PLANET

GUERNSEY

Towards a Sustainable Future!

THIS BOOK IS DEDICATED TO THE PEOPLE OF GUERNSEY AND, IN PARTICULAR, TO BRIDGET OZANNE, OUR MUCH LOVED GUERNSEY BOTANIST WHO SADLY DIED DURING ITS PREPARATION.

"No man is an island, entire of itself; every man is a piece of the continent, a part of the main... Any man's death diminishes me, because I am involved in mankind; and therefore never send to know for whom the bell tolls; it tolls for thee..."

John Donne

Meditation 17
Devotions upon Emergent Occasions

PLEASE PASS THE WORD!

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Printed in October 2007 on recycled paper by local printers Parallel

Cover image adapted from Calvin J. Hamilton/NASA.

PREFACE

Small island communities are among the most vulnerable to the effects of climate change. Some, particularly in the South Pacific, are already losing valuable land to the ocean, whilst their populations make arrangements to move to higher ground or, where that is not available, to other countries. History shows that our islands of the Bailiwick of Guernsey will not be immune from these changes. Indeed, the impact that climate change has already had on our natural environment provides a powerful argument of the need for local action. Guernsey has its part to play as the response of the world community to global warming begins to develop momentum.

Guernsey has an impressive history of recording its local ecology and natural history, stretching back to the 19th century. Together with its extraordinarily rich coastal and marine environment and its geographical location on the northwest fringe of the Bay of St Malo, this makes the island a uniquely informative sentinel of change.

The editor and the authors are to be congratulated for putting together a highly informative body of data on the climatic changes that have already occurred, and the impact these have had on the species distribution of plant, bird and insect life, on flowering dates, on the migration of birds and on marine life. This has been put in the context of change over past millennia, and predictions of where current change may lead us. The final section on opportunities for action should be of importance for everyone in Guernsey.

Last year we celebrated the second centenary of the reclamation of the Braye du Valle, which has made such a contribution to Guernsey's development. It would be a tragedy if by the third centenary, we had started to surrender back to the sea, land that had been so successfully reclaimed from it.

G R Rowland
Bailiff
The Royal Court House
St Peter Port
Guernsey.

PLANET GUERNSEY

Towards a Sustainable Future

A Handbook detailing the Evidence and Impacts of Climate Change in Guernsey, the Consequences and Opportunities for Action.

Compiled and edited by Andrew Casebow
Designed and produced by Chris Regan

ACKNOWLEDGEMENTS

The editor wishes to express his gratitude to Tim Sparks whose initial enthusiasm and editorial assistance made this project possible, and to Donna Le Tissier for managing the administration and assisting in the production of the book.

Particular thanks are due to all the contributing authors and to the editorial team of the Guernsey Climate Change Partnership (Tim Lillington, Nick Day, Muir Ashworth and Charles David), and to our private and business sponsors whose financial support has enabled the publishing of this book.

Tim Sparks has been responsible for statistical analysis (except that carried out on Met office information by Tim Lillington). We are grateful to the Guernsey Biological Records Centre, Digimap and to many private individuals and organisations who have contributed photographs and illustrations.

Finally, Andrew would like to record his thanks to his wife and family who have supported him in the production of 'Planet Guernsey' from conception to birth, and beyond!

GUERNSEY CLIMATE CHANGE PARTNERSHIP
2007

FOREWORD

Human associated climate change is real. There are, as always, questions about particular details, but a clear scientific consensus on the main facts has emerged, that the increase in temperatures seen over the past fifty years is due to the accelerating emissions of carbon dioxide and other greenhouse gases. If unchecked, the increasing levels of these emissions in the atmosphere will lead to massive, irreversible damage to the global environment. If atmospheric levels of these gases are to be stabilised at a level, which avoids the worst effects of climate change, the industrialised countries need to make cuts of 60% by the middle of this century. This is a huge challenge. Identifying the problems associated with climate change is one thing, doing something effective about it is another. In recent years, the Royal Society has been extremely energetic in the analysis of these problems, calling for increased investment in renewable energy sources, working with developing countries, notably China and India, in developing their capabilities in appropriate science and technology, and arguing vociferously for greater political commitment.

It is therefore a real pleasure to have been asked to write a foreword to this publication. Each community must play its part in reducing the threat of global warming, particularly those from the rich, industrialised part of the world. The greater the awareness of the changes that have already taken place, and to where these changes are leading us, the more likely it is that individuals will see the need to participate in what must become a global effort. What better way to boost awareness in a community than to publish local data on sensitive indicators of change. Furthermore, if, as is intended, this publication becomes the first in a series, then an extraordinarily interesting picture should emerge of the effects on an island's environment of a warming world. I congratulate Andrew Casebow and his colleagues in producing this publication. It is in the spirit of the oldest traditions of the Royal Society.

Professor Lord May of Oxford OM AC Kt FRS
(Past President of the Royal Society)
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INTRODUCTION

Andrew Casebow [1]

Humanity is facing its greatest challenge. Climate change will radically affect the environment of our planet. It will lead to starvation, or flooding, for many of our fellow humans, and the extinction of many species of animals and plants.

This booklet is an amalgamation of chapters by individual authors and each has his, or her, own story to tell. We all live and cope with change in our lives. Climate change has occurred in the past and will continue in the future. However, the catastrophic change that is starting to occur at this time is not a natural occurrence, but is caused by mankind; and we are each, to a greater or lesser degree, responsible for this change.

We are very fortunate that one of Britain's leading authorities on global warming, the internationally respected Sir John Houghton, has written an introduction for our booklet that eloquently explains the science of global warming.

Guernsey's undulating cliff paths. One of the many beautiful landscapes the island has to offer. *Image courtesy of VisitGuernsey.*

The booklet is divided into six sections, concentrating specifically on Guernsey, under the following general headings:

- Historical Evidence of Past Climate Change
- Evidence of Climate Change in Guernsey
- Impacts of Climate Change in Guernsey
- Predictions of Future Climate Change
- Consequences of Future Climate Change in Guernsey
- Responding to Climate Change in Guernsey - Opportunities for Action

Each section contains a number of short chapters by a wide range of authors, who all have a connection with Guernsey. Some authors were born and educated in the island, some have spent happy holidays in Guernsey, others have undertaken research here, whilst many of us are fortunate to live and work here. We are all united in our desire to tell you about the climatic changes that are occurring and the dangers that lie ahead if action to curb 'global warming' is not taken quickly. The positive action that we can take to reduce our contribution to what could be a disaster for mankind, and for the many species of plants and animals that share this beautiful planet with us.

This booklet gives you clear evidence that climate change is, indeed, occurring in Guernsey. It shows the impact that it has already had in the island and how it is already affecting our lives. Predictions of the future show that climate change will have huge consequences throughout the world. There is a moral responsibility for us to try to alleviate these changes but to do so we need to take positive action. Everyone should take responsibility, not just individually, but also collectively through government and business.

Taking appropriate action now could benefit us in innumerable ways. For example, oil is already a scarce resource that is becoming more difficult and expensive to obtain, and will run out in the foreseeable future. Developing new technologies and using known methods to save fuel will be beneficial to mankind as well as saving money.

The aim of this booklet is not only to inform and inspire us to take action, but also to motivate us to take responsibility for our own contribution to the future of our planet. What will we do to save Guernsey for our children, and for our children's children?

"We do not inherit the earth from our ancestors, we borrow it from our children."

(Native American proverb)

Colour coding - *Each of the sections in this booklet are coded with a quick reference coloured strip along the right-hand side of each article.*

References

1. Dr Andrew Casebow is States Agriculture and Environment Adviser. Andrew is a member of Magdalene College, Cambridge, and of the University's Geography Department where he undertakes research on climate change and sustainable island development. He and his family have loved living and working in Guernsey for over 20 years.

AN INTRODUCTION TO THE SCIENCE OF GLOBAL WARMING

Sir John Houghton [1]

Figure 1. *Sunrise over Herm Island.* *Image courtesy of VisitGuernsey.*

Climate change due to human activities represents the biggest challenge facing the world in the 21st century.

Summary of the basic Science

'Greenhouse' gases, such as water vapour and carbon dioxide, act as blankets over the earth's surface, keeping it warmer than it would otherwise be. They do this by absorbing infra-red or 'heat' radiation from the earth's surface. The existence of this natural 'greenhouse effect' has been known for nearly 2000 years. It is essential to the maintenance of our current climate to which eco-systems and humans have adapted.

Since the beginning of the Industrial Revolution around 1750, one of these greenhouse gases, carbon dioxide has increased by nearly 40% and is now at a higher concentration in the atmosphere than it has been for many thousands of years. Chemical analysis demonstrates that this increase is due largely to burning fossil fuels – coal, oil and gas. If no action is taken to curb these emissions, the carbon dioxide concentration will rise during the 21st century to two or three times its pre-industrial level.

The climate record over the last 1,000 years shows a lot of natural variability – including, for instance, the 'medieval warm period' and the 'little ice age'. However, the rise in global average temperature (and its rate of rise) during the 20th century is well outside the range of this known natural variability.

Over the 21st century the global average temperature is projected to rise by between 2 and 6°C from its pre-industrial level (see Figure 2); the range represents different assumptions about mankind's future emissions of greenhouse gases. A rise of this amount is large. The difference between the middle of an ice age and the warm periods in-between is only about 5 or 6°C.

The Impact of Global Warming on Human Activity

Some of the most obvious impacts of global warming on human activity will be due to the rise of sea level that occurs because ocean water expands as it is heated. The projected rise, of about half a metre per century, will continue for many centuries, because it takes a long time to warm the deep oceans as well as surface waters. This will cause many problems for human communities living in low-lying regions.

There will also be impact from extreme events. The unusually high temperatures in central Europe during the summer of 2003 led to the deaths of over 20,000 people. Such summers are likely to be commonplace by the middle of the 21st century, and cool by the year 2100.

Water is becoming an increasingly important resource. A warmer world will lead to more evaporation of water from the surface, more water vapour in the atmosphere and more rainfall. Of greater importance is the fact that the increased condensation of water vapour in cloud formations leads to increased latent heat of condensation being released. Since this latent heat release is the largest source of energy driving the atmosphere's circulation, the hydrological cycle will become more intense. This means a tendency to more intense rainfall in some parts of the world, but also less rainfall in some semi-arid areas.

Floods and droughts are the most damaging of the world's disasters. Between 1975 and 2002 over 200,000 lives were lost and 2.2 billion people were affected by flooding caused by rainfall. Over the same period over half a million lives were lost and 1.3 billion

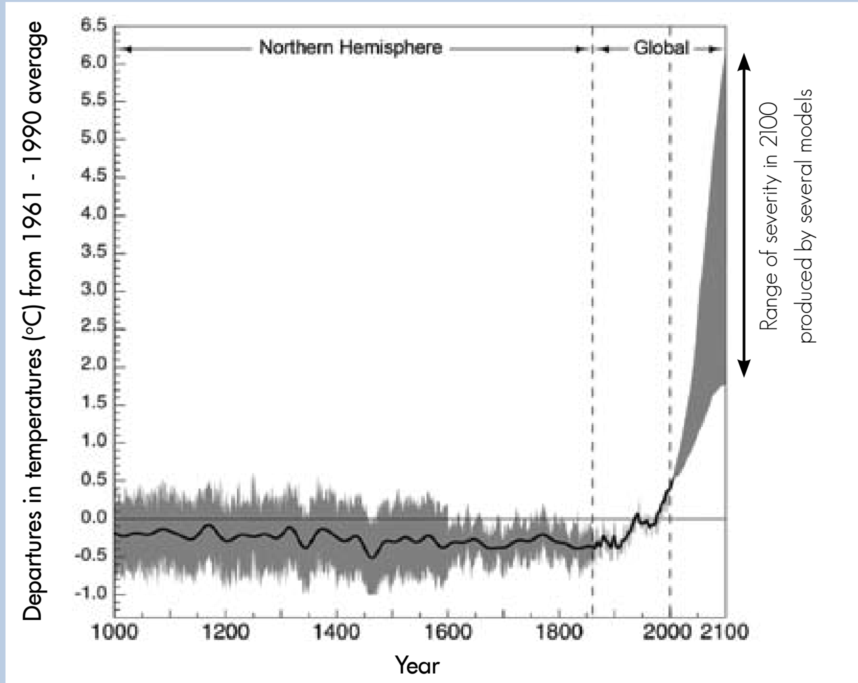


Figure 2. *Variations of the Earth's surface temperature: 1000 to 2100.*
1000 to 1861, N. Hemisphere, proxy data; 1861 to 2000 Global, instrumental; 2000 to 2100, SRES projections.

people were affected by drought. The greater frequency and intensity of flooding and droughts is bad news for most human communities, and especially for those regions such as South East Asia and sub-Saharan Africa where such events occur only too frequently.

Sea level rise, changes in water availability and extreme events will lead to increasing pressure from environmental refugees. A careful estimate has suggested that, due to climate change, there could be more than 150 million extra refugees by 2050. There are also potential changes that, if they occurred, would be highly damaging and possibly irreversible. For instance, large changes are being observed in Polar Regions.

With the rising temperatures over Greenland it is estimated that meltdown of the icecap could begin during the next few decades. Complete meltdown is likely to take many centuries but would add 7 metres (23 feet) to the sea level.

Of further concern is the 'Thermo-Haline Circulation', (often known as the 'gulf stream') which brings a warmer climate to northern Europe. This is a circulation of heat in the deep oceans.

Figure 3. *An iceberg in the Jacobshavn fjord. Greenland continues to lose ice mass, and the rate of loss is accelerating.* *Photo courtesy Konrad Steffen, University of Colorado at Boulder.*

Because of evaporation, the water in the Gulf Stream becomes more salty, and hence of higher density than the surrounding water.

It therefore tends to sink and provides the source of a slow circulation of water that connects all the oceans together. This sinking assists in maintaining the Gulf Stream itself. In a globally warmed world, increased rainfall together with fresh water from melting ice will decrease the water's salinity making it less likely to sink. The circulation will therefore weaken, leading to large regional changes of climate.

Emissions of Carbon into the Atmosphere

Global emissions of carbon dioxide to the atmosphere from fossil fuel burning are currently approaching 7 billion tonnes of carbon per annum and rising rapidly. Unless strong measures are taken they will reach two or three times this level during the 21st century. Therefore, to stabilise carbon dioxide concentrations, emissions must reduce to a fraction of their present levels before the end of the century.

The reductions in emissions must be made globally; all nations must take part but there are very large differences between greenhouse gas emissions in different countries. Expressed in tonnes of carbon dioxide per person per year, they vary from about 5.5 tonnes per person in the USA, 2.5 tonnes per person in Europe, 0.7 tonnes in China, and 0.2 tonnes in India (see Figure 4). Ways need to be found to achieve reductions that are both realistic and equable.

We, in the developed countries have already benefited over many generations from abundant fossil fuel energy. The demands on our stewardship take on a special poignancy as we realise that the adverse impacts of climate change will fall disproportionately on poorer nations and will tend to exacerbate the increasingly large divide between rich and poor.

The Kyoto Protocol represents a beginning for the process of reduction. It is an important start demonstrating the achievement of a useful measure of international agreement on such a complex issue. It also introduces, for the first time, international trading of greenhouse gas emissions so that reductions can be achieved in the most cost effective ways.

The aim must be to stabilise emissions of carbon dioxide. In order to stop dangerous climate change the level needs to be as low as possible. In 1996 the European Commission proposed a 2°C limit on the rise in global average temperature from its pre-industrial level. This implies a stabilisation level for carbon dioxide of about 430 ppm (allowing for the effect of other greenhouse gases at their 1990 levels). Others have proposed "stabilisation in the range 500-550 ppm" that "with care could be achieved without disrupting economic growth", but without firm action atmospheric concentrations of carbon dioxide could go much higher (see Figure 5).

If carbon dioxide is stabilised at 500ppm and the effect of other greenhouse gases at their 1990 levels is added, it is about equivalent to double the carbon dioxide at its pre-industrial level, and will therefore produce a rise in global average temperature of about 2.5°C. Eventually, although human induced climate change may be halted, the impacts at such a level would be large. A steady rise in sea level will continue for many centuries, heat waves such as in Europe in 2003 would be commonplace, devastating floods and droughts would be much more common in many places and Greenland would most likely start to melt down.

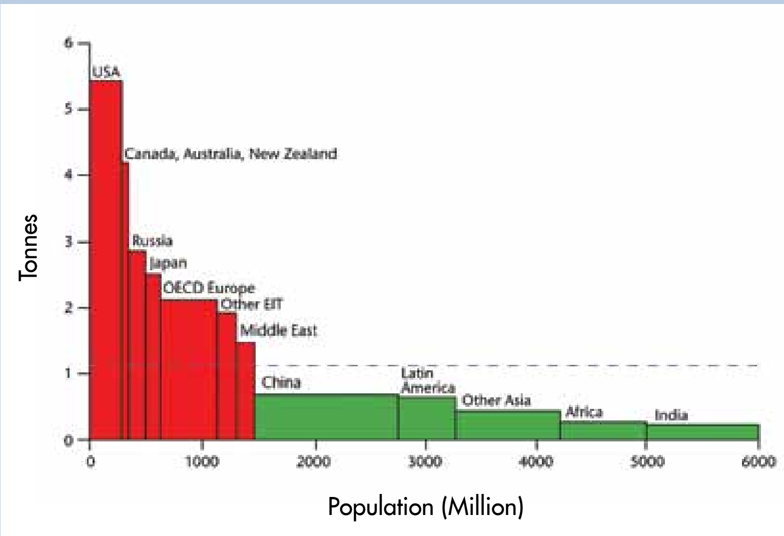


Figure 4. *Carbon dioxide emissions in 2000, per capita versus population.* (after M Grubb 2003).

