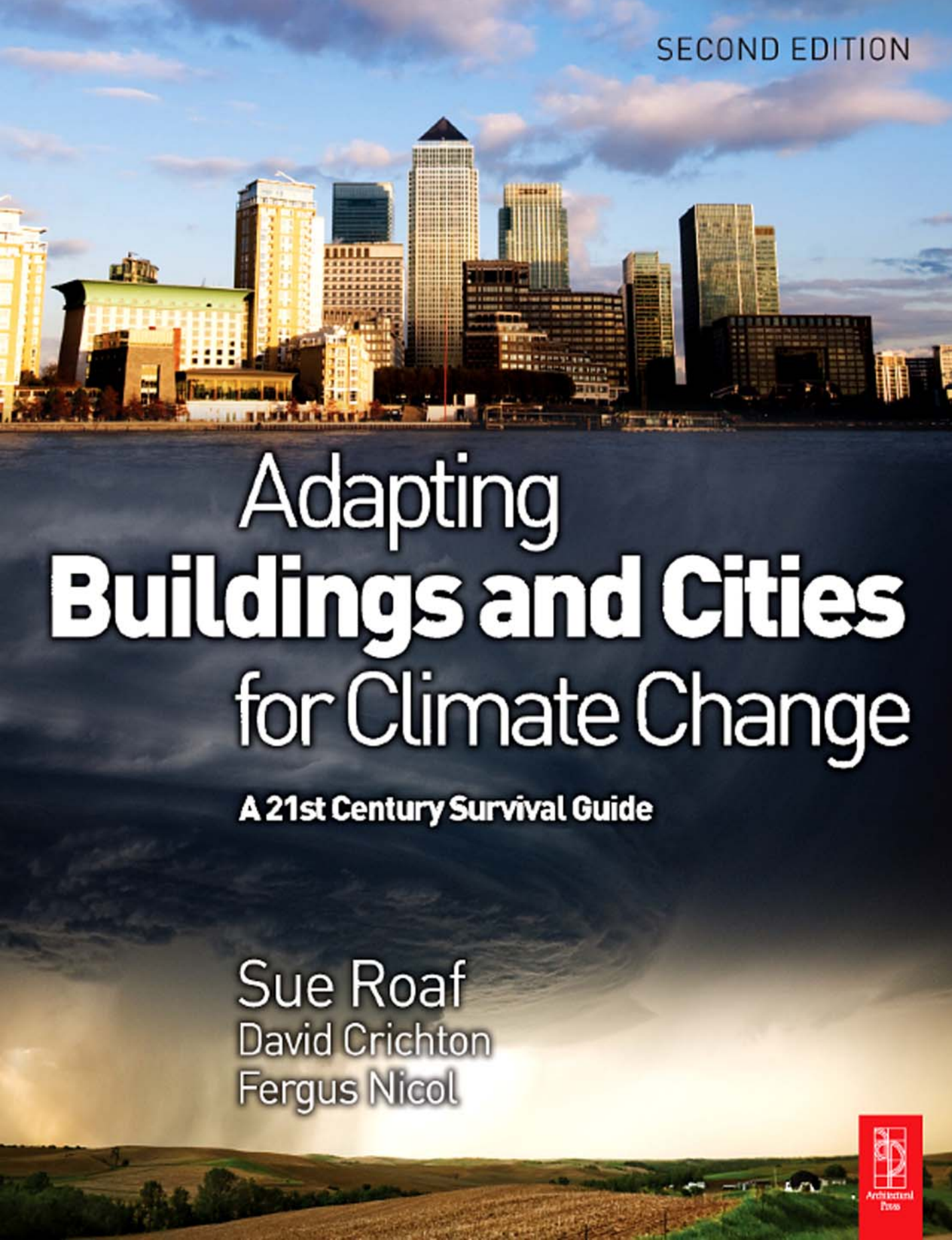
SECOND EDITION
Adapting
Buildings and Cities
for Climate Change
A 21st Century Survival Guide
Sue Roaf
David Crichton
Fergus Nicol
Architectural Press

ADAPTING BUILDINGS AND CITIES FOR CLIMATE CHANGE

A 21st Century Survival Guide

Second Edition

Sue Roaf

David Crichton and Fergus Nicol

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PREFACE TO THE SECOND EDITION

Much has changed since I wrote the preface to the first edition of this book in 2004. The possibilities we wrote of then have begun to manifest themselves as realities in the forms of floods, fires, famines and economic meltdown. The simple question I asked then, however, about why are we doing it all wrong, has not been answered.

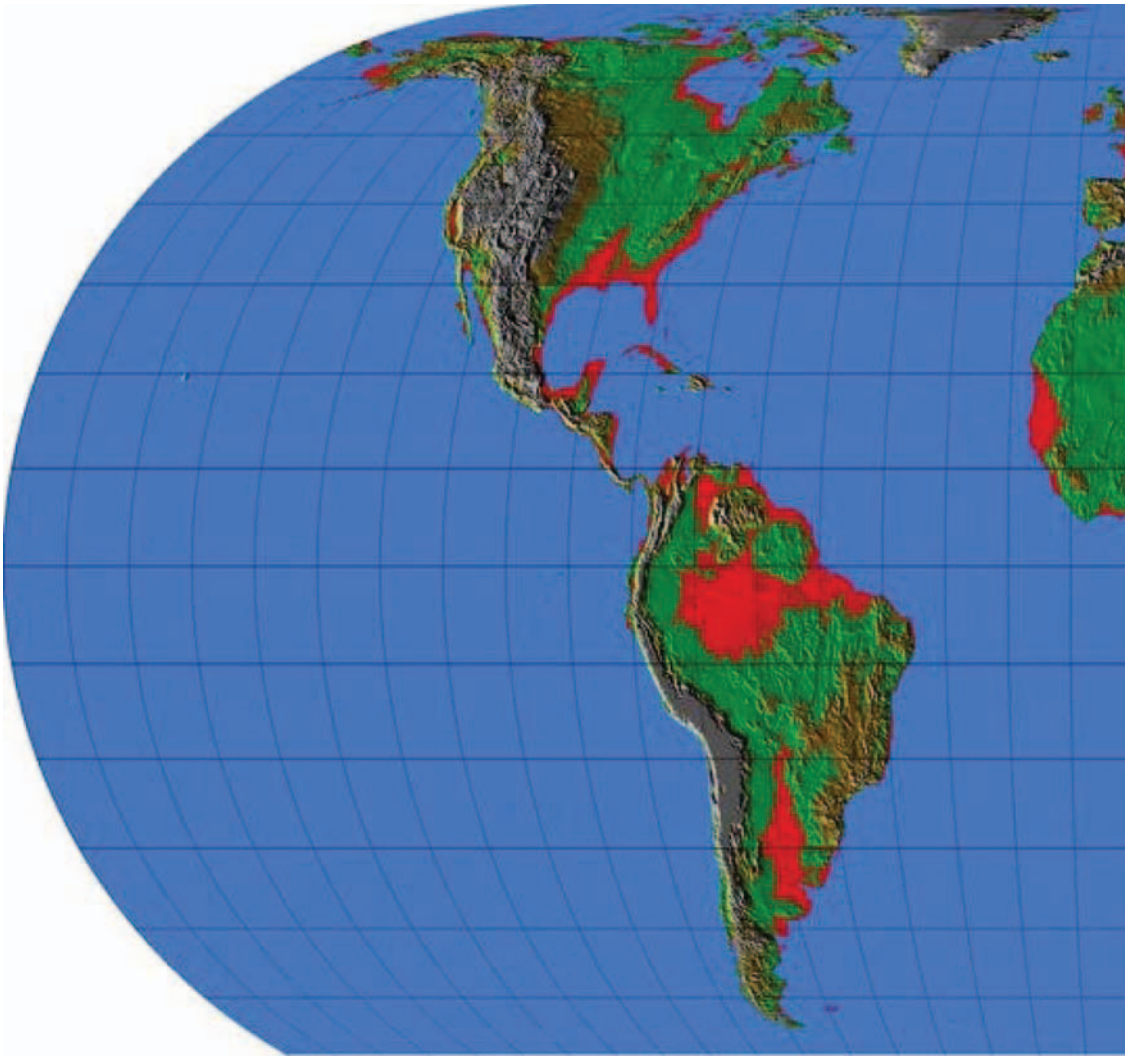
What has really surprised me has been the rate of the changes we see happening all around us. In 2003 the best science told us that the summer Arctic ice would be gone by 2070 and we were shocked. We were recently told that it may be gone in less than a decade. Reports are out that suggest that fundamental resources like Lake Mead in Nevada, the body of water in a hot desert that provides the water and energy for Las Vegas, may be gone within decades. We were told in 2003 that we must not exceed 550 ppm of carbon dioxide (CO_2) in our atmosphere if we want to comfortably survive, now that figure has fallen to 350 ppm, well below current levels.

Today we look around and see a world divided between those who are unrestrained in their energy profligacy, building irresponsible cities where cities should never be, vying to see who can build the tallest building in the world and literally unconnected to the fact that they are contributing to the destruction of our common future. Do they really think that in 10 years' time anyone will want to own or occupy such buildings that are even now environmental pariahs? Are such people so out of touch with reality?

On the one hand, we see the growing generation of climate change refugees, from Myanmar and the Maldives to Hull and Tewkesbury, people who have lost their homes, their livelihoods and all too often their loved ones. Many different groups are now deeply affected by the 'Perfect Storm' we are entering, from those driven from their lands by heat and drought to investors who have been landed with a generation of buildings they can no longer afford to cool in a warming world, or are able to sell.

