and all their interlinkages, it is clear that we cannot afford to be complacent. Even a two degree warming of the planet – which is the outcome of our most optimistic scenario, would most likely have some negative implications for the health and wellbeing of populations – particularly those in the most vulnerable parts of the developing world.

Mitigation will be crucial. To help reduce the likelihood of breaching dangerous tipping points, a major effort is needed right now to shift from traditional fossil fuels like oil and coal to renewable sources of energy like nuclear power and wind. Switching to natural gas may also prove to be a significant step forward though it will need to be combined with carbon capture technology to ensure it is sustainable. To make such a shift requires serious political will.

Under the Kyoto Protocol of 1997 – the world's only existing treaty stipulating emissions cuts – developing nations (which include the economic powerhouses of India and China) are exempt from any legally binding obligations to address their greenhouse gas emissions. The international summit in Durban 2011, provided some cause for hope that this situation would be overturned with negotiators agreeing to start work on a new climate deal that would require both developed and developing countries to cut their carbon emissions. However, the terms of the deal are unlikely to be agreed until at least 2015 and will not come into effect until at least 2020. This is beyond the 2017 watershed noted by Dr Fatih Birol in this report as the point at which the world must be in the process of making significant headway in moving to a sustainable future.

With mitigation efforts stumbling along, adaptation becomes even more vital. This report has emphasised the importance of ensuring resilient infrastructure including the development of accurate early warning systems, we have noted the necessity of improved urban planning and flood management systems and we have discussed the importance of the insurance industry in all of these efforts. Indeed, perhaps one of the most crucial points raised over the course of this report is that all stakeholders must work together to increase the world's resilience to climate risk. From the economist to the scientist, from the architect to the engineer, from the local town planner to central government, and from the small business to the large multinational, there has to be a joined up approach to pooling the expertise of each group if the world is to shift towards the upside scenario.

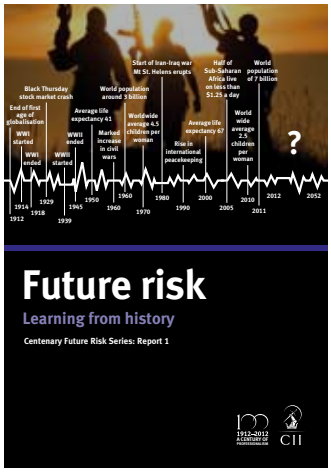
Insurers can and are playing a crucial role here by spreading awareness about climate risk through the pricing of natural hazards, by providing economic incentives for the construction and maintenance of resilient infrastructure and by sharing knowledge and data with policymakers. Insurers are already deeply involved in many of these processes and have won praise for being one of the few industries to have been regularly warning about the risks of climate change.[85] But over the coming decades the industry must embed itself deeper into the multitude of channels and networks through which it can help to ensure that adaptation is not ignored and mal-adaptation is avoided. Innovation will be key to this – both in terms of developing new products like those linked to microfinance as well as through better forecasting of climate risk. And insurers need to continue to be innovative in the way that they engage with policymakers to ensure that their unique insights are fully utilised at the national and international level.

The next report

In our next report within the centenary series, we will look at possible technological futures. Similar to this report, experts will set out diverse and compelling narratives on what the future might hold, and we will seek to build a number of simple scenarios to set out some implications for the insurance and financial services industry.

85 See for example, Jules Boykoff (June 2011) "Why the insurance industry gets climate change", article for the Guardian, last accessed 29 May 2012: http://www.guardian.co.uk/commentisfree/cifamerica/2011/jun/28/climate-change-climate-change-scepticism

Previous reports within the Future Risk series



Future Risk: Learning From history

The first report within our centenary series reflects on past trends and their potential implications for future risk as well as discussing some initial findings from a global survey into the risk perceptions of members of the public from across the globe. It set out the methodology for the entire series and identified themes for further investigation.

Report accessible via:
http://www.knowledge.cii.co.uk/system/files/CII_Future_Risk_Learning_From_History_Final_WEB.pdf

Future Risk: Social and Economic Challenges for Tomorrow

The second report in the centenary series focuses on some of the big socioeconomic risks identified by the first report. Utilising expert analysis from George Magnus of UBS Bank and David Smith of The Sunday Times amongst others, we outlined three possible socioeconomic scenarios and their potential implications for the insurance industry. We then discussed how the industry can play a key role in determining a better future.

Report accessible via:
http://www.cii.co.uk/media/1735259/centenary_socioeconomic_report_final_web.pdf

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