The aim should be to stabilise at a lower level. But is this possible?

The UK government has taken a lead on this issue and has agreed a target for the reduction of greenhouse gas emissions of 60% by 2050.

The cost of this will not be great if action is taken quickly. Economists in the UK Government Treasury Department have estimated the cost to the UK economy of achieving this target. On the assumption of an average growth in the UK economy of 2.25% per annum, they estimated a cost of no more than the equivalent of 6 months growth over the 50-year period.

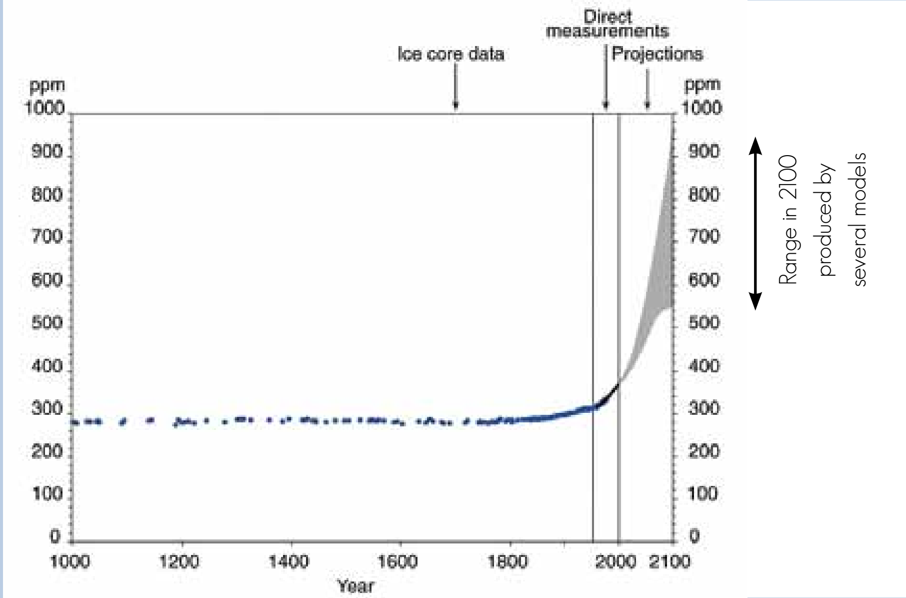


Figure 5. *Past and future CO2 atmospheric concentrations.* (From IPCC 2001 Synthesis Report).

Urgent Actions Needed to Achieve Reduced Carbon Emissions

Three sorts of actions are required:

1. Energy efficiency. About one-third of energy is employed in buildings (domestic and commercial), one-third in transport and one-third in industry. Large savings can be made in all three sectors, many with significant savings in cost. But to achieve these savings will require encouragement and incentives from government and a great deal of determination from all of us.
2. Exploitation of non-fossil fuel energy resources. This includes biomass (including waste), solar power (both photovoltaic and thermal), hydro, wind, wave, tidal, geothermal energy and nuclear.
3. Sequestration. There are possibilities for sequestering carbon that would otherwise enter the atmosphere, either by planting forests or by pumping it underground, for instance into spent oil and gas wells. The opportunities for innovation, development and investment in all these areas is great.

The need for action is urgent for three reasons:

1. Scientific. Because the oceans take time to warm, there is a lag in the response of climate to increasing greenhouse gases. The greenhouse gas emissions that have already occurred will continue to change the climate for 30-50 years.
2. Economic. Energy infrastructure (e.g. in power stations) also typically lasts for 30-50 years. It is much more cost effective to begin to phase in the required infrastructure changes now rather than having to make them much more rapidly later.
3. Political. Countries like China and India are industrialising very rapidly. If we want to provide an example of effective leadership we need to start now.

Both the challenge and the opportunity for all of us are unmistakable.

"No one made a greater mistake than he who did nothing because he could do so little."

Edmund Burke

References

1. Sir John Houghton's career includes posts as Professor of Atmospheric Physics, Oxford University, and Director General, UK Meteorological Office, where he took a particular interest in research into human induced climate change. He chaired the Scientific Assessment Panel on the Intergovernmental Panel on Climate Change (1998-2002). After retiring from the Met Office, he became Chairman of the Royal Commission on Environmental Pollution (1992-8). His many awards include the Japan Prize (2006), the International Meteorological Organisation Prize (1998), and Gold Medals from the Royal Astronomical Society and the Royal Meteorological Society.

1. EVIDENCE OF PAST CLIMATE CHANGE

Andrew Casebow

Figure 1.1 *Wave cut erosion at Cobo bay.*

Change is a normal part of geological history and Guernsey has abundant evidence of the past changes in our climate.

The average annual air temperature at the surface of the planet is just above 12°C. This is the average of day and night temperatures, summer and winter, from the Arctic through the tropics to the Antarctic.

We are living in what is scientifically known as an 'inter-glacial' period, but what is often thought of as a 'brief summer' that has lasted for about the past 10,000 years. These brief warm periods have occurred about every 90,000 years, so that there are known to have been 9 ice ages in the past 780,000 years. Scientists have examined deep ocean sediment cores and ice cores from Greenland and the Antarctic and they all provide similar evidence. For instance, the Vostock ice core taken from the Antarctic shows 4 glacial periods in the past 420,000 years. Professor Nick McCave will explain more in the following chapters.

The planet's temperature at the coldest time during the last glacial period was up to 10°C colder than the present, but the average temperature in the middle of the last 'ice age' was only about 5°C below today's average temperature. The difference now is that our burning of 'fossil fuels' has caused global average temperatures to rise by about 0.7°C in the past 100 years, and global climate models predict a rise in global average temperatures between 1990 and 2100 of between 1.5°C and 5.8°C, depending on future carbon dioxide emissions. However, the climate is not stable even without the greenhouses gases added by man.

When the weather became colder at the end of each 'interglacial period', water became trapped in vast sheets of ice covering much of the Northern Hemisphere, that extended as far south as southern England. As water was locked up in land ice, sea levels fell by as much as 120 metres; so Guernsey and each of the islands, were hills in a vast plain connected to both mainland France and England.

In the warm interglacial periods the sea levels rose as the ice melted. Temperatures during the interglacial periods varied, they were not always as they are today. In some periods the temperature was higher, resulting in greater glacial melting and higher sea levels, whilst in others the temperature was lower, less ice melted and the sea level was lower. For instance, it is thought that the temperature during the last interglacial period was slightly warmer than today and that this caused greater melting of the Greenland glaciers, resulting in a sea level that was several metres higher than the present.

To confuse us further, the level of the land surface has been rising throughout this period, caused by an uplifting of the European Tectonic Plate as Africa collided with Southern Europe. Evidence of the higher sea levels can be seen in the wave cut platforms, fossil cliffs, cliff notches, and raised beaches that can be seen in Guernsey at about 8 metres, 18 metres and 30 metres above current mean sea level. The wave cut platforms and raised beaches that are about 3 metres above the current high water level were created in the last 'interglacial' warm period about 120,000 years ago. There is a large raised beach area at Capelles, some 18 metres above sea level; and others at La Houguette, St Peters, and Rouvets, St Saviours that are 30 metres above sea level. Each of these beaches was created by the sea level during interglacial periods in the last 450,000 years.

The planet's temperature at the coldest period in the last ice age, was only about 5°C below the average temperature now.

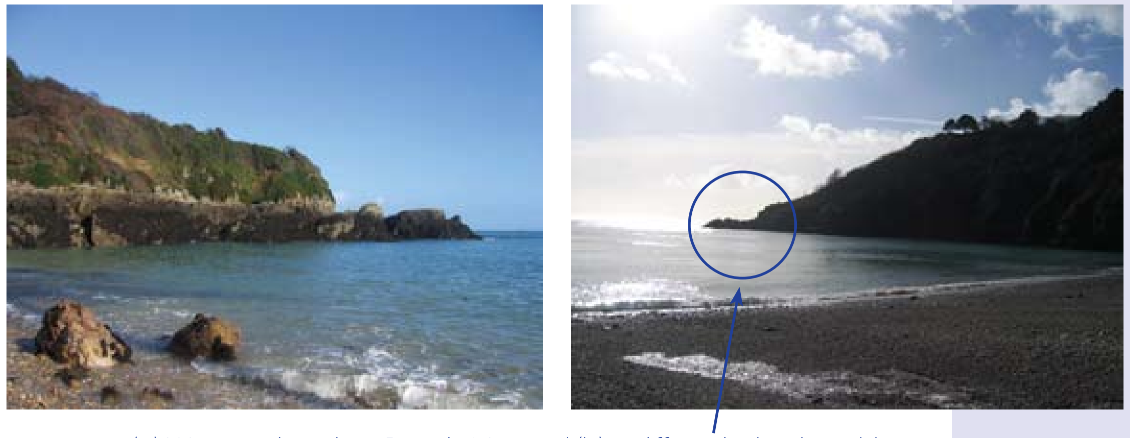


Figure 1.2 *(a) Wave cut beach at Bec du Nez and (b) a cliff notch clearly visible at Fermain.*

Dr John Renouf will explain how sea levels rose 50 metres between 11,000 and 6,000 years ago to cut our islands off from France and England. This process will have occurred repeatedly over the millennia as each successive warm period came and then receded as the cold reasserted itself again. During these cold periods the land was frozen tundra, devoid of all trees and flowering plants. Therefore, trees, plants, wild flowers, birds, animals, and man, will have only repopulated this area since the ending of the last ice age. Dr Renouf and Guernsey States Archaeologist, Dr Heather Sebire, will explain.

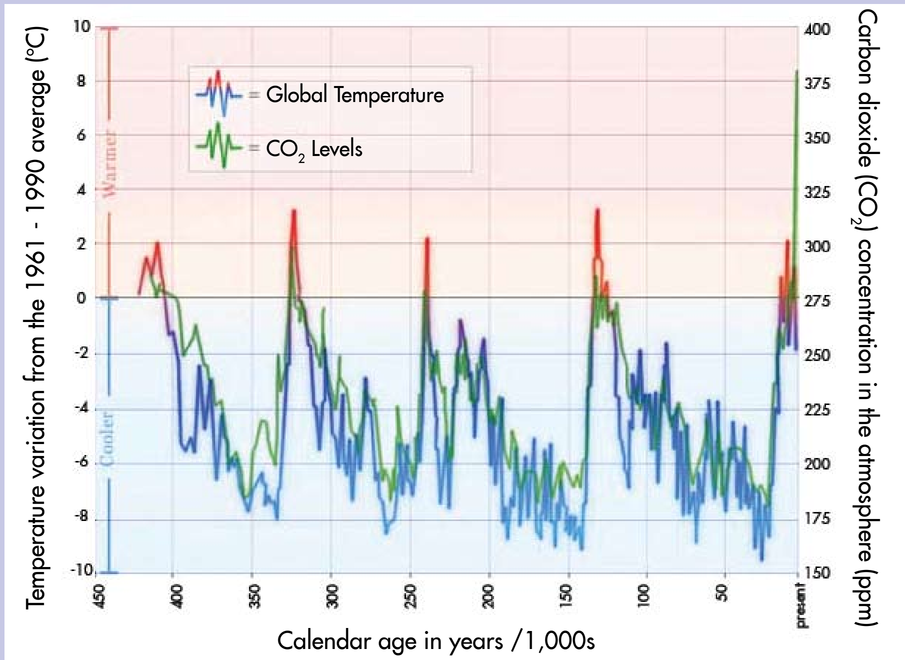


Figure 1.3 *Graph showing the global average temperature and carbon dioxide concentration in the atmosphere. Note how closely these are related. For most of the past 450,000 years, the world has been much colder than it is today - but changes can be abrupt.*

2. HOW THE EARTH'S NATURAL CYCLES AFFECT CLIMATE

Andrew Casebow and Chris Regan [1]

The cycle of ice ages and shorter interglacial periods (and the changes of climate within the ice ages), and even seasonal changes, are caused by cyclical changes in our planet's movement around the sun. They are called Milankovitch Cycles after the astronomer who first calculated them, and there are three main cycles: -

1. Eccentricity - The Earth's Orbit around the Sun

The Earth's orbit around the sun is not a circle (fig 2.1), but an ellipse. The effect of this is to change the distance that the Sun's short wave radiation must travel to the Earth in the different seasons.

At the present time the orbit is at its least elliptical, which means that a difference of only 3% occurs between the extremes, but this still means that the earth receives 6% more solar energy in January than it does in July each year. When the Earth's orbit is most elliptical (on a cycle of about 100,000 years), then the seasonal difference in solar energy would be 20-30%. This changing amount of received solar energy results in substantial changes in the Earth's climate, and in the change from glacial periods (ice ages) to interglacial periods.

The current stage of the cycle may mean that the world is nearing the end of its current 'interglacial period' and, without global warming, temperatures might have started to fall. However, temperature change would be very small compared to the large increases of temperature that are likely to be caused by global warming.

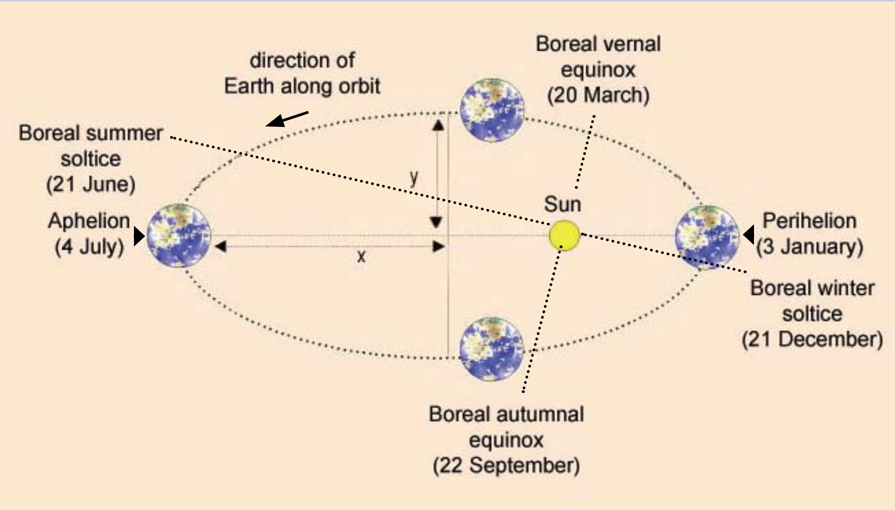


Figure 2.1 *The eccentricity, e, of the Earth's orbit around the Sun is given by the equation* $e^2 = 1 - y^2/x^2$*. The term 'aphelion' means furthest point and 'perihelion' the nearest point from the Sun.*

2. Axial Tilt - The angle of the earth's orbit to the sun

The Earth's tilt (fig 2.2) at the Equator varies from between 21.6° and 24.5° degrees in a periodic manner of about 41,000 years. The tilt today is about 23.5°. These changes in the earth's tilt affect the severity of the earth's seasonal changes and these seasonal changes are much more apparent towards the North or South Pole, away from the Equator.

One suggestion is that the lower axial tilt might promote the growth of ice sheets. The reason for this is that warmer winters could support greater atmospheric moisture and then heavier snowfall. Summer temperatures would be cooler, leading to less melting of the winter snowfall, and greater annual accumulation.

3. Precession

'Precession' (fig 2.3) is the Earth's slow wobble as it spins on its axis, which causes a change in the timing of the annual equinoxes. The axis of the Earth wobbles from pointing towards Polaris (the North Star) to pointing towards the star Vega. Each cycle of this 'wobble' takes 23,000 years.

When the Earth's axis is pointed towards Vega the Northern Hemisphere will experience longer winters because the Earth is furthest from the Sun. This results in greater seasonal contrasts. At present the Earth is nearest to the sun very close to the winter solstice.