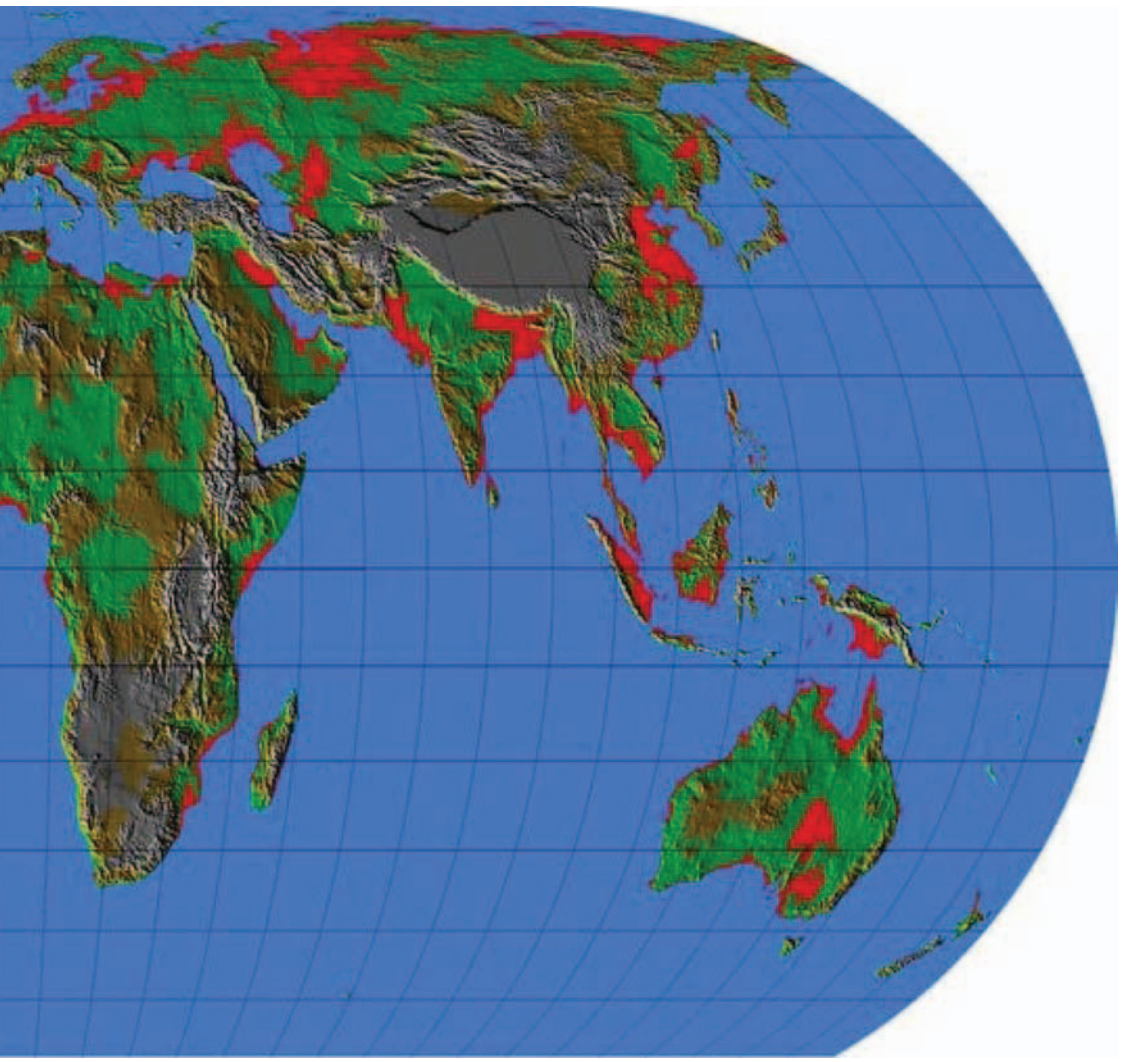
On the other hand, we see ordinary people and communities stepping up to take the lead, where so many of our so called 'leaders' have failed us, and new paradigms of how buildings and communities can be resourced and organized to protect the quality of life of those in them. We are on the threshold of a new and truly twenty-first century language of low-carbon and resilient buildings informed and born of the Global Commons.

The final conclusion of our book is pretty stark. We have been told by the science that we only have a few years to reduce our carbon emissions to levels that will prevent climate chaos, to



1.
Map of the world showing in red those areas that would be inundated if all the ice caps melted, causing a rise in global sea levels of up to 100 m.
Source: Laurence Williams (2002) *An End to Global Warming*. Pergamon. Reproduced with permission.

effectively mitigate. We believe that in the face of rapid and catastrophic change the more pressing challenge is to develop the processes by which we can adapt to at least three degrees of climate change in the coming handful of decades. All around us now is evidence that many are not taking the scale of task ahead seriously. There is no doubt that much can be achieved with new approaches to design, and technological fixes, but it is ultimately only with a fundamental re-ordering of our priorities, our aspirations and our societies that we will create a social, economic and physical environment in which *Homo sapiens* can hope to survive, en masse, safely, through to the end of this century.



This may be a pretty tall order but with the pace of environmental change in the world around us speeding up, perhaps we will find the will and the way, together, to adapt our buildings and cities, economies and societies in time, because we certainly cannot do it alone.

Sue Roaf
April 2009

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At Architectural Press thanks go to Hannah Shakespeare and Mike Travers.

It should be noted that the views expressed in this book are solely those of the authors.

ABOUT THE AUTHORS

Sue Roaf

Sue Roaf is Professor of Architectural Engineering at Heriot Watt University, Edinburgh, and Visiting Professor at the Open University. With degrees from Manchester University, The Architectural Association and Oxford Polytechnic, she has worked widely on ecobuilding design, carbon accounting, adapting buildings and cities for climate change, traditional technologies, and sustainable and low-carbon buildings. She co-designed and owns the Oxford Ecohouse, the first building in the UK with a photovoltaic roof, and does much to promote resilient low-impact and low-carbon architecture through the research, teaching, publishing and conferences she organizes on Solar Cities, Carbon Counting, Architectural Education, Thermal Comfort and Post Occupancy Evaluation. Her PhD was on the Windcatchers of Yazd and she spent 10 years in Iran and Iraq as an architect, archaeologist, anthropologist, lecturer and landscape architect. She has two sons, Christopher and Richard. She has written and edited 10 books, including *Ecohouse*: *A Design Guide*; *Closing the Loop: Benchmarks for Sustainable Buildings*; and *The Ice-Houses of Britain*. She lecturers widely to audiences around the world.

Fergus Nicol

In the 1960s and early 1970s Fergus Nicol researched building physics and human thermal comfort at the Building Research Establishment and the Human Physiology Unit of the Medical Research Council. He also taught in the Schools of Architecture at the University of Science and Technology in Kumasi Ghana and the Architectural Association in London. After a period managing a bookshop he returned to teaching and research in 1992.

Fergus is best known for his work in the science of human thermal comfort, where he has developed, with Professor Michael Humphreys, the 'adaptive' approach to thermal comfort. He has run a number of projects over the last 15 years funded by the EPSRC and other funding agencies and a major EU project, Smart Controls and Thermal Comfort (SCATS). He is a professor at London Metropolitan University, where he is deputy director of the Low Energy Architecture Research Unit (LEARN). He is an affiliated Professor at Heriot Watt University and Emeritus Professor at Oxford Brookes University.

Fergus is a member of UK and European consultative committees on comfort issues. He is helping CIBSE to write the new edition of their Guide A and is an active member of their

Overheating Task Force. He was responsible for the international conference *Air Conditioning and the Low-Carbon Cooling Challenge* in Windsor, UK, in July 2008, attended by many international experts in thermal comfort and thermal comfort standards. He is convenor of the Network for Comfort and Energy Use in Buildings, which boasts nearly 300 members from all over the world and in a wide variety of academic disciplines, consultancies and government bodies.

David Crichton

David is an economist with 30 years' experience in the insurance industry. He has held senior underwriting and claims management positions in both property and casualty business, and has won a number of insurance industry awards, including the first AIRMIC risk management prize awarded to an insurance practitioner. He is a freelance consultant and researcher on climate change impacts and insurance. He has authored a number of books, reports and papers on insurance and climate change.

David has advised governments and insurers in four continents, and has worked for the Association of British Insurers, the CII, the DTI, EU, NATO, NOAA, OECD, various branches of the United Nations, and WWF. He has also been a member of several academic or research boards in the UK. He is a Visiting Professor at the Benfield UCL Hazard Research Centre at University College London This is the leading academic hazard research centre in Europe, specializing in natural disasters and insurance (http://www.benfieldhrc.org/). He is also Visiting Professor at Middlesex University Flood Hazard Research Centre, an Honorary Research Fellow at the University of Dundee, a Fellow of the Chartered Insurance Institute and a Chartered Insurance Practitioner. He is a member of the UK Advisory Committee on Natural Disaster Reduction, part of the United Nations ISDR initiative.

Janet Rudge

Janet Rudge is currently the Energy Officer for Ealing Borough Council, specializing in programmes for the Fuel Poor. She is a registered architect and has worked in both public and private offices. Since 1992 she has researched and taught Environmental and Energy Studies at the University of East London and the Low Energy Architecture Research Unit (LEARN) at London Metropolitan University. She has also worked helping to establish the Network for Comfort and Energy Use in Buildings. Her own research has concentrated on fuel poverty and health, with publications including papers in, for example, the *International Journal of Biometeorology*, *Journal of Public Health* and *Energy and Buildings.* She co-edited, with Fergus Nicol, *Cutting the Cost of Cold: Affordable Warmth for Healthier Homes*, a multidisciplinary reference source on the health impact of cold homes. Dr Rudge is currently an invited lead expert on cold homes for a World Health Organization European project to assess the burden of disease of inadequate housing.

Sari Kovats

Sari Kovats is a lecturer in Environmental Epidemiology at the London School of Hygiene and Tropical Medicine. Her areas of interest are in health issues related to climate change, and she has published widely on the health impacts of heatwaves and associated public health responses,

the role of temperature in the transmission of food-borne and water-borne disease, the association between temperature and rainfall and mortality in cities and the health impacts of flooding. She was a Lead Author in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

2.
Social equality is an essential ingredient for secure communities in changing times: San Paolo, Brazil.
Source: Photobucket.com

PREFACE TO THE FIRST EDITION

This is a book I have been thinking about writing for over 25 years. Every study I have worked on, in those intervening years, has been a stepping-stone towards this publication on the future of architecture. That journey started in the far distant past, in the ancient villages and cities of Iraq, the cradle of civilization where, through seven years of excavation, we touched the lives of those people who ate from the pots, played with the toys, drove the chariots and built the buildings that we uncovered, not decades or centuries, but millennia ago, on the once fertile plains, once again scarred by war. The path to this book passed through nomad tents on tribal roads, and across vast deserts where families, using little more energy than twigs to cook on, lived in comfort, and in some cases luxury, in the extreme climates of what we would see only as barren lands.

Climate in those regions, on the fringes of agriculture, has always been about survival, but the study that first alerted me to the scale of the potential impacts of climate change on our lives in the more temperate lands was one, not on buildings in hot deserts, but on the ice-houses of Britain. Writing on their history in the 1980s, it became obvious that this ancient technology, forgotten behind the miracle of refrigeration, had become climatically obsolete as the world warmed, and that even very small changes in global temperatures, fractions of a degree, could be responsible for the demise of a great international industry, if those changes cross a critical thermal threshold, such as the temperature at which ice melts.

Figure 1 shows how central to our very survival the simple substance ice is, and what a key role it is playing in the re-ordering of global climates, oceans and landscapes.

By the late 1980s the growing global problems of ozone depletion and climate change were beginning to be talked of more often. My concern was growing at the unfairness of the reality – that people in the developing countries are already dying in large numbers because of climate change, whilst it is those in the West who are generating the carbon dioxide emissions that are warming the world.

The desire to show that it need not be like this led to the building of the first photovoltaic home in Oxford, in which my family still comfortably resides. This simple building emits only a few hundred kilograms of CO_2 a year instead of five or six thousand and is *more* comfortable than a highly polluting one. We cut down our greenhouse gas emissions to less than 10% of typical emissions with no loss of quality of life. So why isn't everyone doing it? Why are architects building 'glass houses' and windowless plywood 'blobs' instead of the types of solid, resilient, buildings that offer us some hope for survival in the coming decades?

It beats me! But what I do know is that the road that many of us have followed from the Energy Crisis of the 1970s through the growing issues of climate change, fossil fuel depletion and sustainability has led us towards a present, and a future, that is very different from anything that has been before. One can see why many people want to avoid thinking about it – a future where the issue is increasingly not about comfortable concepts like 'sustainability', but about the harsher realities of designing for 'survival'.

If only the global community had acted more firmly in the 1970s when they saw the challenges ahead perhaps we would not now be facing the predicaments around us! The unavoidable truth is that it has been left to our generation alone, of all those that have come before, to face the awesome challenge of redesigning the world to accommodate the new forces of the late fossil fuel age, of dark cities, a world of slowing economic growth, of climate change and an exploding global population.

It is the scale of the catastrophic changing of circumstances around us that makes it difficult to grasp at any heart to the problem. We are still only equipped with the old ways of thinking, that showed us an illusion of a clear path ahead. But many of us who, for years, have been watching, and working so diligently to get a handle on controlling the impacts of late-twentieth-century development have been surprised by how wrong we got it. We have only been scratching the surface of the problem. In what we once saw as the manageable game of sustainable development, our eyes have been so far off the ball that what follows in this book may be unbelievable, or unpalatable, to many readers. Very few people – remarkable among them being my co-authors David Crichton and Fergus Nicol and the pioneering thinker Edward Mazria[1] – have been able to see beyond the 'business as usual' carrot that draws us, blinkered, on our way.

Few have questioned the horizons, or understood that what we once saw as a single, efficient, road forward to a clean, bright, future has now widened out into a quagmire of complex interrelated forces that urgently require us to think outside the envelope of our own buildings, and above all, to open windows, to embrace a new age of architecture, planning and politics of development. We *can* make a difference, we *can* leave a world fit for our children and grandchildren, but the task is urgent and the task is huge.

Can it be that for decades we have been looking for the warnings in all the wrong places? Because the one thing that is increasingly clear is that the writing is now on the landscape, and the wall.

Sue Roaf

NOTE

1 See <http://www.metropolismag.com/html/content_1003/glo/index.html>.

ACKNOWLEDGEMENTS TO THE FIRST EDITION

My heartfelt thanks go to my co-authors David Crichton and Fergus Nicol, both of them visionaries in their fields. Also to those who have so generously contributed to the contents of the book – Janet Rudge, Sari Kovats, Fiona Mullins, Aubrey Meyer, Colin Campbell – and all of those who have helped in preparing the contents of this book through thought, word or deed.

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The Ecology Building Society
Friends of the Earth

It should be noted that the particular views expressed in this book are solely those of the authors.

1 CLIMATE CHANGE: THE BATTLE BEGINS

WAR IS ALREADY UPON US

The war against climate change pitches mankind against a global threat that vastly eclipses that of terrorism,[1] in battles that have already claimed the lives of hundreds of thousands of ordinary men and women from every continent. Climate change has led us into an era in which war and conflict are endemic,[2] the widespread extinction of species approaches catastrophic proportions,[3] and whole regions and countries will be lost beneath the swelling seas and the expanding deserts of a rapidly warming world. And the really bad news is that 'the world has only one generation, perhaps two, to save itself'.[4]

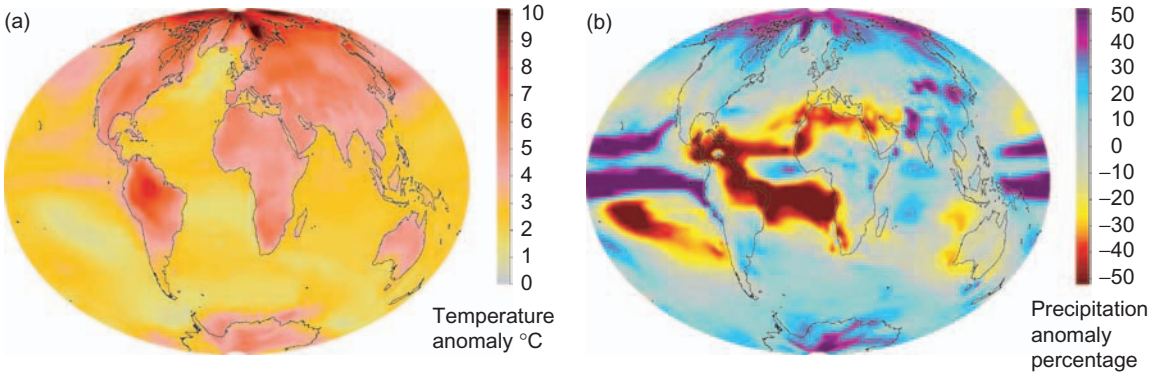
We all instinctively know, already, that the climate is changing, from the small noticed things like the unseasonable patterns of the flowering of plants, the falling of snow and the growing in strength of the wind and the rain. With this knowledge comes a growing apprehension of danger. Deep down, in quiet moments, we ask ourselves questions that a year or two ago were unthinkable:

- What will I do when the lights do go out?
- Will the house flood next year?
- Will my home get so hot this summer that I won't be able to stay in it?
- How long could I survive in this building without air conditioning?
- Where will we go?
- Will we survive?

This book is written to enable you, the reader, to get a clearer view of the ways in which the climate is changing and how these changes will affect *your* life tomorrow and the day after, in the buildings, settlements and regions in which you live and work. Only by emotionally registering, by consciously taking on board, the scale of the impending global disaster ahead will any of us find the strength to act in time to avert the worst of its impacts.

But not only do we have to act fast, we also have to act *together*. Actions will only be effective if we all act together because each of us is 'involved' in the fate of all mankind through the common air that we breathe and the climate we occupy.

As you will see throughout this book, people can apparently be 'familiar' with the excellent science of climate change, and 'know' intellectually the problems that exists, but still fail to engage



1.1.
Scientists have established that climate change is really happening and can, to an extent, model future climates. Here we see the change in the annual average (a) temperature and (b) precipitation, predicted for the 2080s period, relative to 1961–1990, for one climate model, the HadCM3 ensemble-average under an A2 forcing scenario.
Source: *UKCIP02 Scientific Report*,[5] p. 19.

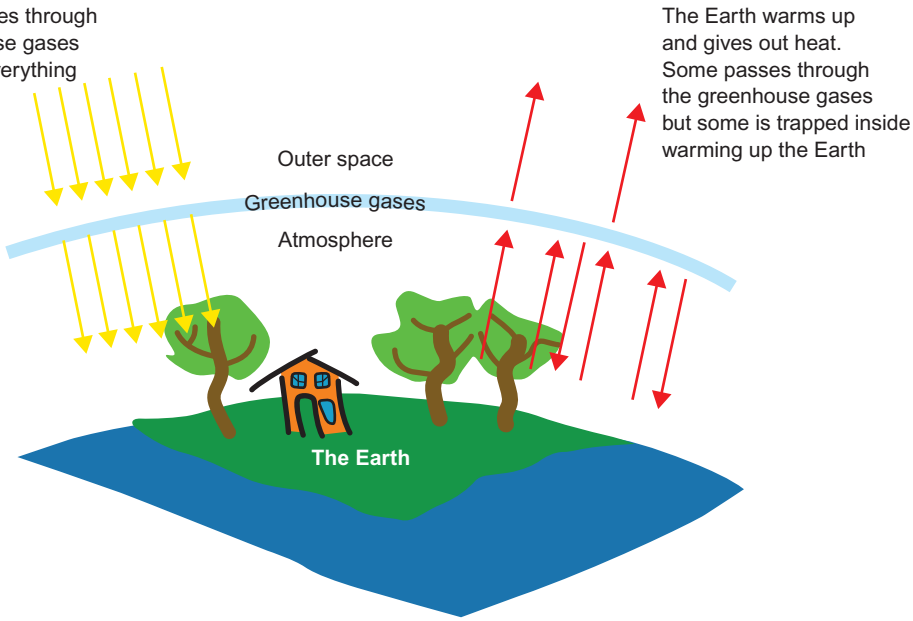
with them, or act upon that knowledge. We know now that many of the gases we emit from the burning of fossil fuels are altering the climate. Every schoolchild learns, or should learn, how these gases are building up in the upper atmosphere to form an increasingly dense layer that allows solar radiation into the Earth's atmosphere, but as this layer gets denser, it prevents more and more heat from radiating back out into space, so warming the lower atmosphere and changing our climate.[6]

The evidence for climate change is growing more alarming each year. The exceptionally hot summers such as those of 2003 and 2005 warned experts that the pace of this warming is faster than previously envisaged in their worst case scenarios.[7] Yet rather than acting to reduce emissions, many apparently well-meaning and well-informed people appear to act wilfully to make the situation worse in communal acts of 'denial', and nowhere more so than in the built environment. Buildings are responsible for producing over half of all climate change emissions, but year on year, 'modern' buildings become more and more energy profligate and damaging to all our children's future. Climate change is personal. 'They' are harming 'our' grandchildren.

In London, for instance, where more is known about the urban impacts of climate change than for almost any other city in the world, the Greater London Authority and the then Deputy Prime Minister heavily promoted the huge developments of the Thames Gateway area. Situated to the east of the capital on the coastal flood plains of the Thames Estuary this area has periodically flooded throughout history, well before rising sea levels and stronger storm surges increased the risk of loss of life and property to the seas here. Leading architects have even suggested that proposed settlement densities are too low, even when they must 'know' of the risks of putting buildings and people in such locations. Are such architects going to live there themselves? Are they ignorant or simply cynically exploiting a business opportunity? How much do such architects and developers really 'know'?

Former US President George W. Bush had repeatedly refused to acknowledge that climate change is happening at all, to the extent that by the end of 2003 there were 12 US states suing the US Environmental Protection Agency because of the failure of the US Government to take action against climate change. And yet the US administration knows of the dangers of climate

(a)