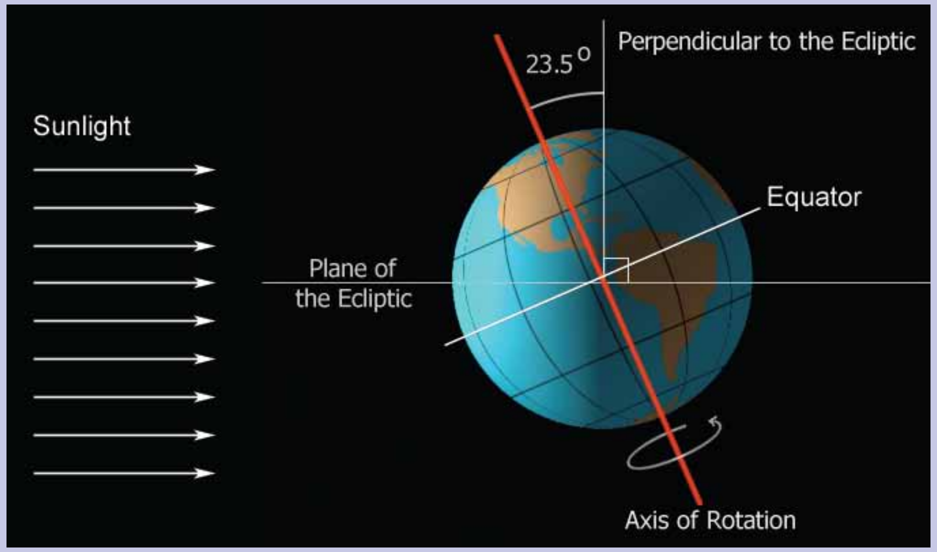


Figure 2.2 *The axial tilt of the earth's orbit to the sun varies. Currently it is at an angle of 23.5°.*

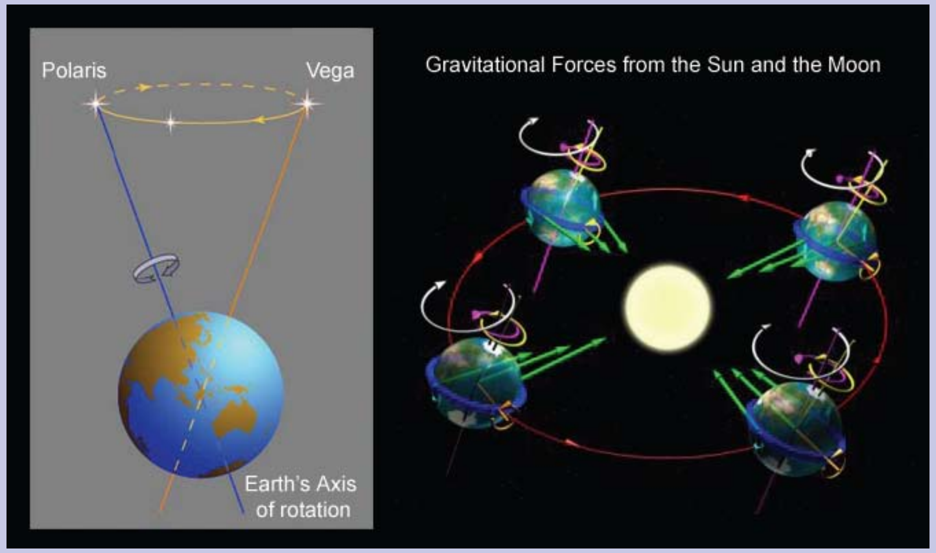


Figure 2.3 *The Earth's precession, or slow wobble as it spins, is caused by the differential gravitational forces of the Sun and the Moon on the Earth. Currently it is very close to the winter solstice which means our winters are generally longer and summers shorter.*

Conclusion

These variables are important because most of the world's landmasses are in the Northern Hemisphere. When the Northern Hemisphere summers are coolest because they are furthest from the Sun (due to greatest orbital eccentricity and precession) and the winters are warmest (due to minimum tilt), snow can accumulate and cover large areas of northern America and Europe. At present only precession is in the glacial mode, with tilt and eccentricity not favourable to the formation of glaciers.

Even when all the cycles favour the formation of glaciers, the increase in winter snowfall and decrease in summer melt is barely sufficient to trigger glaciation, and not sufficient to develop large ice sheets. The growth of ice sheets requires the support of a positive feedback loop. One such 'loop' might be the fact that ice masses reflect more of the sun's radiation back into space, thus cooling the climate and allowing glaciers to expand.

References

1. Chris Regan is a Marketing Communications Executive for the States of Guernsey. He is currently undertaking study with the Open University towards a BSc in Physical Science. Chris was born in Guernsey where he lives with his family.

3. LONG-TERM CLIMATE CHANGE

Nicholas McCave [1]

We are living in an Ice Age. We don't know whether we are in the middle or near the end, but it has been going on for around 30 million years so far.

The last major ice age lasted 50 million years; from around 330 to 280 million years (Myr) ago during what geologists know as the Carboniferous and Permian Periods. More recently, between 100 and 50 million years ago we can find little evidence of any ice at all, because the world was much warmer then. The evidence for these deductions lies in the distribution of fossils. For instance, trees grew in the far north (at a palaeolatitude of 80° N) in warm periods, and sediments such as ice-rafted gravel in deep-sea muds can be found much closer to the equator (at 35° N) during cold times.

So Earth's climate has been anything but stable in the long term. Figure. 3.1 shows results from the most powerful climate indicator that we have, the ratio of oxygen isotopes in marine shells, called foraminifera (Figure. 3.2). This indicator combines the effect of ice volume and temperature over the last 70 million years. The development of cooler climates over the past 50 million years is clear, and particularly the cold of the last 3 million years.

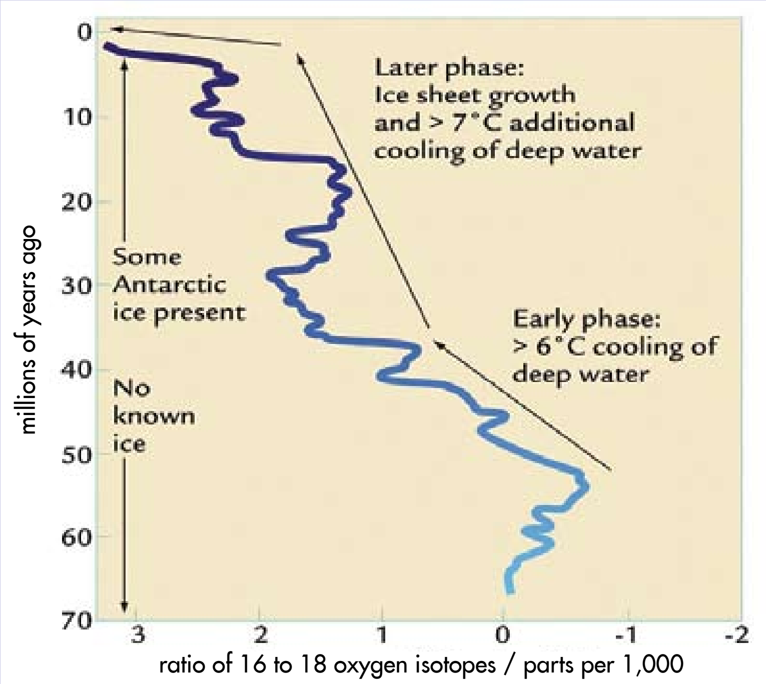


Figure 3.1 *Ratio of oxygen isotopes in marine shells over the last 70 Myr* [2].

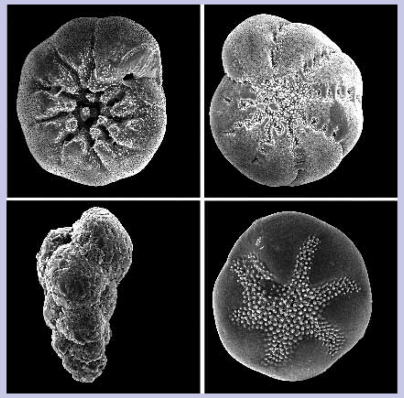


Figure 3.2 *Ice ages can be shown by oxygen isotopes measured in foraminifera - see illustration above.*

In the last million years, perhaps the peak of the present ice age, climate has also been most unstable with around 10 major glacial periods of 100 thousand years duration. These glacial periods that we normally think of as 'ice ages', each lasted some 80-90 thousand years of cold conditions and 10-20 thousand years of warmer conditions. In the last million years there have been very few times when the global temperature has been as warm as it is now, and in the last 11 thousand years during which human civilisation has developed. The three most pronounced warm periods, known as 'interglacials', occurred at around 420, 330 and 125 thousand years ago.

Figure 3.3 is a graph showing the ratio of oxygen isotopes for the last 500 thousand years, and from them you can see the sequence of warm and cold periods following each other, with warm peaks at about every 100 thousand years. In the diagram, warm periods have odd numbers and one can see that only numbers 5, 9 and 11, which represent interglacial periods that occurred at 420, 330, and 125 thousand years ago, have values similar to the present time (number 1). Number 2 is the last glacial maximum that occurred about 20 thousand years ago, with other even-numbered glacial periods; and you can see that some were less severe than others.

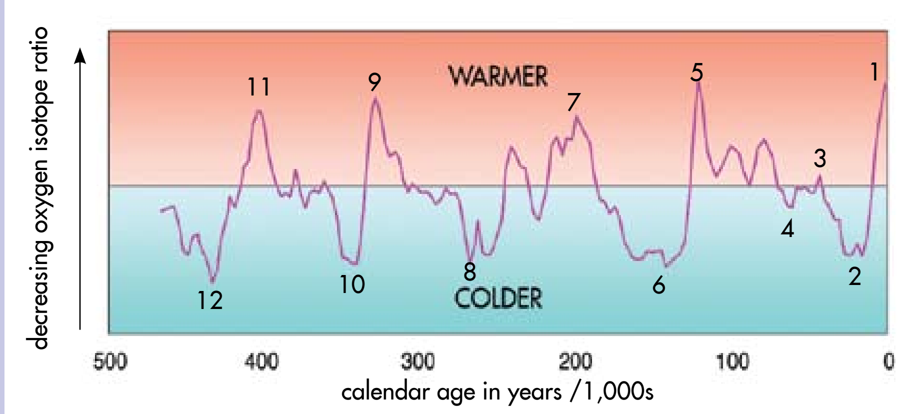


Figure 3.3 *Ratio of 16 to 18 oxygen isotopes in the last 500,000 years. Cooler temperatures result in an increase, whilst warmer temperatures produce a decrease in the ratio. This process is significant in determining climate change.* [3]

Therefore, it can be seen that most of the time over the past 500 thousand years the climate has been much colder than it is at the present, and that the cold was only broken by brief warmer periods, or interglacials. But even the warm periods have not had stable temperatures, as you will see in Chapter 4. Similarly, Figure 3.4 shows that the temperature in the last 'glaciation' fluctuated and grew progressively colder until the last glacial maximum that occurred about 20 thousand years ago, just before the climate warmed dramatically.

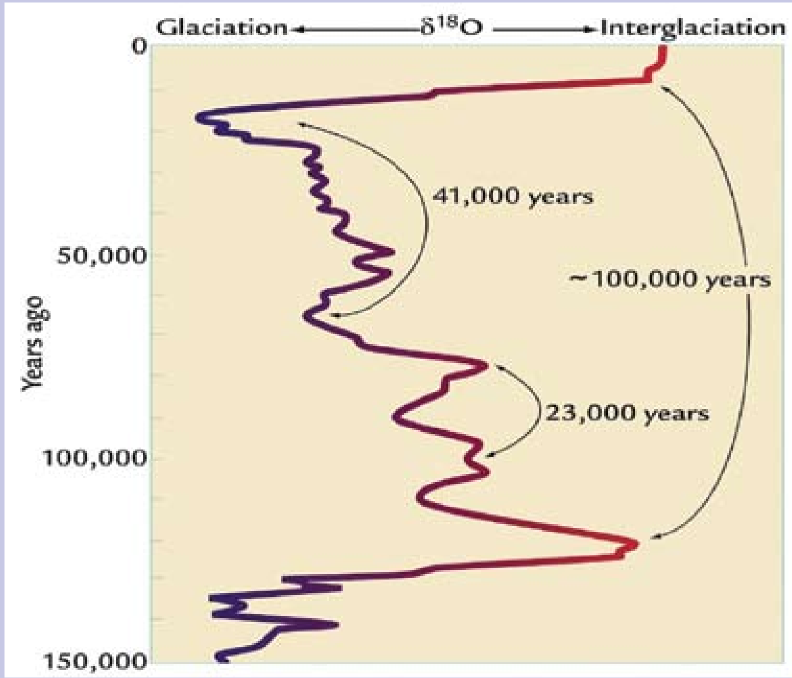


Figure 3.4 *The peaks and troughs in the diagram above refer to Milankovick cycles of 23,000 years, 41,000 years and 100,000 years.*

Professor McCave says "*we use data based on oxygen and carbon isotopes, skeletal chemistry, species abundances, organic molecules and physical properties of sediments as a basis for inferring past temperature, salinity, density, nutrients and flow speed of oceanic water masses*".

An ice age is a geological period during which great glaciers and ice sheets extend from the Polar Regions towards the equator. Individual ice ages wax (glacial phases) and wane (interglacial phases) in strength. The present day climate is an interglacial phase within the Quaternary Ice Age, which began in the Northern Hemisphere about 3 Myr ago and in Antarctica about 30 Myr ago.

References

1. Professor Nicholas McCave. Woodwardian Professor of Geology at Cambridge University since 1985. Fellow of St John's College, Head of the Earth Sciences Department from 1988-1998. His research interests include the deep circulation of the oceans in relation to climate change. A Guernseyman by birth.

2. Ruddiman, W.F., 2001 Earth's Climate: Past and Future. WH Freeman, New York, 465 pp. (Figs. 3.1, 3.4).

3. Data from Lisiecki, L. E. and M. E. Raymo, 2005, Paleoceanography, vol. 20, PA1003. (Fig. 3.3).

4. THE PRESENT INTERGLACIAL PERIOD

Nicholas McCave

Figure 4.1 *Land ice sheets, such as this one in Greenland, contract during the period between ice-ages. This period is called 'interglacial'. The current Holocene interglacial has persisted since the Pleistocene, about 10,000 years ago.*

Anthropologists have argued that the relative climatic stability of the past 10 thousand years has allowed development of modern human civilisation, including the farming of plants, the domestication of animals, and the building of cities. It was only in the past 25 thousand years that our species Homo sapiens emerged as the dominant hominid with the decline of the Neanderthals. However the period from 25 to 11 thousand years ago saw huge climate shifts in the transition from full glacial (with ice down to the Isles of Scilly) to present interglacial conditions, with both major warmings and coolings; which was not good at all for the establishment of stable human communities.

Then about 10 thousand years ago the climate became relatively stable, with estimated global mean temperature shifts of less than 1° C (compared with 5° C glacial to interglacial global change – though obviously much more adjacent to ice sheets). There was one blip on this stable warm climate, that occurred about 8,200 years ago. This was caused by the final collapse of the Canadian ice cap. This produced a sudden discharge of fresh water, that had gathered in a vast lake as the ice melted, into the North Atlantic. It is thought that this sudden influx of cold, fresh water caused a temporary weakening of the current system that brings warm waters from the Gulf of Mexico to north-western Europe. This system – The Gulf Stream and North Atlantic Drift at the surface – depends on the water being dense enough to sink in the Norwegian Sea when it gives up its heat, but the extra fresh water made it too light, thereby slowing the system down.

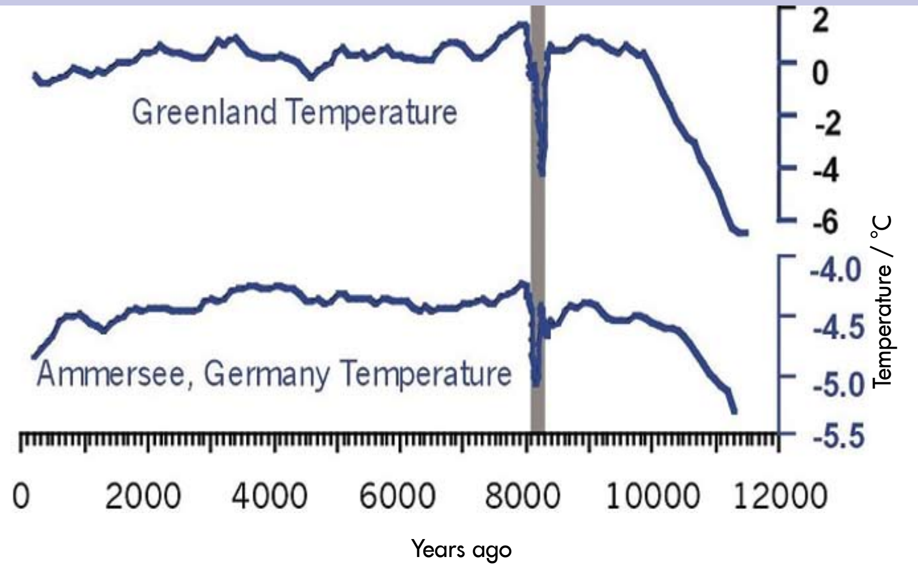


Figure 4.2 *Temperatures both on the Greenland ice cap and in a record from a central German lake show at least 1°C of change* [1].

Figure 4.2 shows that ice and sediment records from Greenland and from a German lake show the same story; that a sudden dramatic fall in temperature occurred about 8,200 years ago. The warmer temperatures seem to have returned after about 200 years, probably as the circulation returned to normal interglacial conditions.