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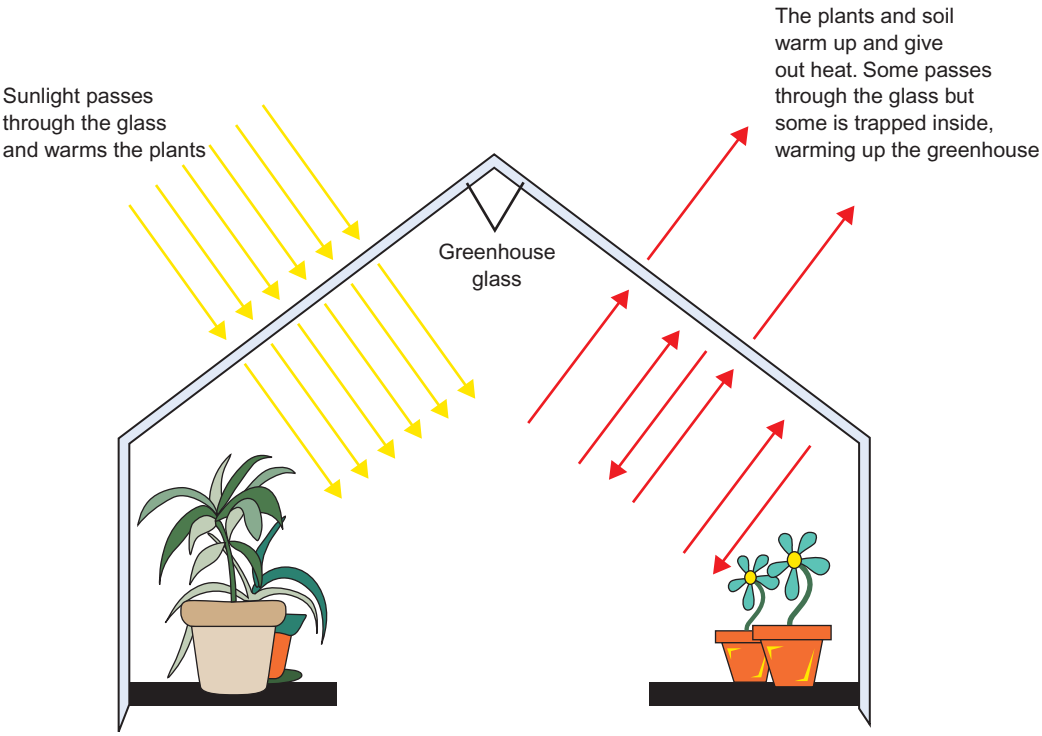
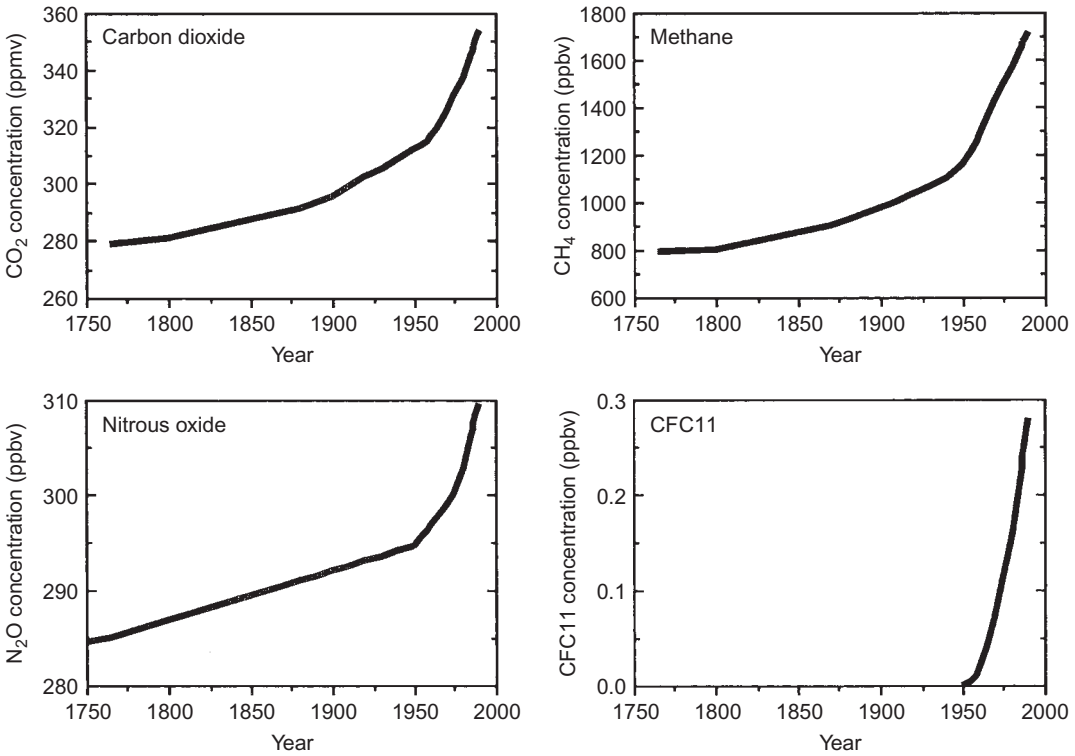
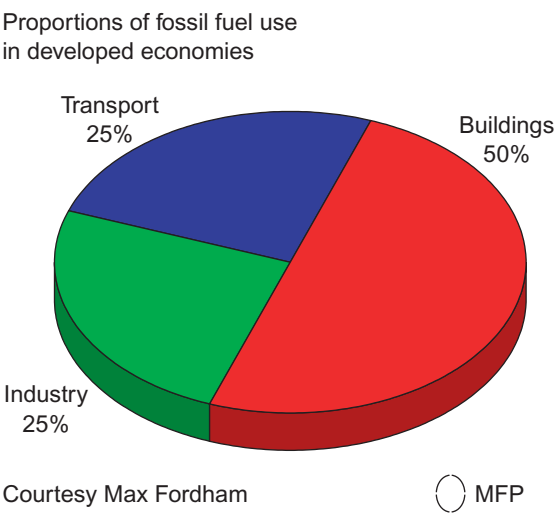


1.2.
The basics of climate change are taught in all British schools and such images of how the greenhouse effect (b) works in relation to the global atmosphere (a) are very familiar to children by the age or 7 or 8.
Source: http://www.defra.gov.uk/environment/climatechange/schools/12-16/info/cause.htm.



1.3.
In the middle of the twentieth century more and more of the world's rapidly growing population bought cars and heated and cooled their buildings, resulting in a rapid increase in concentrations (parts per million/billion by volume) of the major greenhouse gases in the global atmosphere: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and CFC11.
Source: Houghton J.T., Jenkins, G.J., Ephraums, J.J. (eds) (1990) *Climate Change*: *The IPCC Scientific Assessment.* Cambridge: Cambridge University Press, p. xvi.



1.4.
Graph showing the relatively large impacts of buildings in the developed world in terms of their emissions of climate change greenhouse gases.
Source: Max Fordham and Partners.

change to their own homeland because a Pentagon Report in 2003 told them of the endemic war and conflict the world would face as a result of it.[2] Bush changed his mind on this issue in 2007 when he publicly admitted that climate change was happening and yet his administration continued to obstruct action to mitigate and adapt to the changing climate. His successor Barak Obama had swiftly passed a radical Climate Change Bill through Congress in June 2009.

The Australian government continues to be oblivious to the pleas for shelter of the islanders of Tuvalu, where the whole island is more frequently being covered completely by the rising sea every year; and, with impending disaster so close to their own doorsteps, the Australians are refusing not only to give the islanders a refuge but also to consider cutbacks in their own greenhouse gas emissions, on this, the most vulnerable continent on the planet to the impacts of the warming climate. But, perhaps it is too difficult to connect the idea of gas emissions to environmental impacts in remote islands, and it could be understandable that the Australian people feel no sense of responsibility for the plight of the people of Tuvalu, despite the fact that the government of Australia has now begun to take on board the severity of the impacts of climate change as a result of an entrenched drought in parts of the country and the recent report to government of Ross Garnaut on their dire social and economic implications for Australia. But how much do the Australian people 'know' about the plight of their own sunburnt country in a changing climate? Drought is teaching them rapidly now.

Should the word 'know' here be replaced, perhaps, with 'care'?

No wonder that so many people today feel that 'it's a mad world', but why? Surely we are a rational species? Perhaps it all has to do with the actual process of changing, the extent and speed of the required changes, and the costs and risks of acting, or not acting, to make those changes happen.

J.K. Galbraith noted in 1958 that 'conventional wisdom' generally makes people indisposed to change their minds and reminds readers of John Maynard Keynes' famous words:[8]

> Conventional wisdom protects the continuity in social thought and action. But there are also grave drawbacks and even dangers in a system of thought which by its very nature and design avoids accommodation to circumstances until change is dramatically forced upon it … the rule of ideas is only powerful in a world that does not change. Ideas are inherently conservative. They yield not to attack of other ideas but to the massive onslaught of circumstances with which they cannot contend.

We are faced now with the massive onslaught of the circumstances of climate change. This book describes some of those circumstances in relation to buildings, settlements and lifestyles of this, and future decades. As you read on it will become clearer how very difficult, if not impossible, we will find it to contend with the impacts of climate change, to meet head on the challenges of changing 'social thought and action', and to redirect the supertanker of conventional wisdom.

That is why you, the reader, are important, and why this book has been written to make you 'disposed to change your mind', and in turn change the minds of those in your circle of influence, and those in theirs, and so on until the ripple grows to be a tidal wave of change in the attitudes of our society. And though none of us wants it, and we may wish that we lived in different times, it is the responsibility of each and every one of our generation, and ours alone in the whole history of humankind, to take up arms in this battle for our very survival.

But why has it taken us so long to act? The Climate War is already upon us. How did it come to this?

THE ENEMY WAS SIGHTED LONG AGO

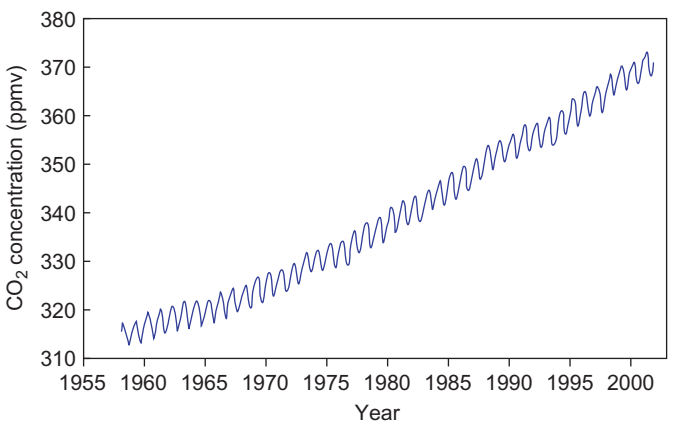
The possibility that the climate could be changing was first identified as far back as the 1960s, and the battle against climate change, and its main contributory gas, carbon dioxide (CO_2), began.

Physical measurements of global CO_2 emissions have been taken since the 1950s.[9] The Mauna Loa atmospheric CO_2 measurements constitute the longest continuous record of atmospheric CO_2 concentrations available in the world. The clear upland atmosphere of the Mauna Loa volcano on the Pacific island of Hawaii is one of the most favourable locations on the planet for measuring undisturbed air because possible local influences of vegetation or human activities on atmospheric CO_2 concentrations are minimal and any influences from volcanic vents may be excluded from the records.

The methods and equipment used to obtain these measurements have remained essentially unchanged during the 50-year monitoring programme. Because of the favourable site location, continuous monitoring, and careful selection and scrutiny of the data, the Mauna Loa record is considered to be a precise record and a reliable indicator of the regional trend in the concentrations of atmospheric CO_2 in the middle layers of the troposphere. The record shows an 18% increase in the mean annual concentration, from 316 parts per million by volume (ppmv) of dry air in 1959 to 373 ppmv in 2002 and 389 in 2009. The 1997–98 increase in the annual growth rate of 2.87 ppmv was the largest single yearly jump since the Mauna Loa record began in 1958.

Such data are used to inform and validate the computer models of the climate[10] which have been used to depict and predict former, current and future climates right down to a resolution of fifty, and now even five, kilometre squares.[11] Such models have provided sufficiently credible evidence, where, for instance, predicted temperatures resemble closely temperatures experienced, for the virtually universal consensus amongst internationally respected scientists and meteorologists that increasing atmospheric concentrations of CO_2, and other gases, with significant absorptivity in the far infrared, 'the greenhouse gases', have already led to significant changes in the climate of the world with far-reaching implications for everyone on this planet.[12]

It was the scientists who charted, and modelled, the first manifestations of the enemy that threatens our species, but issues such as the changing climate, the loss of biodiversity, terrestrial and atmospheric pollution, and resource depletion, are only the standards of the enemy, caught flying in the wind. What the intellectuals, economists and politicians did was to identify the real enemy in our ecosystem – ourselves.



1.5.
The Mauna Loa carbon dioxide record, 1958–2002.
Source: Climate Monitoring and Diagnostics Laboratory of the US National Oceanic and Atmospheric Administration, Mauna Loa, Hawaii.

THE WARNING IS SOUNDED

The global environmental trumpet was sounded for the first time, warning of the enormity of the problems we face, at the first general meeting of the Club of Rome in 1970. The meeting was convened to discuss the state of the world and the development of a computer model of world '*problematique*', to include issues with global dimensions such as population, resources and environment.[13]

In 1970 and 1971, the first large-scale modelling studies of global environmental conditions were actually created, both prepared as input to the 1972 United Nations (UN) Conference on the Human Environment, and both noting the possibility of 'inadvertent climate modification'. The Study of Critical Environmental Problems (SCEP) focused on pollution-induced 'changes in climate, ocean ecology, or in large terrestrial ecosystems'. It cited the global climate models as 'indispensable' in the study of possible anthropogenic climate change.

In 1971 the influential *Study of Man's Impact on the Climate* (SMIC)[14] also endorsed the climate models. Both SCEP and SMIC recommended a major initiative in global data collection, new international measurement standards for environmental data, and the integration of existing programs to form a global monitoring network. These reports are widely cited as the originators of public policy interest in anthropogenic climate change and all these early studies predict 'overshoot and collapse'.

By the time that Edward Goldsmith and four colleagues published their seminal book *A Blueprint for Survival*[15] in 1972, climate change had been woven into the fabric of wider environmental concerns, even by non-experts in the climate field, such as these authors. The book contained a general plea for the application of ecological common sense in the face of mounting evidence of the approaching global environmental crisis.