Since then there have been minor oscillations of climate, shown by sediments excavated from the Atlantic. This suggests 8 cooler periods in the last 10 thousand years. Figure 4.3 shows a higher percentage of sand grains (dropped from icebergs) indicates colder conditions.

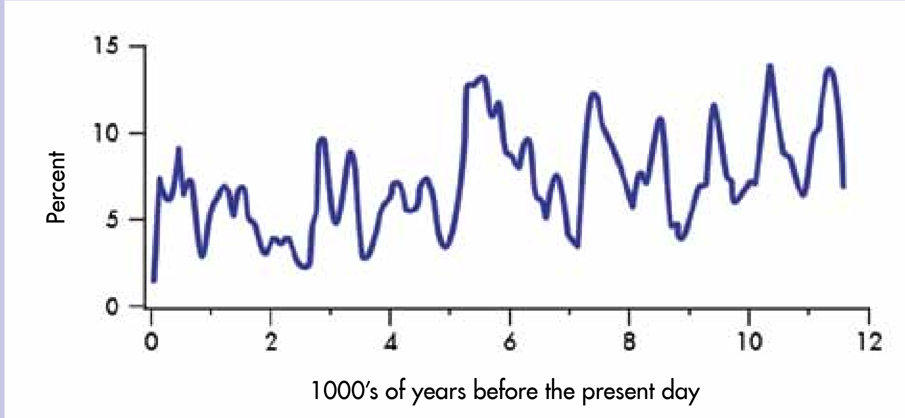


Figure 4.3 *A higher percentage of sand grains indicates colder conditions* [2].

The most recent of these warm/cool oscillations was the Mediaeval Warm Period that peaked between 1000-1200 AD, when there were vineyards in England as far north as Leicestershire; and the succeeding Little Ice Age that peaked between 1550-1800, when the Thames used to freeze over in winter (Figure. 4.4). This temperature fluctuation is clearly evident when tree-rings, that record the conditions when the tree was growing, are analysed. From this it can be seen that at no time in the last 2 thousand years has it been warmer than the present, and that the current trend is taking global temperatures beyond the maximum attained in the past half million years. We are entering uncharted territory.

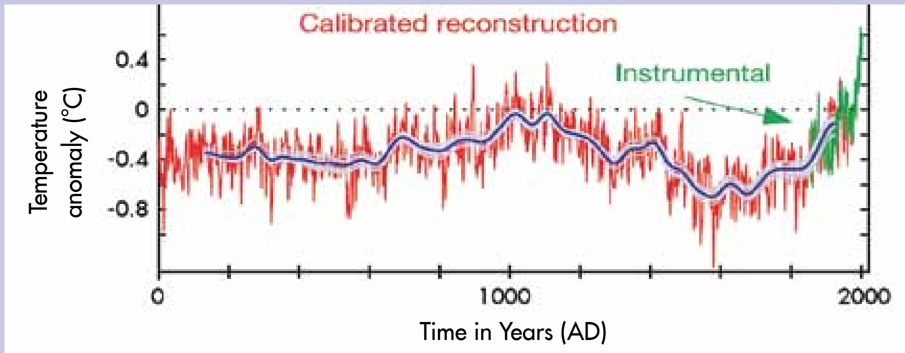


Figure 4.4 *Temperature variations over the past 1,000 years, clearly showing the medieval Warm Period (peak 1,000 – 1,200) and the Little Ice Age (peak 1,550 – 1,800).* [3].

It may be salutary to reflect that whatever we do, the Earth will continue, with or without us. That is the lesson of the cataclysms recorded in the rocks.

As Ronald Wright [4] has so pungently put it

"If we fail - if we blow up or degrade the biosphere so it can no longer sustain us – Nature will merely shrug and conclude that letting apes run the laboratory was fun for a while but in the end a bad idea."

References

1. Von Grafenstein, U. and others, 1998. /Climate Dynamics, /vol./ /14, 73-81. (Fig. 4.2).

2. Bond, G.C. and others, 2001. /Science/, vol. 294: 2130-2136. (Fig. 4.3).

3. Moberg, A. and others 2005, /Nature/, vol. 453: 613-617. (Fig. 4.4).

4. Wright, R., 2005. /A Short History of Progress/. Canongate Press, Edinburgh, 211 pp.

5. SEA LEVEL RISE AROUND THE CHANNEL ISLANDS

John Renouf [1]

During the glacial periods Guernsey had a much colder climate and was a part of the mainland of France and of England for long intervals. Figure 5.1 shows that the sea around Guernsey was part of the European landmass during these times.

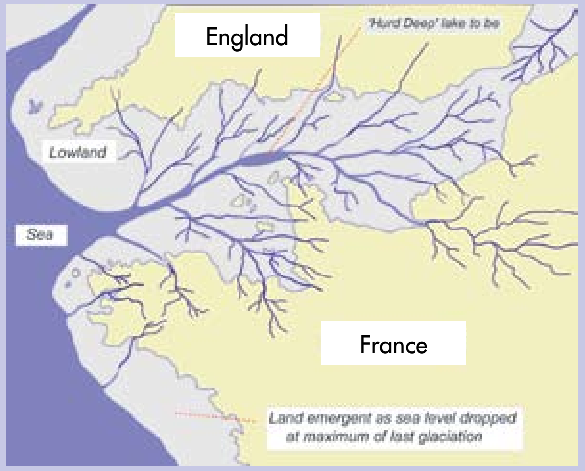


Figure 5.1 *Guernsey was part of the European landmass during the glacial periods.* Sinel Map of 1923 (redrawn).

In the course of the warm Interglacial periods, sea levels globally were several metres higher than the present day, due to differences in temperature and glacial melting. There was, however, one important difference: the land that was at sea level 450,000 years ago is now 30-35 m higher, since the whole of the Channel Islands and adjacent areas has been rising by about 7 cm every thousand years ever since.

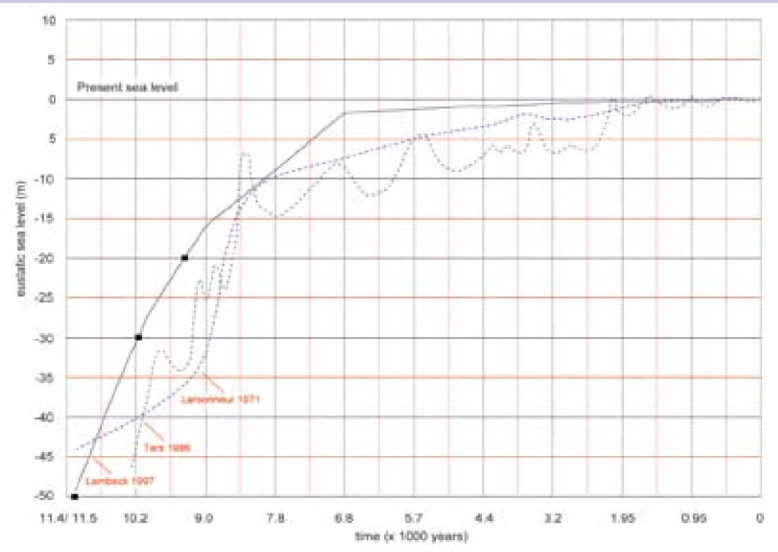


Figure 5.2 *Sea level rise over the last 11,500 years. Points plotted at levels 50m, 30m and 20m lower than present are visualised on page 21 (fig 5.4c, d, and e).* source K Lambeck.

The sea level of 450,000 years ago had pebble beaches and wave cut platforms, and these can now be found at a height of over 30m above Guernsey Datum, as at La Houguette in St Peters, and Rouvets in St Saviours. Other raised beaches and platforms are found at 20-25m (from the Interglacial period about 350,000 years ago), at 15-18m in Capelles (caused during the interglacial 250,000 years ago), and at just above the present high water mark of spring tides (120,000 years ago).

Figure 5.3 *Evidence of a raised beach on the west coast of Guernsey. Large rounded stones are situated below smaller pebbles, upon which smaller material from the end of the last Glacial period is deposited.*

An example of this beach on the west coast of Guernsey is shown in figure 5.3. Large rounded stones are to be seen below smaller pebbles, and these are overlain by more angular small stones in a finer orange yellow material, known as loess, a wind blown deposit from the end of the last Glacial period.

The coldest time during the last Glacial period occurred about 18,000 years ago. Following this the great northern ice sheets began to melt as the climate became much warmer. By the time the Glacial period officially ended about 11,500 years ago, the sea level had already risen by more than 50 metres from its minimum height, that had been more than 100m below that of the present. The scene becomes particularly interesting for Guernsey between 10,000 and 11,000 years ago when the rising sea was cutting the island off from the mainland of France.

Figure 5.4 Sea Level Rise

Figure 5.4a Land and sea at about 18,000 years ago.

Sea level over 100 metres lower than today.

At the height of the last Glacial maximum, the seashore was well out in the Western Approaches. The Hurd Deep to the north of Alderney is a lake.

Figure 5.4b Land and sea at about 14,000 years ago.

Sea level about 75 metres lower than today.

As the great northern ice sheets began melting, the sea level rose rapidly.

Figure 5.4c Land and sea at about 11,400 years ago.

Sea level about 50 metres lower than today.

The Hurd Deep to the north of Alderney is now a deep in the sea. The sea level is still rising rapidly.

Figure 5.4d Land and sea at about 10,200 years ago.

Sea level about 30 metres lower than today.

The shore-line is very close to the west of Guernsey and the island, along with Sark and Alderney are now cut off from France.

Figure 5.4e Land and sea at about 9,400 years ago.

Sea level about 20 metres lower than today.

Guernsey separated but Jersey is still not an island.

Figure 5.4f Land and sea at the present time.

More recently than 10,000 years ago.

The rate of sea level rise slowed considerably and there is difficulty in knowing the precise outline of the seashore at any given time during the last 9,000 years.

The sea level continued to rise but there were fluctuations caused by both general and local causes. The general causes were mostly climatic in nature but the local ones were often caused by the erosion of soft sediments and the effectiveness of sea and tide to remove it. There might have been long periods when a dune barrier at the high tide could have held back the sea before, quite suddenly, it was breached and the sea claimed a significant land area overnight. Thus a clear distinction has to be made between sea level rise and sea encroachment. There is still active erosion going on at present of soft sediments around the coast. This sediment has been at the same level since the sea reached its present height but erosion has only now reached back far enough for the sea to be attacking it.

References

1. Dr John Renouf was formerly Curator of the Museum in Jersey. He trained as a geologist at London University and studied geology in Brittany for his doctorate. He now specializes in the study of former sea levels and consults as a geologist on archaeological matters.

6. LANDSCAPE AND CULTURAL EVIDENCE OF CHANGE IN GUERNSEY

John Renouf and Heather Sebire [1]

At the end of the last ice age the climate of north-western France and the Channel Islands was an open, dry steppe-like tundra with no tree cover and a low herbaceous ground cover (Figure 6.1a). The loessic (silty) soil of the main plateau of Guernsey was possibly being blown into place at this time.

Initially the climate rapidly warmed for a thousand years or more, but then became colder again. It was a cold, arctic environment of mostly low, shrubby vegetation but with the odd patch of open woodland (Figure 6.1b).

Then the climate rapidly warmed again about 11,000 years ago and, within something over a thousand years, a well-established forest became widespread. Birch, hazel and pine were quite common (Figure 6.1c). By 8,750 the forest had become dense and birch and pine were in decline. About this time the island of Lihou provides evidence of Mesolithic human habitation. Hazel nuts were in ready supply as shown by their recovery from the sediments.

The first Neolithic farming peoples arrived in the Channel Islands about 7,000 years ago (Figure 6.4). There is little pollen evidence available to determine the vegetation accurately, but it suggests that a typical oak forest existed at that time, with areas of other vegetation types on wetland and on more open areas. The pollen record provides the first evidence of human activities affecting the vegetation. Forest clearance is revealed from the pollen and vegetation remains. This is the pivotal moment in the story of the island's vegetation as from this moment on the human influence becomes significant, and has remained so to this day. The climate during this period was also about 1°C warmer than today, and witnessed the climax development of the mixed oak forest in northwest Europe. Subsequently the climate has been cooler, often wetter and generally more uncertain but the distribution of the natural vegetation cover that would have developed under these varying conditions is no longer identifiable since human agricultural and pastoral practices have modified it in many different ways.

Figure 6.1 *Views looking west from Lihou showing the dramatic changes in vegetation as the climate ameliorated from the intense cold of the Ice Age.* **Figure 6.2** *Early evidence of Neolithic man.*

Figure 6.1a *18, 000 years ago - Open, dry steppe-like tundra are typical of the Channel Islands climate.*

Figure 6.1b *13,000 years ago - Low vegetation and patches of open woodland are quite common.*

Figure 6.1c *8,000 years ago - Birch, hazel and pine forests are widespread.*

Figure 6.2 *6350 years ago - Les Fouaillages Dolmen, first evidence of early Neolithic human activity.*

Cultural changes in the human habitation of Guernsey occurred both within the Neolithic and during the succeeding Bronze and Iron ages (Figure 6.3).

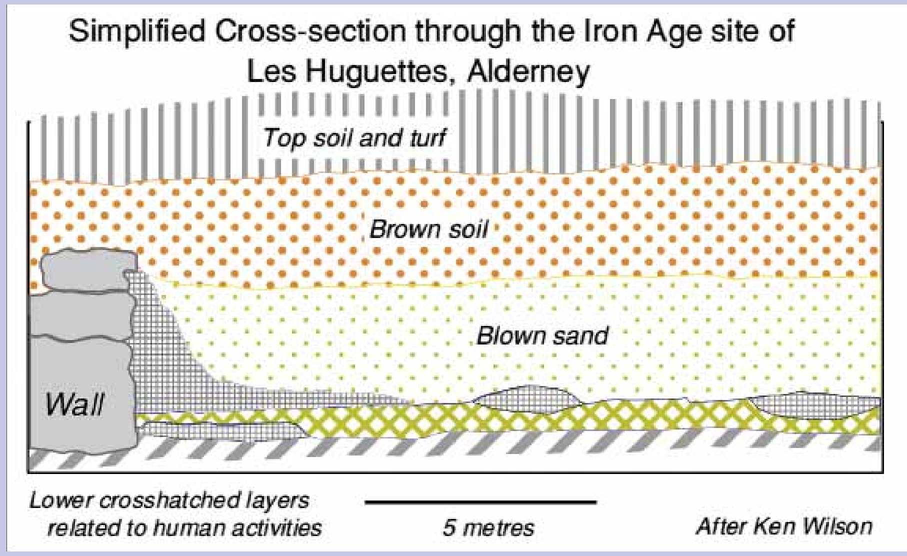


Figure 6.3 *Iron age pottery manufacturing site of nearly 2,500 years ago at Les Huguettes in Alderney. Abandoned probably because of blowing sand.*

During Gallo-Roman times, there is widespread evidence of the establishment of small centres around Guernsey's coasts evaporating seawater to produce salt –the so-called briquetages. A Medieval site at Albecq (Figure 6.4) on the west coast is of value to any discussion of climate in Guernsey since it represents a time when there was a significant climatic change under way: that from the earlier Medieval Warm Epoch to what is usually called the Little Ice Age. The site here was buried by wind blown sand, which is quite likely to be part of a widespread phenomenon in northwest Europe during the 14th/15th centuries. Serious wind blow and sea encroachment associated with much increased storminess is well documented.

Figure 6.4 *The site at Albecq (Medieval period, Guernsey's west coast) show the occupation layers overlain by blown sand as a result of storms and sea encroachment, indication of some degree of climatic change.*

Guernsey Climate and Landscape

18,000 years ago
The landscape lacked trees apart from the smallest of shrubs. The climate was cold not unlike today's arctic tundra. Woolly Mammoth and Woolly Rhinoceros roamed the plains around Guernsey.

14,000 years ago
The landscape still lacked trees and the climate remained cold. Woolly Mammoth and Woolly Rhinoceros were possibly gone from the area.

11,000 years ago
The climate has warmed considerably and there is, along with the grassy plains, open woodland with much birch but also oak, hazel and other trees that have spread from the south. Guernsey is about to become an island.

8,000 years ago
A richer tree cover has developed, probably covering much of the landscape. The climate is mild and not too different from the present.

7,500 years ago
Oak and hazel woodland are now fully established and will remain the dominant vegetation cover over large areas to the present day, except that human interference has modified that natural situation to a major degree. Open heath and grassland cover significant areas of cliff and dune.

References

1. Dr Heather Sebire is Archaeology Officer at Guernsey Museum. She has carried out extensive rescue excavations in the Bailiwick of Guernsey over the last twenty years and has particular research interests in the prehistory of the Channel Islands.