The Blueprint demanded a radical change in our approach to the environment, necessary if we are indeed to avoid 'undermining the very foundations of survival' for our species and the planet, citing the rise in global population, the increase in per capita consumption, disruption to ecosystems and depletion of resources at a rate that was not supportable. These trends, they estimated, would inevitably lead to a collapse in society if nothing was done about it. They, interestingly, foretold that politicians would tend to act to exacerbate the problems rather than act to solve them:

> At times of great distress and social chaos, it is more than probable that governments will fall into the hands of reckless and unscrupulous elements, who will not hesitate to threaten neighbouring governments with attack, if they need to wrest from them a larger share of the world's vanishing resources.[16]

The book was, however, largely concerned with the impacts of overexploitation of the Earth's resources, the underlying problem that lies at the very root of our dilemma today. It provided excellent benchmarks against which we can measure the extent to which our species has effectively degraded the natural capital of our planet and polluted its ecosystems. But the authors also mention, in a couple of paragraphs, the potential for CO_2 emissions to lead to significant climate change:

> The CO_2 content of the atmosphere is increasing at a rate of 0.2 per cent per year since 1958. One can project, on the basis of these trends, an 18 per cent increase by the year 2000, i.e. from 320 ppm to 379 ppm. SCEP considers that this might increase temperature of the earth by 0.5°C. A doubling of CO_2 might increase mean annual surface temperatures by 2°C.

They were subsequently proved to be very close to the actual recorded warming between 1947 and 1997 of between 0.25 and 0.5°C.

In the early 1970s, several other large-scale atmospheric issues came to the attention of the general public. Notable among these were acid rain, upper-atmospheric pollution problems raised by supersonic transport and stratospheric ozone depletion. What is so difficult to grapple with is the issue of who exactly is the invisible enemy in this war, where are they, who owns the problem and how does one fight against air?

FIRST ENCOUNTERS

While the scientists of the world have long been wrestling with the theoretical problem of climate change and resource depletion, for the general public the first of the 'environmental shocks' that brought home the reality that the twentieth century dreams of infinite cheap energy and limitless resources were unrealistic was the Energy Crisis of the mid-1970s. With it came the dawning realization that oil, the magic energy source from which the wealth and enjoyment of nations was built, of which every barrel can do the same 'work' as 540 man-hours of effort,[17] would one day run out. Futurologists then claimed we only had 30 years of oil left, a prediction that has proved to be, perhaps, less than half right, but globally, people started counting the barrels, and comparing them to the available reserves, and understandably, investing in renewable energy programmes.

The first public blow had been struck; mankind was perceived to be vulnerable and, by now, officially engaged in a battle, not against the air, but against their own fossil fuel dependency and time, two equally powerful adversaries. And the richest nations, ironically, became the most vulnerable.

THE WEAPONS ARE HONED

In 1971 SMIC had recommended that a major initiative in global data collection, new international measurement standards for environmental data, and the integration of existing programs to form a global monitoring network should be developed. The ozone challenge provided the perfect opportunity to see how effectively mankind, communally, could respond to what appeared to be a rapidly developing, global, catastrophe.

Ground-based measurements of ozone were first started in 1956, at Halley Bay, Antarctica. Satellite measurements of ozone started in the early 1970s, but the first comprehensive worldwide measurements started in 1978 with the Nimbus-7 satellite. In addition to the physical measurements, in 1974 M.J. Molina and F.S. Rowland published a laboratory study[18] demonstrating the ability of chlorofluorocarbons (CFCs) to catalytically break down ozone in the presence of high-frequency ultraviolet (UV) light. Further studies estimated that the ozone layer would be depleted by CFCs by about 7% within 60 years.

Based on the recommendations of such studies, the USA banned CFCs in aerosol sprays in 1978, showing a level of real leadership at this stage, which spoke of the courage of the then US administration. Slowly, various nations agreed to ban CFCs in aerosols but industry fought the banning of valuable CFCs in other applications. A large shock was needed to motivate the world to get serious about phasing out CFCs and that shock came in a 1985 field study by Farman, Gardiner and Shanklin[19] that summarized data that had been collected by the British Antarctic Survey showing that ozone levels had dropped to 10% below the normal January levels for Antarctica.

The severity, and rate, of the global ozone depletion spurred the UN to sponsor a resolution called the Montreal Protocol that was originally signed in 1987, based on negotiations started between European–Scandinavian countries and the USA over CFCs in aerosol sprays in 1983. The protocol went through a series of revisions, each one named after the city where the revision committee met, as new information from science and industry has become available. The meeting in Copenhagen in November 1992 laid down the most stringent phase-out schedule of CFCs for the world to date; and was signed by over 100 nations representing 95% of the world's current CFC consumption. Trade sanctions on CFCs, halocarbons and products containing them, were imposed as of April 1993 on nations not signing the protocol, and in May 1993 this ban was extended to the export of halocarbon solvents such as methyl chloride and carbon tetrachloride. This protocol laid out a schedule for the phase-out of CFCs and related halocarbons by the year 2030. An additional impact of the protocol was to mandate the sharing of technology between countries in order to speed the replacement and recycling of CFCs.

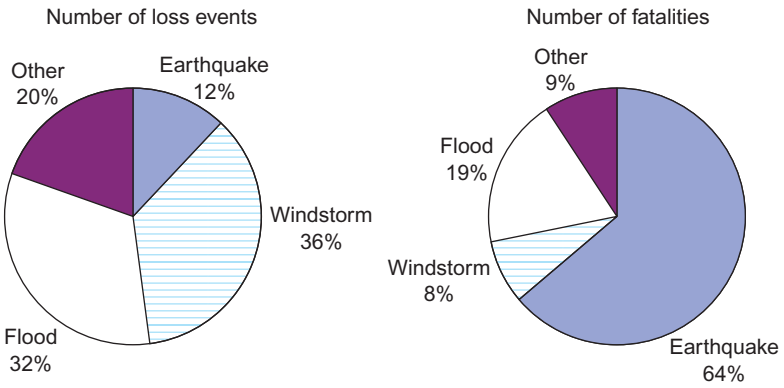
In 1988, Sweden was the first country to legislate the complete phase-out of CFCs, with a scheduled phase-out in all new goods by 1994. In March 1989 environmental ministers of the European Parliament announced a total phase-out of CFCs in Europe by the year 2000.[20] What the ozone problem demonstrated, to the world, is that when faced with a challenge as large as that of the stratospheric ozone problem, the global community has the science, the strategy, the will and the fiscal, legal and statutory mechanisms to contain that problem. It provided a precedent study for the larger challenge of containing climate change. It does offer some hope that we can act communally to maximize our chances of survival.

There has been significant variation in the size of the ozone hole over the past decade and while in August 2003, ozone values over Antarctica were already below 200 Dobson Units (DU), they rose sharply until 2006, when they descended to an almost record low. By 2007 they were back up at their 10-year average.[21] Scientists have predicted that with the reduction in ozone-depleting emissions the ozone hole could close up by 2070, but the actual scientific processes and climate impacts of the reduction in the size of the hole are only partially understood, for instance on surface wind speeds, although significant research is being carried out on the subject.[22]

THE COUNCIL OF WAR MEETS[23]

By the mid-1980s, the simulated predictions of the scientists on the warming climate began to demonstrate a close approximation to what was actually happening in the measured record, with clear evidence of increasing temperatures and the frequency and intensity of extreme weather events. The sheer scale of the problems humanity, and the planet, might face if, indeed, the climate was changing more than its natural variability would allow, began to manifest themselves, in the dollars spent in insurance payouts on climate events, the numbers killed in climate-related events, and the movement of species and deserts across the face of the globe.

In 1988, at the behest of national governments from around the world, the UN Environment Programme and the World Meteorological Organization, by now the 'War Council' leaders, established the Intergovernmental Panel on Climate Change (IPCC),[24] consisting of hundreds of leading scientists and experts on global warming. The Panel was asked to assess the state of scientific knowledge concerning climate change, evaluate its potential environmental and socio-economic impacts, and formulate realistic strategies to deal with the problem.



1.6.
Related number of insurance loss events and related fatalities by event types and number of fatalities in 2001.
Source: Munich Re, *Topics: Annual Review of Natural Catastrophes 2001*; for the 2002 review see http://www.munichre.com/pdf/topics_2002_e.pdf). Such figures underestimate climate-related deaths, as reported by other sources.

Two years later, in 1990, the IPCC published a report concluding that the growing accumulation of human-made greenhouse gases in the atmosphere would 'enhance the greenhouse effect, resulting, on average, in an additional warming of the Earth's surface' by the next century, with continued temperature increases thereafter unless measures were adopted to limit the emissions of these gases.

The findings of the First IPCC Assessment Report of 1990 played a decisive role in leading to the United Nations Framework Convention on Climate Change (UNFCCC),[25] which was adopted at the Earth Summit in Rio de Janeiro in 1992 and opened for signature. The Convention entered into force on 21 March 1994 and under it the industrialized countries agreed to aim to return their emissions to 1990 levels by 2010.

The relationship between the IPCC and the UNFCCC is worth clarifying. Under the UNFCCC a Subsidiary Body for Scientific and Technological Advice (SBSTA) was established. At the first of the annual Conference of the Parties to the UNFCCC (COP-1) in Berlin (February 1995), the functions of the SBSTA were clarified and SBSTA was requested to:

1. Summarize and interpret the latest international scientific research for the politicians (COP) and 'support' of the review of the adequacy of commitments (targets)
2. Assess the implications of research and advise on the development and improvement of comparable methodologies for:
   - National inventories of emissions and removals of greenhouse gases.
   - Projecting national emissions and removals of greenhouse gases and comparison of respective contributions of different gases to climate change.
   - Evaluating the individual and aggregated effects of measures undertaken pursuant to the provisions of the Convention.
   - Conducting impact/sensitivity analyses.
   - Assessing adaptation responses.

Since Rio, there have been annual follow-up COP meetings to try to establish agreements on exactly how emissions and impacts are going to be measured, and how to manage and

programme the targets and tools used in the negotiations. On 11 December 1997, at the conclusion of COP-3 in Kyoto, Japan, more than 150 nations adopted the Kyoto Protocol. This unprecedented treaty committed industrialized nations to make legally binding reductions in emissions of six greenhouse gases:

- carbon dioxide.
- methane.
- nitrous oxide.
- hydrofluorocarbons (HFCs).
- perfluorocarbons (PFCs).
- sulphur hexafluoride (SF_6).

The called-for reductions varied from country to country, but would cut emissions by an average of about 5% below 1990 levels by the period 2008–2012. The USA agreed to reductions of 7%, Japan to reductions of 6% and the members of the European Union (EU) to joint reductions of 8%. Key to the US agreement to such a relatively ambitious target was a concurrent agreement that a system of emissions trading among industrialized countries be established, by which nations with binding limits could buy and sell, among themselves, the right to release greenhouse gases.

Much has happened since then, but by 12 August 2003, 84 parties had signed, including Canada, and 113 parties have ratified or acceded to the Kyoto Protocol.[26] In December 2003, COP-9 was held in Milan, to discuss the tricky issue of carbon sinks and emissions trading, and how to incorporate them in the global targets for the Protocol, an increasingly central issue as many countries attempt to avoid the need to make deep cuts in their own greenhouse gas emission inventories by investing in cheap 'carbon sinks' abroad. COP-10 in Buenos Aires in 2004 took stock of the achievements in terms of adaptation and mitigation strategies in the first 10 years of the Treaty. COP-11 in 2005 was held in Montreal in Canada, COP-12 in 2006 in Nairobi and COP-13 in 2007 in Bali.

On the 15 December 2007, in a last minute agreement at the COP-13 in Bali, all countries that are party to the Kyoto Agreement, and the USA (reluctantly), agreed upon a Bali Action Plan and Roadmap that outlined a broad range of actions relating to the mitigation and adaptation for climate change committing to:

- *Achieving* deep cuts in global emissions targets in accordance with the UNFCCC.
- *Reaffirming* as priorities economic and social development, and eradication of poverty.
- *Responding* to AR4 (Fourth Assessment Report) findings that global warming is unequivocal and needs urgent action.
- *Recognizing* that (really) deep cuts in global emissions will be required to achieve the ultimate objective of the Convention (avoiding climate chaos).

The sense of urgency at Bali was palpable and four main areas were dealt with in detail:

- A new framework for emissions inventories and reporting mechanisms for deforestation and land use.
- An adaptation fund and programme to enhance the ability of nations to adapt in time.
- Technology transfer mechanisms and financing reinforced and developed.
- Ad Hoc Working Group on Long Term Cooperative Action under the Convention set up to produce an action plan for presentation to COP-15 in Copenhagen in 2009, on which will be based the proposals for the post-Kyoto treaty.

A further function of the COP meetings is to report back on progress against targets and to this end in the Clean Development Mechanism arena, relating to projects whereby emissions reductions in one country can be claimed as carbon reductions by a funding country. For the year 2006/07 825 projects were reported, achieving 84 049 697 million certified emissions reductions and the development of 32 new agreed baseline and monitoring methodologies.

There have been four reports from the IPCC on the changing status of the science on climate change. In 2007 the IPCC was awarded a Nobel Peace prize for its work in climate change. The language used in the four successive reports of the IPCC tell of the alarming rate in the increase of this change. AR4, published in 2007, leaves little room for doubt about its mechanisms and causes.

The first volume of the Fourth IPCC Report, AR4, released in February 2007 in Paris, confirmed that global warming was happening, while the second, issued in April 2007 in Brussels, focused on the impact of the phenomenon on the world's populations and species.

The third volume of the AR4 report, dated May 2007, reported on the means of mitigating the worse impacts of global warming and focuses on the economic implications and technological options for tackling global warming. It states that emissions must start declining by 2015 to prevent the world's temperature from rising more than 2°C over pre-industrialized temperatures. The report also states that the low costs of buying insurance against these changes that would mean climate catastrophe in the coming decades, through the use of technologies currently available, is less than 0.1% of world gross domestic product (GDP) per annum.

AR4 of the IPCC had firmly established the link between anthropogenic emissions of greenhouse gases and climate change and reported step changes in the severity of their impacts. Many countries that were holding out for real targets for medium-term emissions reductions were thwarted, but it is felt that the COP-15 at Copenhagen will produce real targets for the post-Kyoto Treaty, driven on by the current US government.

AGENDA 21: THE ARMY IS FORMED

Once the decision to go to war was taken an army had to be assembled. This process started at Rio.

In 1992, the Earth Summit in Rio de Janeiro, properly titled the 'United Nations Conference of Development and the Environment', was profoundly influential. Twenty years after the first

Box 1.1 The language of the four IPCC reports has changed (see http://www.ipcc.ch/)

- 1st Report – 1990: 'We are now aware that *the general amplitude of the increase in the warming of the planet conforms to the predictions of the climate models*, but that this amplitude is comparable to that which occurs with the natural variability of the climate'.
- 2nd Report – 1995: 'In the corpus of the observations *lead us to believe* that there is a human influence on the climate of the planet'.
- 3rd Report – 2001: 'The recent observations provide *convincing indications* that the heating of the planet over that last five years is attributable to the activities of humans'.
- 4th Report – 2007: '*Warming of the climate system is unequivocal*. Most of (>50% of) the observed increase in globally averaged temperatures since the mid-twentieth century is very likely (confidence level >90%) due to the observed increase in anthropogenic (human) greenhouse gas concentrations'.

Box 1.2 The Bali Action Plan (See http://unfccc.int/meetings/cop_13/items/4049.php)

The Conference of the Parties,

Resolving to urgently enhance implementation of the Convention in order to achieve its ultimate objective in full accordance with its principles and commitments,

Reaffirming that economic and social development and poverty eradication are global priorities,

Responding to the findings of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change that warming of the climate system is unequivocal, and that delay in reducing emissions significantly constrains opportunities to achieve lower stabilization levels and increases the risk of more severe climate change impacts,

Recognizing that deep cuts in global emissions will be required to achieve the ultimate objective of the Convention and emphasizing the urgency to address climate change as indicated in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,

1. Decides to launch a comprehensive process to enable the full, effective and sustained implementation of the Convention through long-term cooperative action, now, up to and beyond 2012, in order to reach an agreed outcome and adopt a decision at its fifteenth session, by addressing, inter alia:
   - (a) A shared vision for long-term cooperative action, including a long-term global goal for emission reductions, to achieve the ultimate objective of the Convention, in accordance with the provisions and principles of the Convention, in particular the principle of common but differentiated responsibilities and respective capabilities, and taking into account social and economic conditions and other relevant factors …
   - (b) Enhanced national/international action on mitigation of climate change …
   - (c) Enhanced action on adaptation …
   - (d) Enhanced action on technology development and transfer to support action on mitigation and adaptation …
   - (e) Enhanced action on the provision of financial resources and investment to support action on mitigation and adaptation and technology cooperation including consideration of:
     - (i) Improved access to adequate, predictable and sustainable financial resources and financial and technical support, and the provision of new and additional resources, including official and concessional funding for developing country Parties …
     - (ii) Positive incentives for developing country Parties for the enhanced implementation of national mitigation strategies and adaptation action …
     - (iii) Innovative means of funding to assist developing country Parties that are particularly vulnerable to the adverse impacts of climate change in meeting the cost of adaptation …
     - (iv) Means to incentivize the implementation of adaptation actions on the basis of sustainable development policies …
     - (v) Mobilization of public- and private-sector funding and investment, including facilitation of carbon-friendly investment choices …
     - (vi) Financial and technical support for capacity-building in the assessment of the costs of adaptation in developing countries, in particular the most vulnerable ones, to aid in determining their financial needs …
2. Decides that the process shall be conducted under a subsidiary body under the Convention, hereby established and known as the Ad Hoc Working Group on Long-term Cooperative Action under the Convention, that shall complete its work in 2009 and present the outcome of its work to the Conference of the Parties for adoption at its fifteenth session

3–7. Setting out the terms of reference and financing arrangements for the COP14 in 2008.

Box 1.3 Carbon trading (by *Fiona Mullins*)

The United Nations Framework Convention on Climate Change (UNFCCC),[i] the Kyoto Protocol and emerging greenhouse gas emissions trading schemes are based on calculations of tonnages of each greenhouse gas (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6). National greenhouse gas inventories of emissions are calculated and reported for UNFCCC compliance (and for future compliance with the Kyoto Protocol if it enters into force). The inventories are reported both in the tonnages of the actual gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6) and also aggregated as a total CO_2 equivalent number. Each metric tonne of non-CO_2 gas is converted to CO_2 equivalents using a global warming potential number.

Greenhouse gas quantities are normally expressed in CO_2 equivalent units (CO_2e). Because each gas has a different impact on global warming, each non-CO_2 gas is multiplied by a Global Warming Potential (GWP) which reflects its impact relative to CO_2. The input data to this calculation are the tonnages emitted of each greenhouse gas, but the totals are reported in tonnes of CO_2 equivalent. For example each tonne of CH_4 is equivalent to 21 times a tonne of CO_2 because that is the standard metric used to approximate the effect of a tonne of CH_4 in the atmosphere compared to a tonne of CO_2 over a 100 year timeframe.

Emissions trading schemes for greenhouse gases use this same calculation methodology. For the UK emissions trading scheme, all greenhouse gases are potentially included, with some companies bringing N_2O and HFCs into the scheme as well as CO_2. The non-CO_2 units are translated into CO_2 equivalents for reporting and compliance purposes. For the EU emissions trading scheme, only CO_2 emissions are included in the first phase (2005–08) so the only relevant unit is metric tonnes of CO_2. Other gases may be added later as monitoring of them improves.

[i]See http://unfccc.int/index.html

global environmental conference in 1972 in Sweden, the UN sought to help governments rethink economic development and find ways to halt the destruction of irreplaceable natural resources and pollution of the planet.[27] One-hundred-and-eight heads of state were represented and the documents it produced included the *Rio Declaration on Environment and Development, Agenda 21*, the *Framework Convention on Climate Change*, and the *Convention on Biological Diversity*. Although these documents have not all achieved universal ratification, they have served as blueprints for the implementation of important sustainable development initiatives.

The Summit's message – that nothing less than a transformation of our attitudes and behaviour would bring about the necessary changes (harking back to Goldsmith's Blueprint of 1972) – was transmitted by almost 10 000 on-site journalists and heard by millions around the world. The message reflected the complexity of the problems faced. Governments recognized the need to redirect international and national programmes and policies, in light of a 'grand survival plan' to ensure that all economic decisions fully took into account the environmental impacts of their actions, establishing for the first time in the context of international law, acceptance of the 'polluter pays' principle. The Rio Declaration set forth 27 universally applicable principles of sustainable development within which important themes were:

- Patterns of production: particularly the production of toxic components, such as lead in gasoline, or poisonous waste, many of which are major contributors to greenhouse gas emissions.
- Alternative sources of energy: to replace the use of fossil fuels which are linked to global climate change.

- A new reliance on public transportation systems: emphasized in order to reduce vehicle emissions, congestion in cities and the health problems caused by polluted air and smog. Transport emissions are a major contributor to greenhouse gas emissions.
- The growing scarcity of water: a major issue which is linked to a warmer climate as well as to increasing population and pollution.

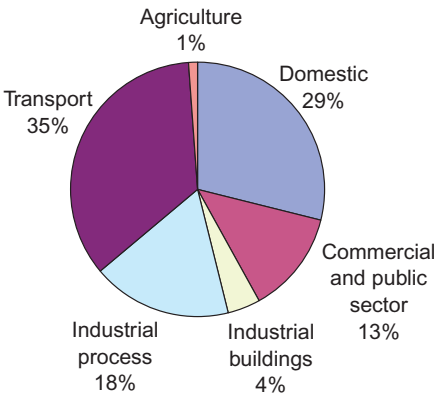
The two-week Earth Summit in Rio was the climax of a sophisticated process, begun in December 1989, of planning, education and negotiations among all member states of the UN, leading to the adoption of Agenda 21, a wide-ranging blueprint for action to achieve sustainable development worldwide. Although Agenda 21 had been weakened by compromise and negotiation, it was still the most comprehensive and potentially effective programme of action ever sanctioned by the international community.

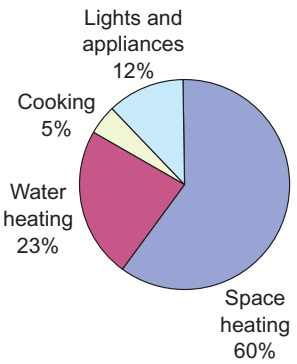
Much of the success of Agenda 21 has been derived from the training on environmental issues, instilled within its delivery, to the army of workers it has enlisted in the war on environmental degradation and climate change, from local council employees to heads of state. These forces have been armed, through the Agenda 21 process, with the units and measures, tools and methods, indicators and benchmarks that enable the most ordinary of people to be part of the most extraordinary monitoring project ever seen, the measuring of the rates and extent of the degradation of the planet on which we depend for our very survival. For, only by measuring the rates and extent of that degradation has it been possible to understand the risks we actually do face, and develop strategies to mitigate and avert them.