7. EVIDENCE OF CLIMATE CHANGE

Andrew Casebow

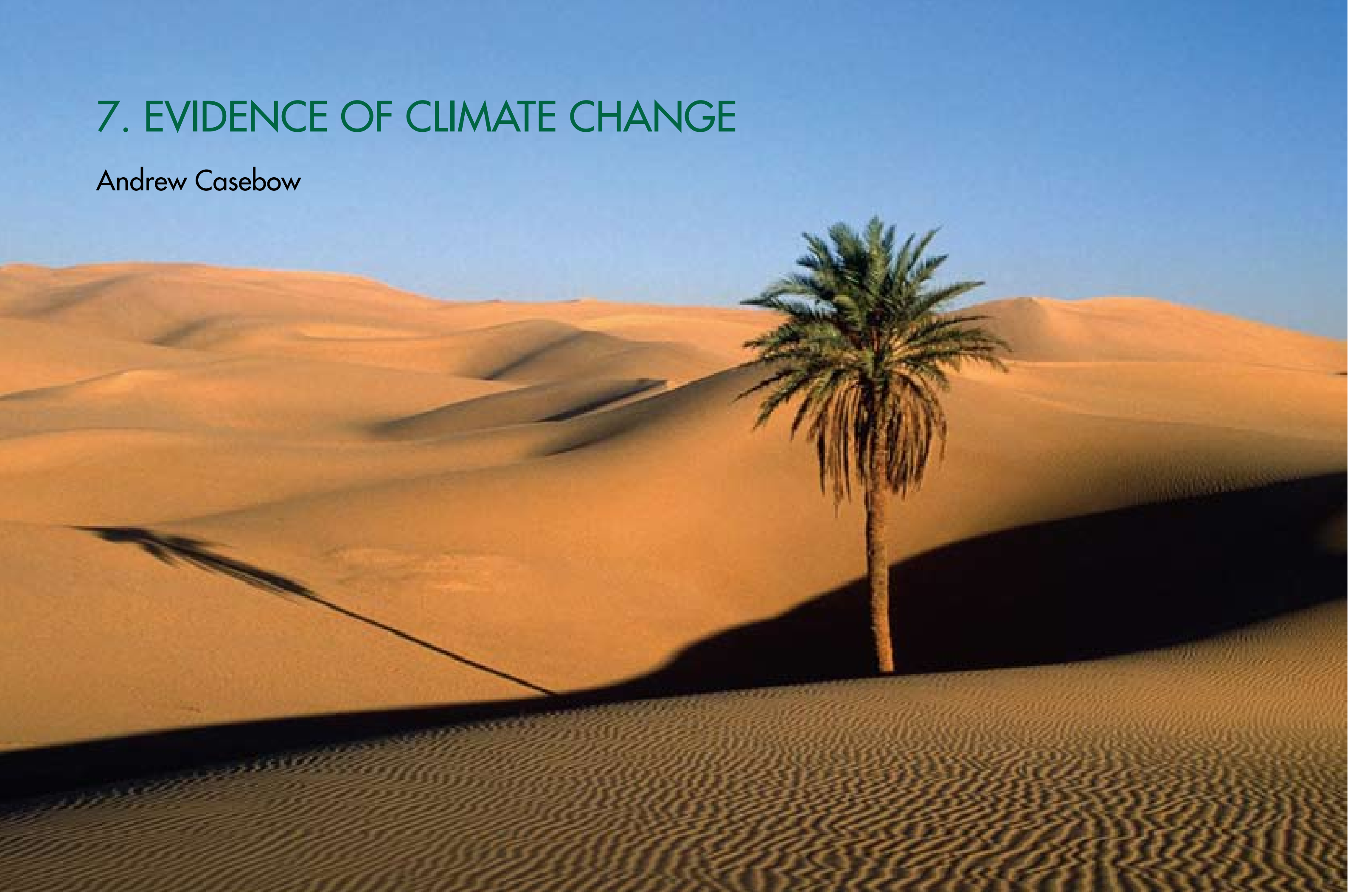


Figure 7.1 *Global warming is likely to cause the expansion of deserts in the future.*

As each year passes there is an increasing amount of evidence to confirm that climate change caused by global warming is really occurring. We may think that the climate is stable and we may even think that it has always been the same as it is now, but that is because we live for such a short period of time, and our memories are so limited and imperfect. We have to look back into written records and other evidence to realise that the climate has never been stable.

But what do we mean by terms such as 'climate change' and 'global warming'?

The weather that we experience is caused by the fluctuating state of the atmosphere around us. The 'climate' is often thought of as 'average' weather, but in fact it is 'the synthesis of weather over a long period, including extremes as well as averages'.[1] The climate that is normally experienced in Guernsey is different to the climate that we would expect if we went on holiday to a hot dry climate, for instance, to a country such as Morocco in North Africa; or to a very wet and humid climate that might be found in a rain forest in Borneo, or the Amazon. Changes in climate have caused famines, mass migration and the collapse of civilisations in the past.

The earth's climate is in a very delicate balance. 'Normal' climate change is caused by many different naturally occurring cycles, mainly concerned with the earth's movement around the sun,[2] that influence the amount of heat energy that is absorbed. These cycles continue over many thousands, and hundreds of thousands of years. The climate change that is occurring now, that we refer to as 'global warming', is caused by a difference in the concentrations of gases and chemicals in the earth's atmosphere. This is called the 'greenhouse' effect.

In Guernsey, the Island's Meteorological Office has been recording information on air temperatures, rainfall patterns, the amount of sunshine that we enjoy, the wind, and the wintertime frosts and snow fall since 1843. Met Officer, Tim Lillington, has analysed this information and will explain how the air temperatures in Guernsey have progressively increased in recent years, resulting in fewer frosts in the winter; and how rainfall patterns have changed making our climate drier in the summer months. These are all changes that we might expect to occur if the earth's climate was warming, and so they are an early indication that the change is caused, not by the earth's natural cycles, but by the effect of global warming.

In recent years the Intergovernmental Panel on Climate Change (IPCC) has been working to improve the understanding of climate change. The Panel has produced four reports – in 1990, 1995, 2001, and in 2007. The latest report confirms the earlier findings and provides very persuasive evidence that climate change caused by global warming is occurring. The key findings are that:

- Warming has now been observed throughout the world - in the atmosphere, on the land and from below the surface of the oceans, so "there is now greater certainty that the planet is undergoing warming".[3]
- Human activity, through the generation and release of greenhouse gases, has been a significant contributory factor in the global temperature rise.
- Research shows that the climate is changing faster and in a more dramatic fashion than has previously been reported.

Most recently, it was reported in September 2007 that the extent of the Arctic sea ice had diminished to such an extent that the 'North-West passage' linking Northern Europe with Asia, had become open and free of ice. It remained navigable for about 5 weeks from 11th August 2007. Scientists at the University of Colorado's 'Snow and Ice Data Centre' suggest that at the current rate of decline the Arctic will be ice-free by the summer of 2030 [4].

References

1. Phillip Eden (2003). The Daily Telegraph Book of the Weather, Continuum, London.

2. The changes of climate, with successive 'glacial' 'interglacial' periods, is caused by cyclical changes in our planet's movement around the sun. See page 14.

3. http:/www.metoffice.gov.uk/research/hadleycentre/ar4/wglreport.html.

4. http://nsidc.org.

Figure 7.2 The Greenhouse Effect

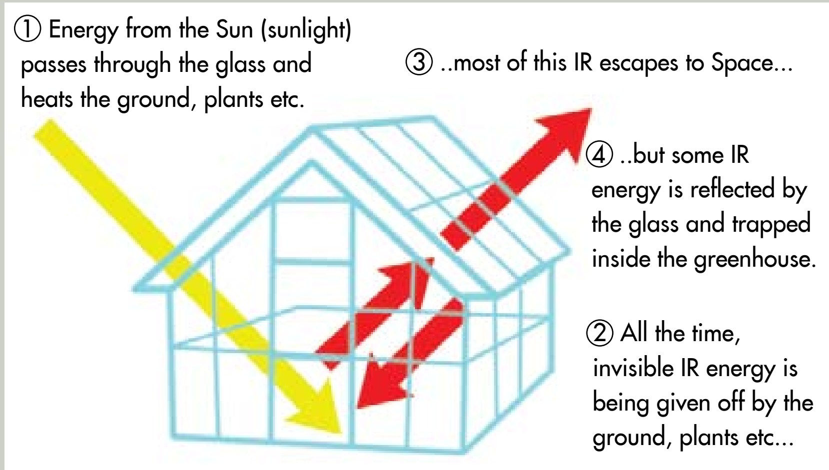


Figure 7.2a *Some of the energy from the Sun is 'trapped' within the greenhouse in the form of heat. IR energy refers to the infra-red part of the energy spectrum.*

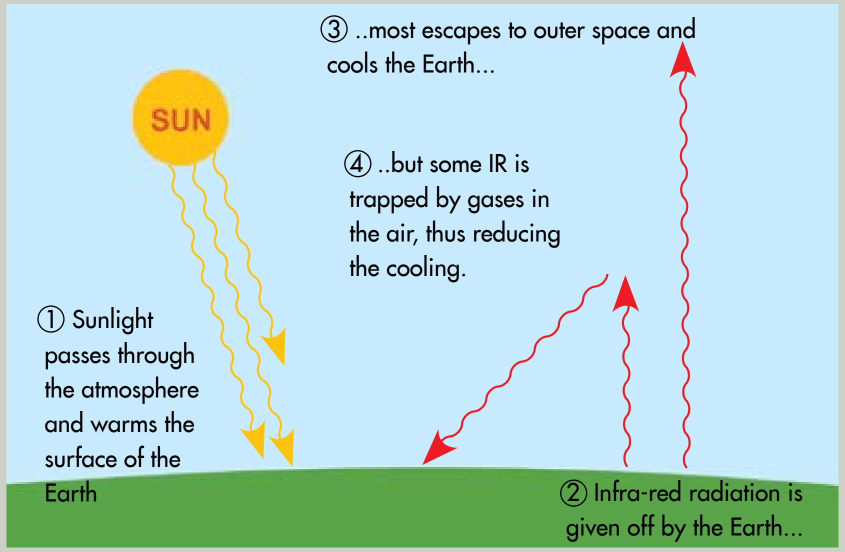


Figure 7.2b *The 'Greenhouse' analogy. Certain gases in the Earth's atmosphere 'trap' energy which increases the temperature. This is namely the 'Greenhouse Effect'.*

Source Hadley Centre Climate Briefing 2005.

8. CAUSES OF THE GREENHOUSE EFFECT

Andrew Casebow

We rely upon the Earth's 'greenhouse effect' to keep us warm. Natural greenhouse gases, such as carbon dioxide, methane and water vapour, act as a blanket to keep in the warmth generated by the sun's rays. Without it our climate would be similar to that of Mars, with temperatures below zero; life as we know it could not survive.

However, man has removed forests and has burnt coal, oil and gas in ever-greater quantities, and this has increased the amount of carbon dioxide in the atmosphere. An expanding human population also produces huge quantities of methane from decomposing rubbish and animal production. The increased concentration of these gases in the atmosphere makes it trap more of the earth's incoming heat and so our planet heats up, and more water vapour is produced (Figure 8.1).

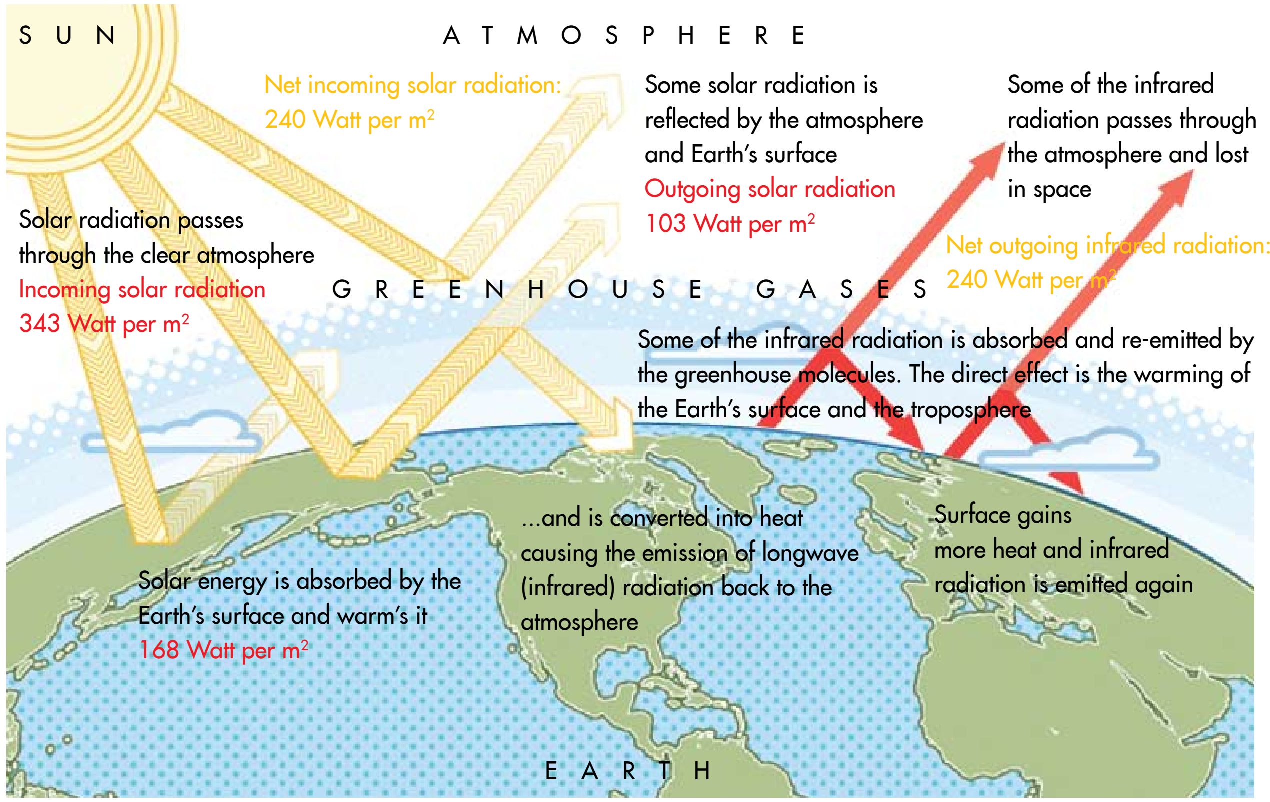


Figure 8.1 *Schematic diagram showing the Earth's energy cycles and the 'Greenhouse Effect'.*

It takes a huge amount of energy to warm the water in the world's oceans, and so they warm up very slowly and will take a long time to cool down again. The result is that the weather system has more energy, derived from the sun's heat and, as a consequence, the weather becomes more extreme. There is more evaporation of water, more clouds, heavier rain and stronger winds.

The concentration of greenhouse gases in the atmosphere has been steadily increasing. During the last ice age the concentration of carbon dioxide (CO_2) in the atmosphere was between 200 and 220 parts per million (ppm), but over the past 20,000 years as man cut down and burnt woodland and forests this gradually increased.

By the beginning of the 19th Century the concentration of CO_2 in the atmosphere was about 280 parts per million, and it was still only about 316ppm by 1960. From Figure 8.2 it can be seen to have been rising steadily since regular monitoring began in 1959. The concentration increases every winter and reduces each summer because of photosynthesis, converting CO_2 into plant growth. Rather poetically, this effect has been described as the earth 'breathing'.

It is known that the concentration of CO_2 in the atmosphere is very closely linked to the earth's temperature. Dangerous climate change is likely to occur if the earth's mean temperature rises by more than 2°C, which relates to a level of CO_2 in the atmosphere of 400 – 450ppm.

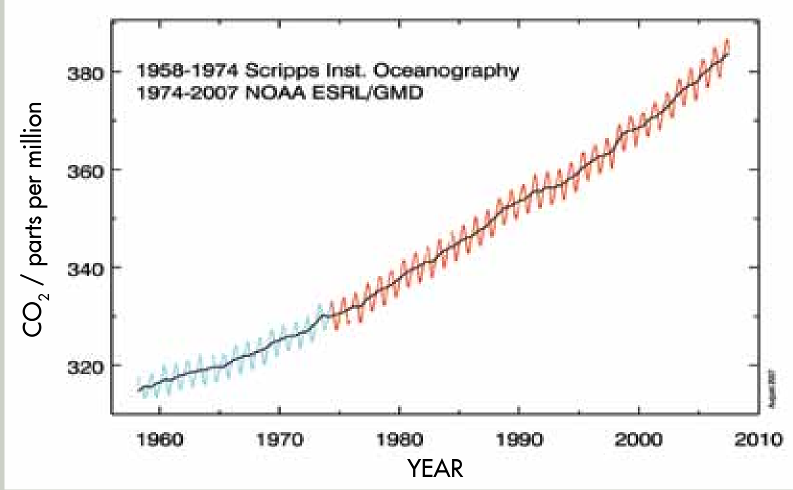


Figure 8.2 *Monthly average carbon dioxide in the atmosphere from 1955 to 2005.*

Source: National Oceanic and Atmospheric Administration (NOAA), Climate Monitoring and Diagnostics Laboratory (CMDL), Carbon Cycle Greenhouse Gases.