If one, simplistically, thinks of the climate change issue in terms of a war, then in overall command is the UN and its related organizations. Beneath it are the services represented by global treaties, gathered under banners such as Climate Change, Health, Poverty and Biodiversity, within which the laws, regulations and guidelines targeted at specific aspects of the global problem are developed. The IPCC and the World Health Organization (WHO) are definitely embedded in the intelligence unit at HQ, while Agenda 21 is responsible for the marshalling and training of the massed ranks of the forces. Nations act rather like battalion leaders commanding significant forces, under sectoral units such as transport, the environment and education. It is perhaps possible to compare other big players such as the World Trade Organization to parallel armies, acting, or not as the case may be, alongside the UN in its fight against climate change.

Within any army there are rogue commanders and infiltrators of the opposing forces who, for reasons of ignorance, convenience, malice or personal profit, attempt to impede the progress of the forces,[28] but no doubt, as the risks escalate, any restraint with which such counter-forces are dealt will decrease as the gloves come off. Internal fighting will break out and the obvious growing tensions between lobby groups will flare up. A case in point is the interests of the mining and agricultural sectors of Australia where the dominant coal industry has been able to protect their group interests, the selling of coal, against the weaker farmers' lobby who stand to lose everything as the great 'sunburnt country' gets browner.

Similarly, in the USA the oil lobby funds much government thinking on environmental issues while the farmers of the Mid-West who are slowly losing their lands to the droughts, floods and hurricanes, currently find it less easy to get a fair hearing at the top table in Washington. It is now happening that such minorities are turning to the law for recompense, just as those who were harmed by the knowing and malicious actions of the tobacco barons and the asbestos industry have recently won such major class actions in America.[29] It is certainly the case that in many





1.7.
Total UK delivered energy consumption by sector (*left*) and carbon emissions from buildings by source (*right*).
Source: Pout, C.H., MacKenzie, F. and Bettle, R. (2002) *Carbon Dioxide Emission from Non-domestic Buildings: 2000 and Beyond*. Watford: Building Research Establishment and Department for Environment, Food and Rural Affairs, p. 10.

places on the Earth the water wars between nations and interest groups have begun, and the parties are also resorting to the law to get justice in the face of environmental disputes.[30]

THE BATTLE RAGES

The battle, on many fronts, is growing more and more heated as the climate warms. The world is hotter now than it has been at any time in the past 2000 years. Eleven of the last 12 years (1995–2006) rank amongst the 12 hottest years on record, with temperatures in the Arctic increasing at over twice the average global rate over the past 100 years.[31]

The increase in the impact of climate change on the economy is well reflected in the magnitude and related costs for extreme climate events – up to 80% of all payouts by value – to the international insurance industry.[32]

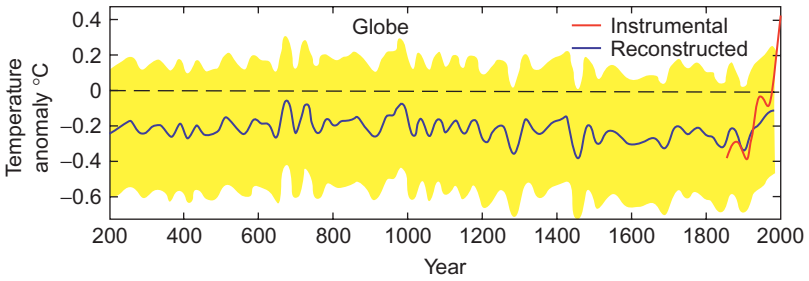
The year 2003 proved to be a warning year. In July 2003 Sir John Houghton, former Chairman of the IPCC, informed the British public, in an article in the *Guardian* newspaper, that global warming was now a real weapon of mass destruction,[33] wielded by man himself:

> The World Meteorological Organization warned in July 2003 that extreme weather events already seemed to be becoming more frequent as a result [of global warming]. The US mainland was struck by 562 tornados in May (which incidentally saw the highest land temperatures globally since records began in 1880), killing 41 people. The developing world is the hardest hit: extremes of climate tend to be more intense at low latitudes and poorer countries are less able to cope with disasters. Pre-monsoon temperatures in India reached a blistering 49°C (120°F)–50°C (9°F) above normal. Once this killer heat wave began to abate 1500 people were dead. While none can ascribe a single weather event to climate change with any degree of scientific certainty, higher maximum temperatures are one of the most predictable impacts of accelerated global warming.

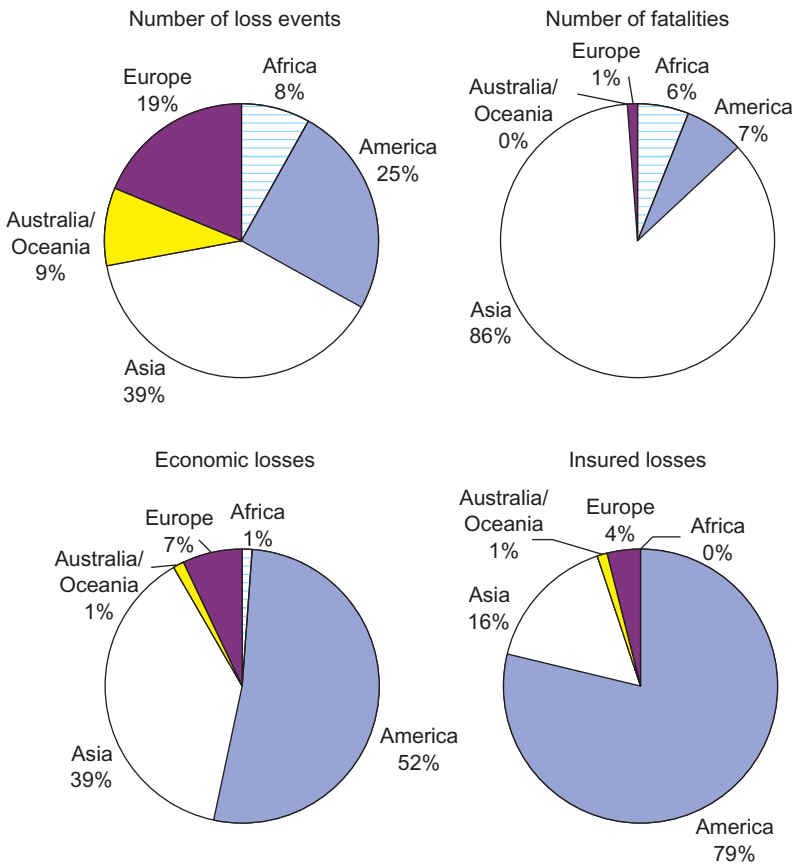
In the following month of 2003, 35000 Europeans died of heat stroke, with some 15000 of those in France alone. The warning had already begun to come true.

THE COSTS OF THE WAR

In 2006 Sir Nicholas Stern's Review on the Economics of Climate Change was the first comprehensive UK review of the economic impacts of climate change. It clearly demonstrated that all countries will be affected by climate change, but the poorest countries will suffer earliest and



1.8.
Reconstructed global temperature anomaly (based on 1961–1990 instrumental reference period, adapted from Mann and Jones[31])



1.9.
Payouts by the insurance industry for natural disasters by geographical region.
Source: Munich Re, *Topics*: *Annual Review of Natural Catastrophes 2001*, see http://www.munichre.com/pdf/topics_2002_e.pdf.

most.[34] Its major conclusions were that average temperatures could rise by 5 °C from pre-industrial levels if climate change goes unchecked. His fairly dire conclusions are summarized below. He recommended *three elements of policy* for an effective response: carbon pricing, technology policy and energy efficiency. Carbon pricing, through taxation, emissions trading or regulation, will show people the full social costs of their actions. Technology policy should drive the

large-scale development and use of a range of low-carbon and high-efficiency products. Climate change should be fully integrated into development policy, and rich countries should honour pledges to increase support through overseas development assistance. In December 2007 the UK Government pledged to put a carbon cost to every project it develops across government departments.

The Stern Review[34] concluded that 'business as usual' would cause a further 5.8°C rise in mean temperature, which would incur costs in excess of 20% of global GDP, while the cost of emission reduction measures to stabilize the temperature would be only 1% of GDP. The Stern Review, in conjunction with the IPCC AR4, marked a turning point in the global debate on climate change. It is impossible to state the extent to which Stern has caught the mood of the time, or created it, but either way there seems to have been a pronounced shift away from the debate over the science and towards the economics of mitigation versus adaptation.

The Australian climate change impacts report by economist Ross Gernaut for the Australian Government in 2007/08 further confirmed the potential extent of the social and economic impacts of a warming world,[35] but still politically corrective action was dilatory. Gernaut placed an emissions trading scheme (ETS) at the heart of the Australian response, but the value put on carbon is inevitably proportional to the amount of carbon that is needed to be saved and therefore traded. This is where it may be difficult to agree. One major problem in dealing with the issue is the widely varying and rapidly moving targets espoused by different groups.

Up until the Fourth IPCC Report there appeared to be some leeway in terms of the time available to achieve what were CO_2 emission reduction targets in the region of 450–550 ppm. However, in April 2007 the head of climate science at the NASA Goddard Institute for Space studies in New York, James Hansen, and his team shocked the scientific community by publishing a paper claiming that climate stability could only be guaranteed if we were to reduce CO_2 levels from the current level of 385 ppm in the atmosphere back to the 350 ppm mark.[36] The near-term impacts of not doing so are listed as including the inability of populations to adapt to rapidly changing temperatures, melting alpine glaciers, sea levels that rise several metres this century, and the loss of sea ice and coral reefs. The required levels of emissions reduction can be achieved, they propose, by phasing out coal generation except where the resulting CO_2 is sequestered, by adopting farming and forestry practices that sequester carbon from the atmosphere, and through the proposed costing of carbon.

One of the most effective books on the subject of what the impacts of the climate war will be was published in 2007 by Mark Lynas, on the impacts for humanity and the planet that may be caused by each degree that the global temperature rises.[37] It makes for grim reading and provided a basis, along with the Stern Report, for the form taken by our conclusions in the final chapter of this book.

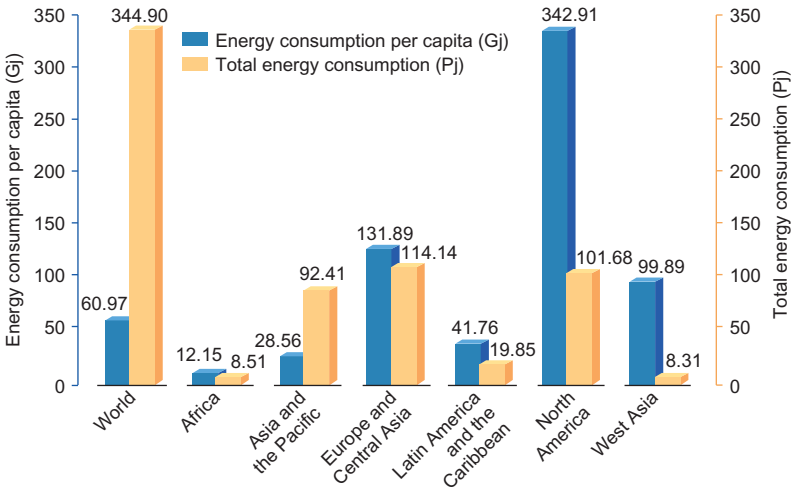
THE WEAPONS ARE BEING HONED

As the rate of change in the climate accelerates to alarming levels the bid to meet more and more challenging targets is raised, and the weapons to meet deep cuts are being honed. Huge steps forward to tackle emissions regionally and by sector are being made around the world in an attempt to improve our mitigation defences, with the EU playing a real leadership role on the larger issues such as aviation.

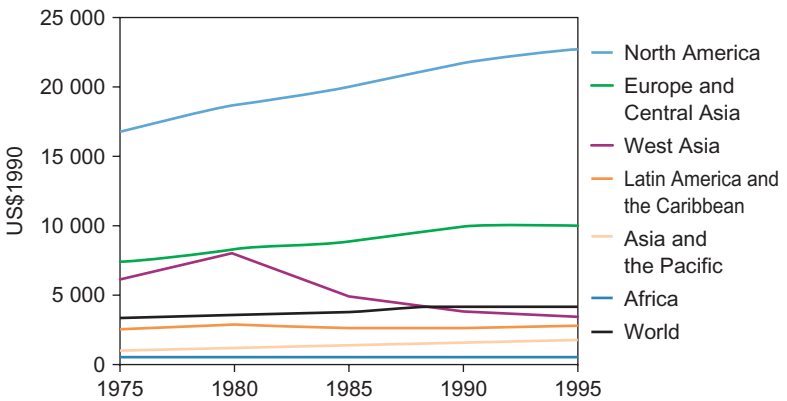
Temp rise (°C)	Water	Food	Health	Land	Environment	Abrupt and Large-Scale Impacts
1°C	Small glaciers in the Andes disappear completely, threatening water supplies for 50 million people	Modest increase in cereal yields in temperate regions	At least 300 000 people each year die from climate-related diseases (predominantly diarrhoea, malaria, and malnutrition) Reduction in winter mortality in higher latitudes (Northern Europe, USA)	Permafrost thawing damages buildings and roads in parts of Canada and Russia	At least 10% of land species facing extinction (according to one estimate) 80% bleaching of coral reefs, including Great Barrier Reef	Atlantic Thermohaline Circulation starts to weaken
2°C	Potentially 20–30% decrease in water availability in some vulnerable regions, e.g. Southern Africa and Mediterranean	Sharp declines in crop yield in tropical regions (5–10% in Africa)	40–60 million more people exposed to malaria in Africa	Up to 10 million more people affected by coastal flooding each year	15–40% of species facing extinction (according to one estimate) High risk of extinction of Arctic species, including polar bear and caribou	Potential for Greenland ice sheet to begin melting irreversibly, accelerating sea level rise and committing world to an eventual 7 m sea level rise Rising risk of abrupt changes to atmospheric circulations, e.g. the monsoon Rising risk of collapse of West Antarctic Ice Sheet Rising risk of collapse of Atlantic Thermohaline Circulation
3°C	In Southern Europe, serious droughts occur once every 10 years 1–4 billion more people suffer water shortages, while 1–5 billion gain water, which may increase flood risk	150–550 additional millions at risk of hunger (if carbon fertilization weak) Agricultural yields in higher latitudes likely to peak	1–3 million more people die from malnutrition (if carbon fertilization weak)	1–170 million more people affected by coastal flooding each year	20–50% of species facing extinction (according to one estimate), including 25–60% mammals, 30–40% birds and 15–70% butterflies in South Africa Collapse of Amazon rainforest (according to some models)	
4°C	Potentially 30–50% decrease in water availability in Southern Africa and Mediterranean	Agricultural yields decline by 15–35% in Africa, and entire regions out of production (e.g. parts of Australia)	Up to 80 million more people exposed to malaria in Africa	7–300 million more people affected by coastal flooding each year	Loss of around half Arctic tundra Around half of all the world's nature reserves cannot fulfill objectives	
5°C	Possible disappearance of large glaciers in Himalayas, affecting one-quarter of China's population and hundreds of millions in India	Continued increase in ocean acidity seriously disrupting marine ecosystems and possibly fish stocks		Sea level rise threatens small islands, low-lying coastal areas (Florida) and major world cities such as New York, London, and Tokyo		
More than 5°C	The latest science suggests that the Earth's average temperature will rise by even more than 5 or 6°C if emissions continue to grow and positive feedbacks amplify the warming effect of greenhouse gases (e.g. release of carbon dioxide from soils or methane from permafrost). This level of global temperature rise would be equivalent to the amount of warming that occurred between the last age and today – and is likely to lead to major disruption and large-scale movement of population. Such "socially contingent" effects could be catastrophic, but are currently very bare to capture with current models as temperatures would be so far outside human experience.					

1.10.
Highlights from the Stern Report of 2005 showing the escalation in possible impacts or increasing global temperatures. *Source*: The Stern Report, 2005, HMSO.

Some areas have not been dealt with adequately, such as the emissions from shipping. The UN International Maritime Organization (IMO) reported in December 2007 on the emissions caused by its 47 000-strong global fleet. There has been a huge rise in shipping over the past decade and between 2008 and 2012, it is predicted that 6100 new container ships and bulk carriers, the world's largest ships, will be built, a 50% increase on total shipping capacity that is the same number in five years as the number of new jumbo jets expected to take to the skies in 10 years.



1.11.
Total and per capita energy consumption 1995 by region. *Source*: http://www.unep.org/geo2000/english/figures.htm.



1.12.
Gross domestic product per capita 1995 by region. One of the problems faced is that the wealth of nations is directly related to their emissions in the tradition analyses of the trends in the twentieth century economy. This will change radically with the new predicted clean economies of the twenty-first century in which high emissions per capita will be a sign of poverty. *Source*: http://www.unep.org/geo2000/english/figures.htm.

Shipping appeared to have escaped scrutiny but it emits around 2% of global emissions, at least equal to airlines. And some say that it could account for twice the emissions of flying. Shipping, like aviation, falls outside the Kyoto Protocol but it accounts for almost 90% of all world trade, and this figure is rising.[38] But who owns these emissions and within whose borders do they lie?

On 27 May 2008, Members of the European Parliament (MEPs) on the environment committee voted overwhelmingly to include aviation in European ETS a year earlier than planned, in 2011 rather than 2012 as had been proposed by the Commission and the 27 national governments. They also lowered the cap from 100% of 2004/05 emissions to 90%. The plan would cost passengers £8 extra on EU flights and £32 on transatlantic routes, adding to the economic pressure on flying being experienced as a result of soaring fuel prices.[39]

Countries within Europe are taking enormous strides forward in building their own low-carbon economies. Germany has built the world's leading solar economy, being followed in this field by the massive investment in solar technologies by China.

Amongst European governments Spain has the highest dependency on fossil fuels, using them to meet 84% of its energy needs, and in 2007 it spent some 17 billion euro on oil imports. Rising fuel prices have been pushing up inflation. The Spanish Government is taking firm action

to reduce energy consumption, and in 2005, taking a lead from the city of Barcelona and state of Catalan, introduced the first European solar law requiring all new homes to have solar hot water systems on their roofs. They calculate that they will save millions of euro spent on imported oil by cutting speed limits on dual carriageways outside major cities, bringing it in line with Barcelona, which already has a top speed limit of 50 mph. They are also handing out over 49 million free low-energy light bulbs, two per household, and by 2012 all light bulbs will be low energy. With these as part of a broad swath of measures between now and 2014, the Spanish Government hopes to reduce oil imports by 10% a year, cutting annual consumption by 44 million barrels. Air conditioning systems in public buildings will be set no lower than 26°C and in winter Spaniards, except in hospitals, will not be able to turn their heating higher than 21°C. Street lighting will be cut by 50% and the metro system will stay open later so that people can leave their cars at home. The government is planning to manufacture 1 million electric cars and all government vehicles are to meet at least 20% of their energy needs with biofuels. Commercial airlines will be allowed to use military routes to make routes 20% shorter.[40]

But the EU is not the only region taking firm action. Japan was the first country to introduce carbon labels on food, drinks, detergents and appliances from spring 2009, under a government-approved calculation and labelling system developed by the Trade Ministry. Again, this pioneering position has made them confront the questions of how to produce a robust calculation system that prevents 'in-house labelling schemes' being used that make some products appear to be more attractive than others. The carbon footprint for a bag of crisps, for instance, is:

1 bag of crisps = 75 g CO_2
44% growing potatoes
30% chip production
15% packaging
9% delivery
2% disposal

The main driver for consumers to adopt low-carbon products appears to be the rush to be seen to be environmentally friendly, but there are obviously fairly firm limits to how much consumers would be willing to pay for eco-friendly goods. This is a problem that has been tackled in the UK, where high-carbon products are already being penalized under the tax regime (Table 1.1).

Table 1.1 Annual road tax for cars registered after 1 March 2001 (announced in the Spring Budget 2007)

Car band	*CO_2 (g/km)*	*Diesel cars (£)*	*Petrol cars (£)*	*Alternative fuel cars (£)*
A	Up to 100 g	0	0	0
B	101–120 g	35	35	15
C	121–150 g	115	115	95
D	151–165 g	140	140	120
E	166–185 g	165	165	145
F	186–225 g	205	205	190
G	226 g plus	300	300	285

Source: Vehicle Certification Agency's website: www.vcacarfueldata.org.uk

UK ministers were instructed to factor the shadow carbon costs into their financial calculations for any new plans, policies and investment decisions on transport, construction, housing, energy and planning. To do this they will use the shadow price for carbon, which represents the cost to society of the environmental damage done by carbon. The starting price for carbon in 2007 was put at £5.50 a tonne and it is predicted to rise annually to a price of around £59.60 a tonne in 2050. However, the theory that the carbon price will act against projects for new roads and power stations does not seem to have been effective, as the UK Government subsequently gave permission for a new generation of coal-fired power stations. One real problem this poses to the Government is how to do the calculations to ensure that they are universally consistent across departments.

TARGET LOCK-ON IS PROVING DIFFICULT

Another problem in trying to arrive at 'joined-up' thinking on how to reduce the impacts of climate change has been the lack of agreement on what reduction targets we should be meeting, before the question of how we meet them even arises.

The most credible method of achieving agreement on the required levels of emission reduction is that of 'Contraction and Convergence' (C&C), which has been described as looking increasingly like 'the only game in town'.

C&C, devised by Aubrey Meyer at the Global Commons Institute, is all about reducing the total global output of greenhouse gases, by gradually reducing national emissions to targets based on per capita quotas over time. To meet the more stringent atmospheric levels over the course of the century total global emissions would have to drop from an average of 1 tonne of CO_2 per person to below 0.3 tonnes per person over time depending on what is the final atmospheric level aimed at and how quickly it has to be achieved. C&C has the potential to smooth over the political and economic cracks that are threatening to tear down the Kyoto, and subsequent Protocols.

The convergence figures represent what it is estimated to be the carbon emissions reductions needed to stabilize climate change. The discrepancy between the reality of what we emit and what is required is being faced up to by some governments and the EU. On 23 January 2008 the EU put forward an integrated proposal for Climate Action in which a mandatory target of 20% of all energy use for the EU would come from renewables by 2020 and set a 10% minimum target for biofuels by 2020.[41] A plethora of action plans and associated targets has been proposed and adopted by many different groups and organizations, from local communities to towns and cites, states and countries, and over the next few years we may see these coalesce into a credible coordinated attempt by humanity to put in place the implementable strategies we need, quite simply, to survive. At the heart of such a targets framework, if it is to work, must lie the notion of C&C.

FIGHTING IN THE RANKS

Resistance to changing our own ways of life is enormous and is fought on many fronts. One of Former President George W. Bush's first actions when he came to power was to withdraw the USA from the Kyoto treaty. Despite the USA being one of the most vulnerable continents to extreme weather damage, the issues of global warming have been, by and large, presented to the