To investigate the extent to which global warming may be natural or man-made a model of the climate system was developed by the UK's Hadley Centre. Figure 8.3 shows average annual temperature and model predictions based on natural cycles, including known emissions from volcanoes and the effects of sunspots and other factors, and there is a wide differential between what actually occurred and the model prediction over the past 30 years.

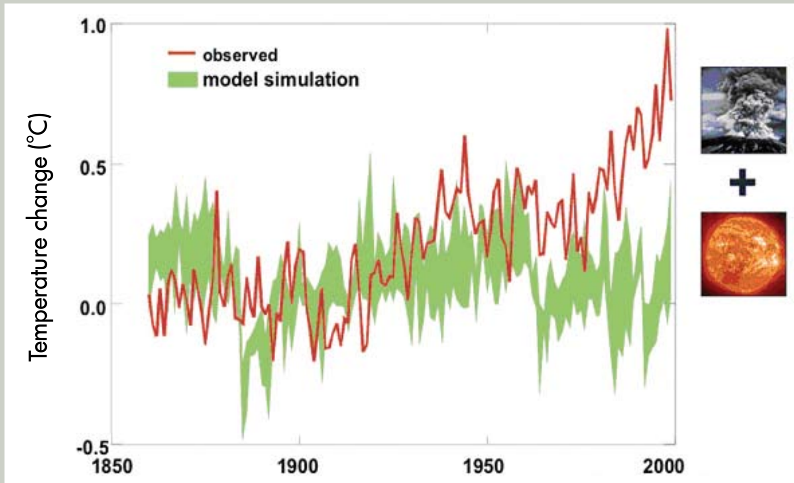


Figure 8.3 *Mean annual temperatures and model predictions based on natural solar and volcanic cycles. The past 30 years show a widening disparity.*

Source: Met Office Hadley Centre.

However, when the known emissions of CO_2 were added into the model, then the model simulation matched the actual temperature almost exactly, suggesting that the temperature increase was caused by the higher concentration of man-made CO_2 in the atmosphere (Figure 8.4).

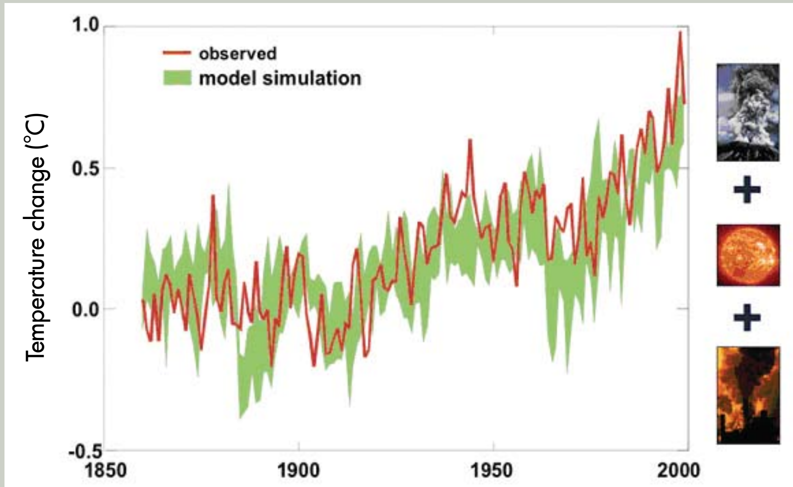


Figure 8.4 *Mean annual temperatures and model predictions based on natural cycles and human activity are similar, this suggests disparity in Figure 8.3 is man-made.*

Source: Met Office Hadley Centre.

9. THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

Andrew Casebow

Figure 9.1 *The IPCC 4th Assessment reports that human activity is almost certainly the cause of 'Global Warming'. CO_2 emissions from oil fired powerstations is just one of many contributors to this effect.*

This year has been a watershed. Previously, some Governments had chosen not to accept the overwhelming evidence that climate change was occurring. Many people considered that there was still a 'debate' about whether or not climate change caused by global warming was a reality. There was still a lot of misinformation and discussion about the causes of climate change and whether it was a naturally occurring phenomenon. Then the 4th Assessment Report from the IPCC[1] was published.

The report shows that it is virtually certain that climate change induced by human activity is happening, and is occurring faster than had been previously anticipated.

> The Intergovernmental Panel on Climate Change is the world's leading authority on climate change. It was set up by the World Meteorological Organisation (WMO)[2] and the United Nations Environment Programme (UNEP)[3] in 1988.
>
> *"The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of human induced climate change, its potential impacts and options for adaptation and mitigation."*

The IPCC provided its first major assessment report in 1990, a second in 1996, a third report in 2001 and its most recent fourth report in 2007. Together, they provide the most comprehensive scientific information available, prepared by teams of the world's leading climate scientists.

The reports carefully distinguish between what is known with reasonable certainty, and the areas where uncertainties remain. The language used is very 'measured' and conservative, and for findings to be incorporated into the report they must have a very wide degree of international acceptance that they are correct.

The full reports and summaries are available at http://www.ipcc.ch.

The IPCC 2007 report points out that: "*Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increase in carbon dioxide concentration are due primarily to fossil fuel use and land use change, whilst those of methane and nitrous oxide are primarily due to agriculture.*"

Carbon dioxide is the most important greenhouse gas caused by human intervention. "*The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280ppm*[4] *to 379ppm in 2005. The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years.*"

"*The global atmospheric concentration of methane has increased from a pre-industrial level of about 715ppb*[5] *to 1732ppb in the early 1990's and was 1774ppb in 2005. It is very likely that the increase in methane is due to human activities, mainly agriculture and fossil fuel use. The concentration of nitrous oxide has increased from a pre-industrial level of about 270ppb to 319ppb in 2005. More than a third of all nitrous oxide emissions are due to human activity and are primarily due to agriculture.*"

There are still some individuals and organisations that seek to undermine the science of climate change and the work of the IPCC. The Royal Society of London believes that "They appear motivated in their arguments by opposition to the UN Framework Convention on Climate Change and the Kyoto Protocol, which seek urgent action to tackle climate change through a reduction in greenhouse gas emissions."

"*It has been claimed that the rise in atmospheric concentrations of carbon dioxide is actually a consequence of climate change, rather than a cause. The IPCC report pointed out that the chemical analyses of the carbon dioxide show that the increase in the atmosphere, and an accompanying decrease in oxygen concentrations, are primarily due to the burning of fossil fuels and deforestation.*"[6] However, a number of climate change sceptics still continue to believe, despite the scientific evidence, that climate warming is caused by natural phenomena, and have been arguing for a business-as-usual approach. In response, Sir Martin Rees, President of the Royal Society, has said:

"*Global temperature is increasing. This warming threatens the future health and wellbeing of many millions of people throughout the world. This is especially true of those in the developing countries who are the least able to adapt and who are likely to be the worst affected. Many factors play a part in global warming but there is significant scientific evidence that greenhouse gas emissions, particularly carbon dioxide, are responsible for most of the temperature rise. If present trends continue the projected climate change will be far greater than that already experienced. Greenhouse gas emissions are something that we can and must take action on.*"

> "Those who promote fringe scientific views but ignore the weight of evidence are playing a dangerous game. They run the risk of diverting attention from what we can do to ensure the world's population has the best possible future."

References

1. Intergovernmental Panel on Climate Change: http://www.ipcc.ch/.

2. http://www.wmo.ch/.

3. http://unep.org/.

4. Parts per million.

5. Parts per billion.

6. http://www.royalsoc.ac.uk/.

10. RECORDED CHANGES TO AIR TEMPERATURES IN GUERNSEY

Tim Lillington [1]

Figure 10.1 *Sunbathers at Petit Bôt Bay. Image courtesy of VisitGuernsey.*

Annual mean air temperature

Most of us are aware that in the last few years air temperatures in Guernsey have been generally higher than normal. The memorable 2003 summer heat wave led to a maximum air temperature of 34.3°C being recorded at the airport observatory on August 9th, beating the previous record of 32.8°C set in 1990.

2003 also turned out to be the warmest year since records began in 1843, with local record breaking temperatures in March, April, May, July, August and September. Across the English Channel, a milestone was reached when Faversham in Kent recorded 101.3°F (38.5°C) – the first time in recorded history that air temperatures in the UK had topped the 100°F mark.

So how warm has it really been and is the perceived rise in air temperatures purely a blip or part of a longer term trend? To find the answer we need to study the record and analyse the data.

Figure 10.2 clearly illustrates that Guernsey has not escaped the global warming phenomenon. Annual mean air temperature data has been used to calculate a 30-year average on a decadal, i.e. ten yearly, basis. This is a very conservative method of indicating trends that are undistorted by short term fluctuations or occasional extreme events. The earliest and latest averaging periods are, of necessity, not fully thirty years, but are long enough to be included for comparison.

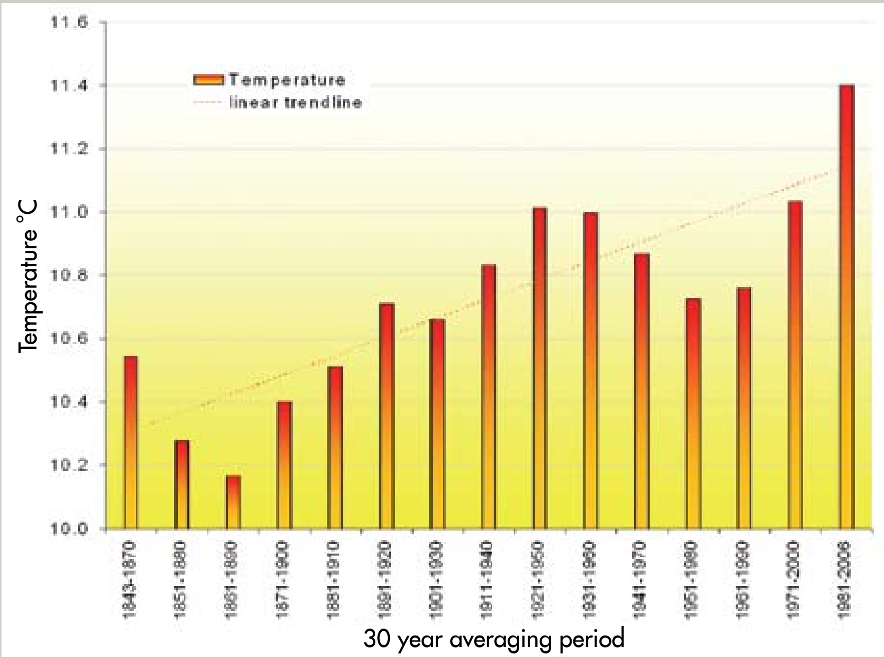


Figure 10.2 *Decadal 30-year running average of mean air temperature. Source: Guernsey Met Office*

The graph illustrates a real and significant rise in mean air temperature in the order of 1°C over the period 1843 to 2006. The rise is particularly noticeable in the last averaging period (1981-2006).

A more detailed monthly look

So, having established a general trend of rising air temperatures over the period since records began in 1843, we can now look more closely at the monthly figures to identify how these changes have occurred.

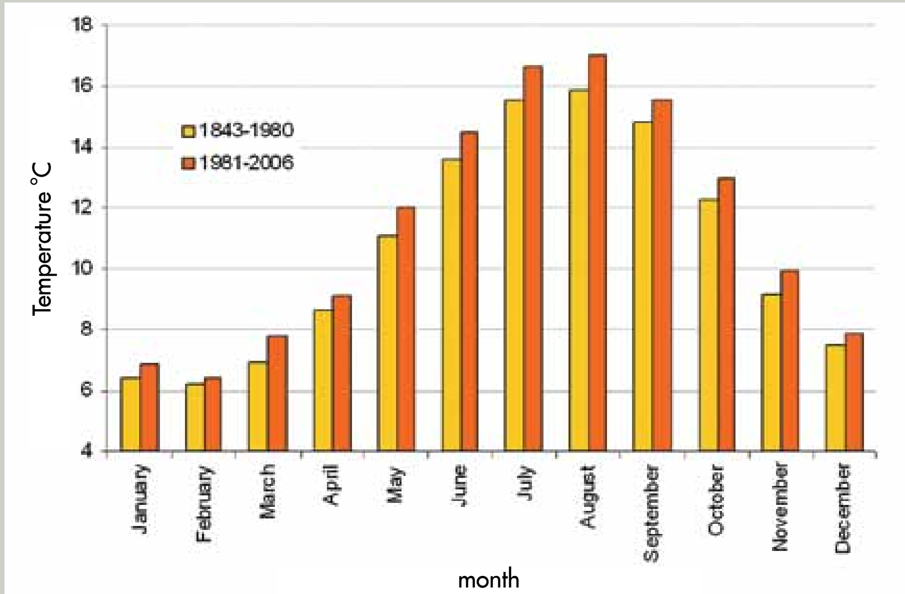


Figure 10.3 *Comparison of the longer-term period average of 1843 - 1980 against the most recent period average of 1981 - 2006. Source: Guernsey Met Office.*

The graph indicates that each month of the year is getting warmer. The summer months show the biggest change with both July and August showing an increase of 1.1°C. Interestingly March and November show relatively large increases (0.9°C and 0.8°C respectively) while the smallest increases occur in February (0.2°C) and December (0.4°C).

Summary

1. Air temperature in Guernsey has risen in the order of 1°C since records began in 1843.
2. Every month has become warmer with the summer months showing the biggest change (+1.1°C), but with spring and autumn temperatures also increasing significantly.

References

1. Tim Lillington is the Senior Meteorological Officer at Guernsey airport and has been observing and recording the weather at the observatory for 37 years. He has been involved with a number of UK government research based publications on climate change including the 2003 British-Irish Council report on climate change scenarios for islands within the BIC region.

11. RECORDED CHANGES TO THE FREQUENCY OF FROST EVENTS IN GUERNSEY

Tim Lillington

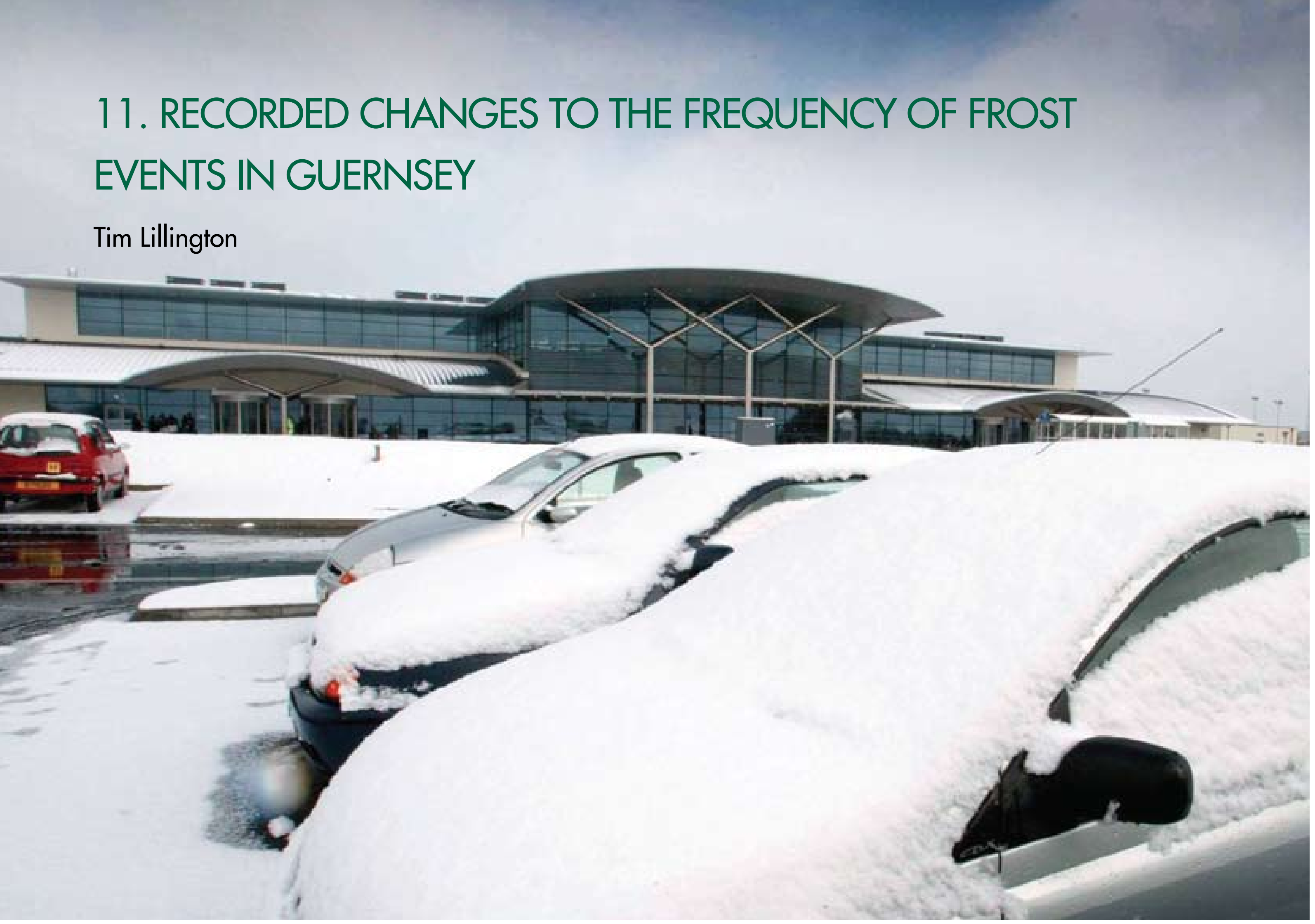


Figure 11.1 *Snow covered cars at the Guernsey airport, a rare scene nowadays. Pictures reproduced courtesy The Guernsey Press Co Ltd.*

One noticeable absentee from our weather in recent years seems to have been frost. "*We need a good cold snap to kill off the bugs*" goes the old adage – and how true it is that the absence of a few good days of freezing temperatures during the winter and early spring seems to bring with it a whole host of problems for much of the flora and fauna of Guernsey.

By restricting our analysis to the post war figures we can get a dependable idea of what is really happening to our lower air temperatures. Figure 11.2 indicates the number of days that air temperatures have fallen below zero (0°C) over the winter period. For this exercise, early year frosts are included in the previous year's figures to provide an overall "winter figure".

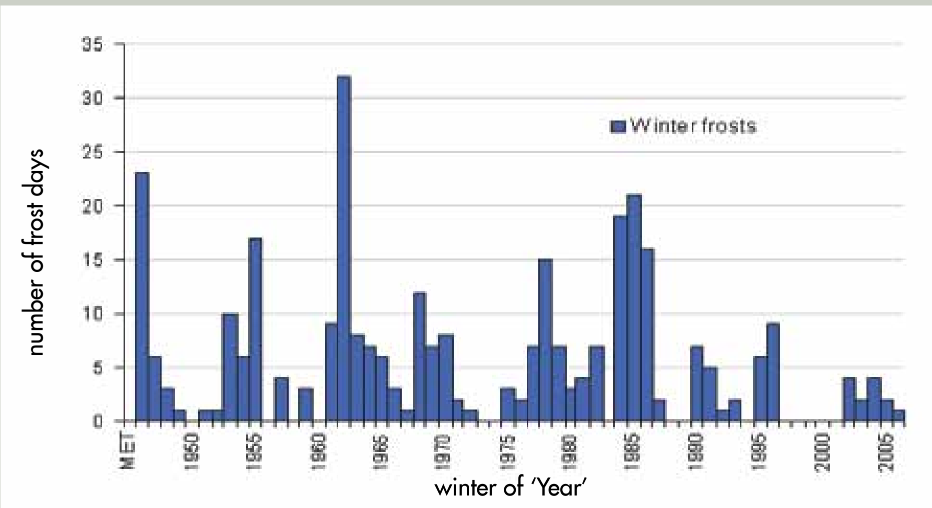


Figure 11.2 *Days of winter air frosts (Air temperature < 0°C).*

Source: Guernsey Met Office.

The figure indicates a significant reduction in air frosts. In total, 15 winters have been frost-free since 1946, five of those in the last decade. A total of 317 days of frost have been recorded throughout this period of 60 winters - an average of 5.3 a year. The last 10 winters have only produced 13 days of air frosts - an average of 1.3 a year – a 75% reduction in real terms.

Severe frosts now seem to be a thing of the past and again we can provide a simple graph that illustrates the validity of that impression. Figure 11.3 shows severe frosts, defined as those days when air temperatures fall below -2.4°C.

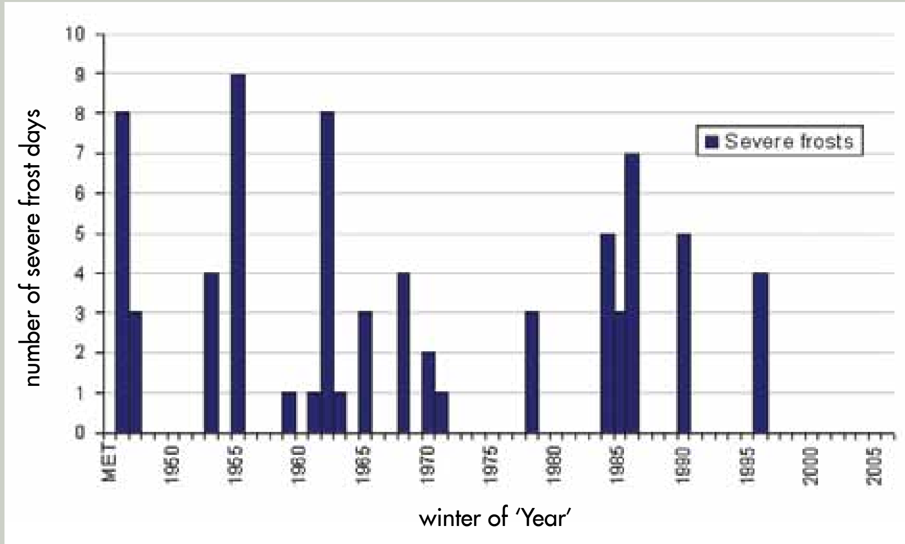


Figure 11.3 *Days of severe winter air frosts (Air temperature < -2.4°C).*

Source: Guernsey Met Office.

The graph clearly identifies a decline in severe air frosts in recent years. None have been recorded in the last decade and out of a total of 72 recorded since the war – an average of 1.2 a year, only 9 have occurred in the last twenty years – an average of 0.4 a year - a 66% reduction in real terms.

Figure 11.4 *Snow fall in early spring. Pictures reproduced courtesy The Guernsey Press Co Ltd.*

Summary

1. Air frosts are becoming rarer. There has been a 75% decrease in the incidence of air frosts since the Second World War.
2. Severe air frosts have declined to the point of extinction with none being recorded in the last decade.

12. RECORDED CHANGES IN RAINFALL PATTERNS IN GUERNSEY

Tim Lillington

Figure 12.1 *Flooding in the Talbot Valley. Pictures reproduced courtesy The Guernsey Press Co Ltd.*

Annual rainfall

The general perception of rainfall patterns in any location is generally influenced by the most recent events, such as a prolonged wet spell or a period of drought. Of course, some years are noticeably extreme; 1317 millimetres (mm) of rain fell in 1960 in Guernsey compared to only 531mm in 1989. The current 30 year average is 824mm.

In 1917, Adolphus Collenette, a local chemist and meteorologist, published a map of the local distribution of rainfall in Guernsey. This was the result of many years work involving collating the data from rainfall recording sites scattered across the Island. Because of his work, and using the appropriate corrections, we are able to look at and compare the complete record of rainfall data since 1843.

Comparison of annual totals over a reasonable period of time is the only way to determine any overall trend so, by using a similar technique to that used for mean air temperature in the previous chapter, Figure 12.2 illustrates the recorded changes to the 30 year average annual rainfall since 1843. The graph indicates a general decrease in annual rainfall of the order of 35mm over the period.

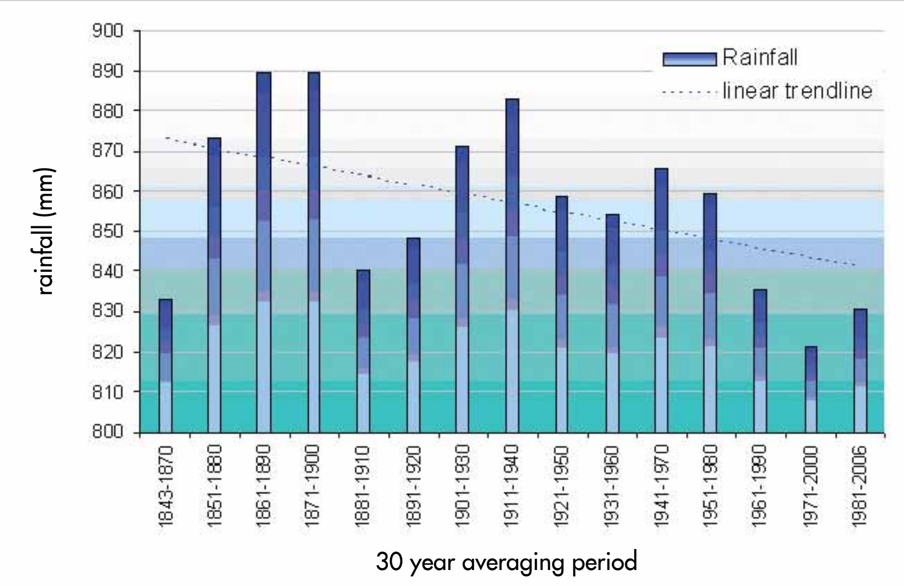


Figure 12.2 *Decadal 30-year running average of annual rainfall. Source: Guernsey Met Office.*

A seasonal look

Sticking to the principle of comparing the decadal 30-year running averages, analysis has shown that a pattern is emerging with seasonal trends. Figure 12.3 compares the winter/spring (DJFMAM) rainfall patterns to those of the summer/autumn (JJASON) period. The graph clearly indicates a long term reduction in summer/autumn rainfall in the order of 16% whereas the winter/spring rainfall has shown a 10% increase. Our findings in Guernsey are already similar to predicted climate change scenarios of drier summers and wetter winters.

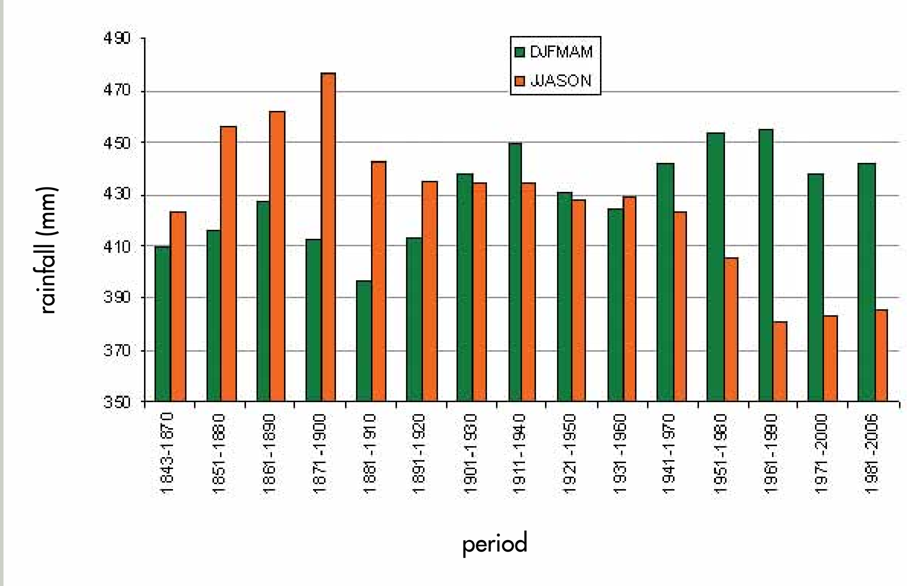


Figure 12.3 *Decadal 30-year running average of seasonal rainfall (winter/spring plotted against summer/autumn). The wet summer of 2007 bucked the trend of drier summers and illustrates the wisdom of using thirty year averaging periods to determine climatic trends.*

Source: Guernsey Met Office.

Figure 12.4 *Winter/spring rainfall is up 10% and wetter winters are predicted. Pictures reproduced courtesy The Guernsey Press Co Ltd.*

Summary

1. Annual rainfall in Guernsey has fallen by about 4% since records began in 1843.
2. During that period, summer/autumn rainfall has fallen by 16% and winter/spring rainfall has risen by 10%.

13. RECORDED CHANGES IN LOCAL SUNSHINE AND WIND

Tim Lillington

Figure 13.1 *Strong winds transport sand across the dunes at Vazon.* *Pictures reproduced courtesy The Guernsey Press Co Ltd.*

Sunshine and wind are perhaps the poor relation in terms of climate change science and do not get paid much attention. But change there has been and the two elements are worthy of a closer look.

Sunshine records have only been kept since 1894 and Figure 13.2 below again uses the decadal thirty year running average to highlight any long term shifts in sunshine. The results are fairly un-dramatic and indicate that following a slow and steady decline, current levels are clawing their way back to the long term average of 1870 hours.

What is interesting is the 1961 to 1990 low of just over 1800 hours. This may well indicate in which direction sunshine totals were heading before the civilised world starting cleaning up its act with regard to particulate pollution. 1981 was the dullest year on record with 1532 hours and 1959 the sunniest with 2263 hours. It is worthy of note that the sunniest year on record (1959) was followed by the wettest year on record this century (1960).

Having decided that nothing significant is happening as far as local annual sunshine levels are concerned, we can dig a bit deeper and examine the monthly statistics. In Figure 13.3, we have used the last full thirty year averaging period (1971–2000) and compared the monthly figures to the long term (1894-2006) average. The results are fairly surprising.

Spring and early summer months show a sharp drop in sunshine totals whereas the end of the year is slightly sunnier. The drop in March sunshine totals is the most dramatic, having fallen by a full 10% and the four consecutive months of March through to June are 5% down in total. However, this may not be as surprising as it seems. All seasons are becoming warmer, and after a mild, wet winter, the rise in spring warmth leads to increased evaporation adding to the amount of water vapour in the atmosphere. This in turn will often result in greater cloud cover and reduced sunshine amounts. It has already been seen in the previous chapter on air temperatures that March has experienced one of the largest rises in mean air temperature in recent years.

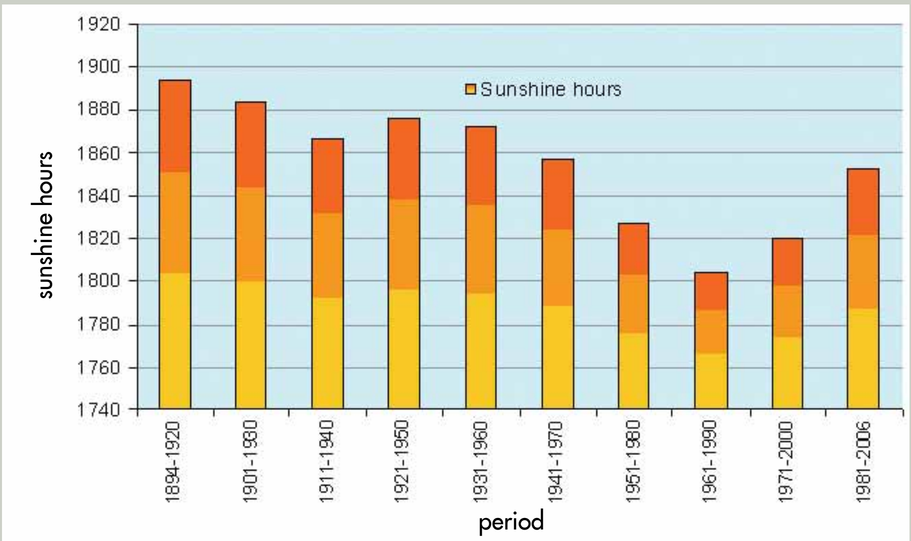


Figure 13.2 *Decadal 30-year running average of sunshine.*

Source: Guernsey Met Office.

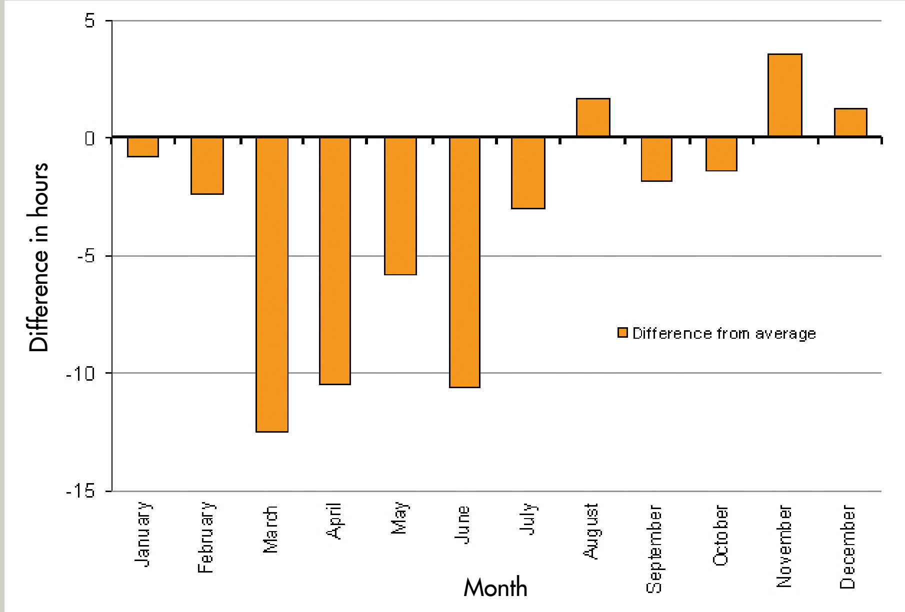


Figure 13.3 *Monthly sunshine totals. Current 30-year average (1971-2000) compared to overall (1894-2006) average.*

Source: Guernsey Met Office.

Unfortunately, wind records are still in the process of being analysed and if we want to study high wind (gale) figures, we can currently only go back to 1975. However, wind patterns complete the picture as far as the main climatic elements are concerned and Figure 13.4 below shows the number of days when a gale was recorded over the last 32 years. (A gale is recorded when the mean wind speed reaches 34 knots or more).

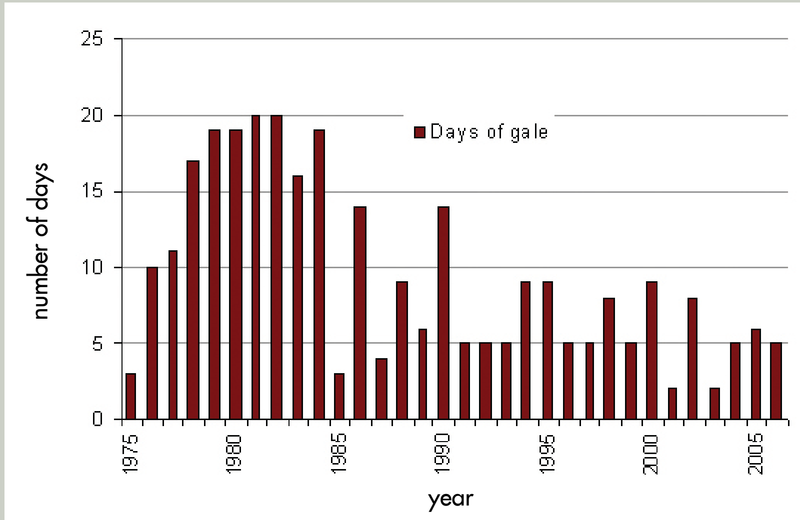


Figure 13.4 *Number of gale days per year 1975 - 2006.*

Source: Guernsey Met Office.

It will come as no surprise that the decade 1975 – 1984 was far windier than of late. The number of local disasters at sea during that spell lingers in the minds of those Islanders old enough to remember.

Summary

1. Generally, sunshine totals have fallen since records began by nearly 5% but recent decades have seen a recovery.
2. Monthly sunshine figures show that March, April, May and June sunshine is down by about 5% in total with March showing the largest fall of 10%.
3. The limited data on gales indicate that they are becoming less frequent.

14. IMPACTS OF CLIMATE CHANGE IN GUERNSEY

Andrew Casebow

Figure 14.1 *Global warming is already having an impact on wildlife. On the land and in the air it is affecting plants, animals, insects, and birds.* Images copyright C David, Guernsey Biological Records Centre. Little Egret copyright Mike Roger.

From left to right: Humming-bird hawk moth, Gazania, Laminaria ochroleuca, seaweed, Little Egret and Cabbage Palm.

Climate change is occurring here, in Guernsey. Air temperatures are noticeably increasing, there are few really cold days during the winter months and we are becoming used to a mid-summer drought in most years. Sea temperatures are also increasing. Although the rise in sea water temperatures take much longer to occur due to the huge mass of sea water that needs to be warmed, the surface temperatures near our shores warm much more quickly.

Global warming is already having an impact on wildlife. On the land and in the air it is affecting plants, animals, insects, and birds, and if sufficient information was available I am sure that we would find that it was affecting almost all species to some extent. This seems to be caused not just by the increasing temperatures but also by the breakdown of established seasonal weather patterns.

The scientific study of the first dates of flowering or leafing of trees and wild plants; the first sighting of swallows and other migratory birds; the timing of egg laying and breeding; the first frogspawn in our ponds; and all the indications that spring is arriving are recorded in the study of phenology. Everyone is encouraged to record their own sightings each year and, if they wish, to contribute these to a national phenology website at www.naturescalendar.org.uk. In the autumn, the dates when the last migrants leave the island, when the leaves of different trees fall, and all the other indications of autumn can also be recorded. This has shown that in recent years the flowering dates of many wild flowers are becoming earlier, the arrival dates of migrating birds and insects, and the breeding dates of many birds are all becoming earlier, but autumn is also becoming later. We are seeing greater numbers of what were very unusual or only occasionally visiting birds, butterflies and moths; and some have become resident and breed within our island.

Within the sea and among the creatures that live on the shoreline, climate change is also causing dramatic changes. The plankton that lives in the sea, which is at the base of the marine 'food chain' for many species, is affected by water temperatures and is moving northwards particularly during the summer months, as it prefers cooler waters. The creatures that rely on it as a food source are also moving northwards following the cooler nutrient rich waters. Other southern species are also moving northwards into new territory. Species such as spider crabs, certain species of limpets and barnacles, and even our native ormer, that are on the northernmost extent of their range, are moving northwards and eastwards as the water warms sufficiently further north. Fish, too, are moving in their

range and there have been far greater catches of bass and red mullet in recent years, but as so little is known about these marine species it is not possible to say whether this is due to climate change or to other cyclical factors.

A few dedicated people have been collecting information on the flowering dates, arrival dates, or movements of different species, but very little of this was initially collected to observe climate change. This section is the result of much 'detective work' in tracking down the various people who have recorded information over the years, and then of analysing it. Whilst I have enjoyed much of the detective work I am very indebted to Tim Sparks of the Centre for Hydrology and Ecology in England who has collated and analysed the data to provide evidence of the impacts of climate change on wildlife in Guernsey.

In this section we have gathered together information that shows some of the effect that warming is having on farming and wildlife. Since 1985, Nigel Jee has been noting down the dates each year when wild plants in his Castel garden have come into flower; whilst Charles David, the late Bridget Ozanne, and Jamie Hooper of the Guernsey Biological Record Centre have been collecting their own detailed records on insects, plants and birdlife. Mark Lawlor, recorder for the La Société Guernesiaise Bird Section, has collated lists of the first sightings of migrant birds and, at the old Horticultural Advisory Service Station at St Martin's (now part of the Commerce and Employment Department), daily records of moths have been recorded since 1973.

On marine life, the Sea Fisheries Section of the Commerce Department has recorded weekly seawater temperatures in St Peter Port that closely match those recorded at Cherbourg. At the same time the Marine Biological Association (from Plymouth) has been recording shoreline creatures on our coastline and the SAPHOS organisation has been collecting data on the movements of plankton within the Channel. It all makes fascinating reading.

15. IMPACT OF RISING SEA TEMPERATURES

Andrew Casebow

Figure 15.1 *Spider crabs are in decline in local waters as they migrate north to escape rising sea temperatures.*

Sea water temperatures have been recorded each week in Guernsey since 1980. These are surface water measurements taken at the Signal Station in St Peter Port harbour. As such, the water temperature can be affected by sunshine and rainfall, although readings are taken in the shade and avoiding heavy rainfall in an attempt to minimise these effects.

The mean annual temperature has fluctuated from a minimum of 11.5°C in 1991 to a maximum of 13.6°C in 1999. In 2006 the mean annual sea temperature was 12.7°C. A cold late winter resulted in this figure being the lowest since 1996, although Guernsey's mean annual sea temperature has not fallen below 12°C since 1992.

There has been an overall increase in surface seawater temperature of about 1.7°C over the 26-year period, mirroring an increase in the recorded water temperature of the North Atlantic of about 1°C in the past 30 years. Similar results have been recorded at Cherbourg on the French coast, and a graph showing fluctuations in the mean annual sea surface temperature for the coastal waters of the English Channel since 1870, is shown in chapter 17, page 44.

Guernsey is very special. It is situated on the convergence of Boreal (cold temperature) and Lusitanian (warm temperature) marine bio-geographical regions. The overlap of these regions promotes increased species richness in our waters. Cold-water species at their southern limit are likely to lose their 'climate space' and migrate northwards as temperatures rise in the future. Other, warm water, species are likely to spread into island waters from France or from further south.

Fish stocks and sea creatures are at the forefront of this change because there is no natural division between landmasses to restrain their movement, and also because many species are naturally mobile. There has been a marked increase in the abundance of bass (a warm water species) in recent years, replacing other white fish in Guernsey waters. In the 1960s bass was a rather unusual catch but in recent years over 100 tonnes per annum have been landed. There has also

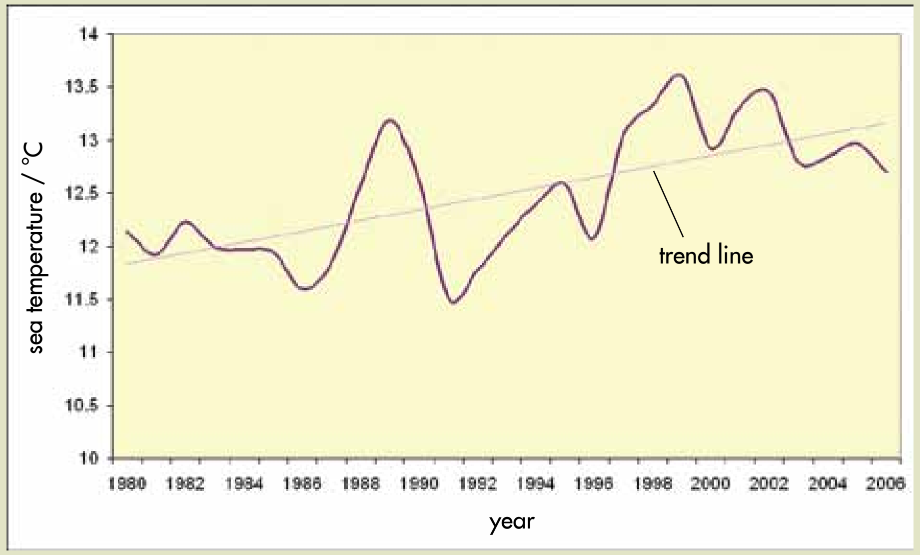


Figure 15.2 *Surface water temperature taken from St Peter Port Harbour 1980 – 2006. There has been a warming trend with an increase of about 1.7°C since 1980.*

been a big increase in the abundance of black sea bream. However, sea bream populations tend to be cyclical and as a result the return of black sea bream after 30 years (they were last abundant in the 1970s) is not necessarily caused by climate change. Some species which were formerly common, such as red sea bream, are now rarely caught.

Douglas Herdson of the National Marine Aquarium in Plymouth notes, "Angling records prove that some species have become more common. There have been range extensions, and some species have begun breeding in British waters". Local fishermen have had to adapt, perhaps faster than ever before, to changes in fish stocks. It is now more profitable to fish for bass than, for example, crabs. David Wilkinson, Technical Officer in the Guernsey Sea Fisheries Department (part of the States Department of Commerce) notes that there has been a decline in the number of spider crabs caught locally over the past 5 years as their distribution has extended northwards.

The impact of climate change on the sea plankton population and seashore species are discussed in the following chapters.

Figure 15.4 *A catch of bass aboard a Guernsey fishing boat. Bass landings have risen substantially in recent years as the abundance of bass has increased in Bailiwick waters, particularly during the winter pre-spawning and spawning period.*

Figure 15.3 *The warming seas may be encouraging warm water species, such as bass, to migrate to Guernsey waters in greater numbers. These line caught fish from the Bailiwick are exported to France.*

Further information:

www.national-aquarium.co.uk/.

www.sealordphotography.net/.

16. INDICATORS OF CLIMATE CHANGE IN THE PLANKTON COMMUNITY

David G Johns and M Edwards.
Sir Alister Hardy Foundation for Ocean Science (SAHFOS) [1].

Relevance

The plankton community, with both plant (phyto-) and animal (zoo-) constituents, represents the base of the marine food web, and thus any changes can influence higher forms of marine life (such as fish). Zooplankton consist of not only permanently planktonic organisms, such as small crustacean called copepods (Figure 16.1), which provide an extremely important food source for larval fish, but also temporary members, such as the larval stages of crabs and lobsters. Long term (1958 to present day) sampling by the Continuous Plankton Recorder (CPR) survey has enabled the study of changes in abundance, community composition, and peaks in seasonal timings, which can all impact higher up the food chain, and are often attributed as indicators of climate change.

Here we discuss changes in the abundance and distribution of zooplankton in recent years, and show the results for one species, the copepod Clausocalanus, which is indicative of warmer, more southerly waters. The long-term changes of Clausocalanus (Figure 16.2) show that it has increased six-fold during the past 15 years.

Sensitivity to climate and other factors

Zooplankton, being near the very bottom of the food web and having a rapid generation time, can respond to climate change quicker than many higher organisms. They are therefore good indicators, and have been used in previous studies. Many are of economic importance, either directly as the larval stage of exploited species, or indirectly as the food of exploited species.

Figure 16.1 *A copepod, a small crustacean that is a primary source of food for larval fish.*

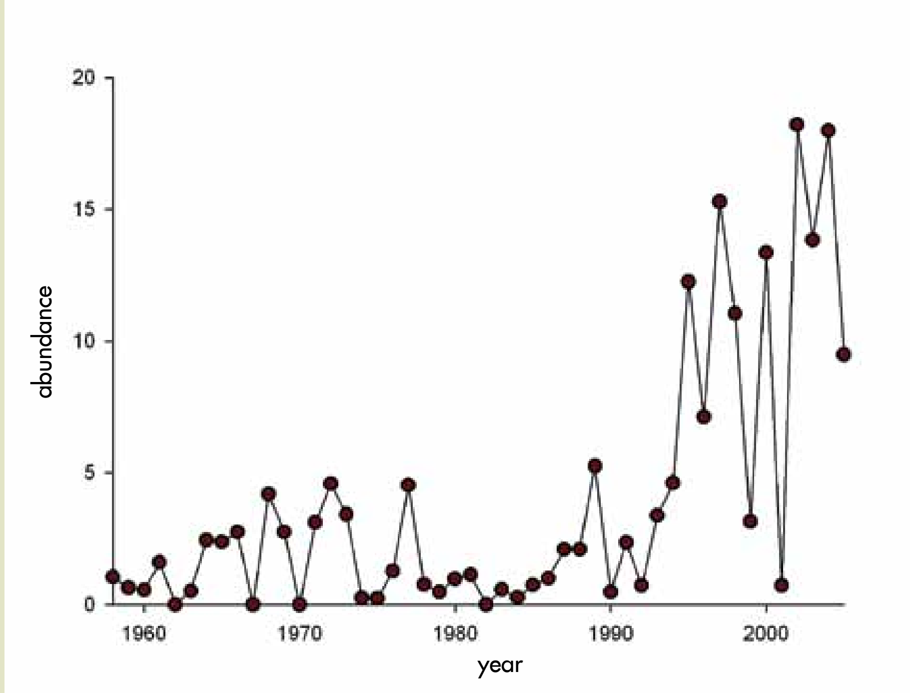


Figure 16.2 *Plot of long term abundance of Clausocalanus, an indicator of warm water.*

Change over time and likely impacts to Guernsey

Analysis of long-term plankton data for the English Channel and Channel Islands has shown the following changes in response to climate warming:

- Changes in temperature have affected the lowest elements in food webs, and this has propagated upwards.
- Copepod species have shifted 10° northwards in latitude, due to increased sea temperatures.
- Increased temperatures have allowed successful invasion by warm water species. These have moved further northwards as waters warmed, or been introduced via the ballast water in ships.
- There has been a change in one of the most abundant and important copepods, Calanus, with the colder (previously more abundant) species declining and the warmer water species increasing. But, the combined number of both species has dropped, meaning there is potentially less food for larval fish.
- The start of seasonal cycles have changed, getting earlier, potentially causing a mis-match between inter-dependent organisms.
- An increase in the occurrence of Noctiluca scintillans, a potentially harmful (to fish and invertebrates) phytoplankton species.

These trends are likely to continue, due to an increase in warming, and will have an effect on which fish species (both fin- and shell-) can be commercially harvested in the future.

References
1. The Sir Alister Hardy Foundation for Ocean Science (SAHFOS) is an international charity that operates the Continuous Plankton Recorder (CPR) survey. The Foundation has been collecting data from the North Atlantic and the North Sea on biogeography and ecology of plankton since 1931. http://www.sahfos.ac.uk/.

17. THE EFFECTS OF CLIMATE CHANGE ON INTERTIDAL SPECIES

Nova Mieszkowska [1], R Leaper, J Hill, A.J Southward & S.J Hawkins.
Marine Biological Association of the UK [2].

Relevance

Intertidal animals and plants live at the margin between the sea and the land and so these organisms are subject to changes in both environments. They can therefore serve as early warning indicators for the impacts of climate change. The larval stages of many species can be indicative of changes occurring in offshore waters. Low intertidal and subtidal kelp beds are nursery grounds for juvenile fish, and are also an important part of the near-shore community. Long-term data sets exist for intertidal invertebrates around the coast of the British Isles, including data collected in Guernsey during the 1950s, 1970s, 1980s and, more recently since 2000s. These data allow the responses of species to fluctuations in the climate to be determined.

Sensitivity to climate and other factors

Intertidal species are subject to wide fluctuations in temperature, and are often already living close to their thermal tolerance limits. Rapid warming of the climate that has occurred in the English Channel over the last 2 decades (Figure 17.1) has altered the environmental regime of the intertidal zone and species that are fixed to rocks or move only small distances are being forced to adapt or die.

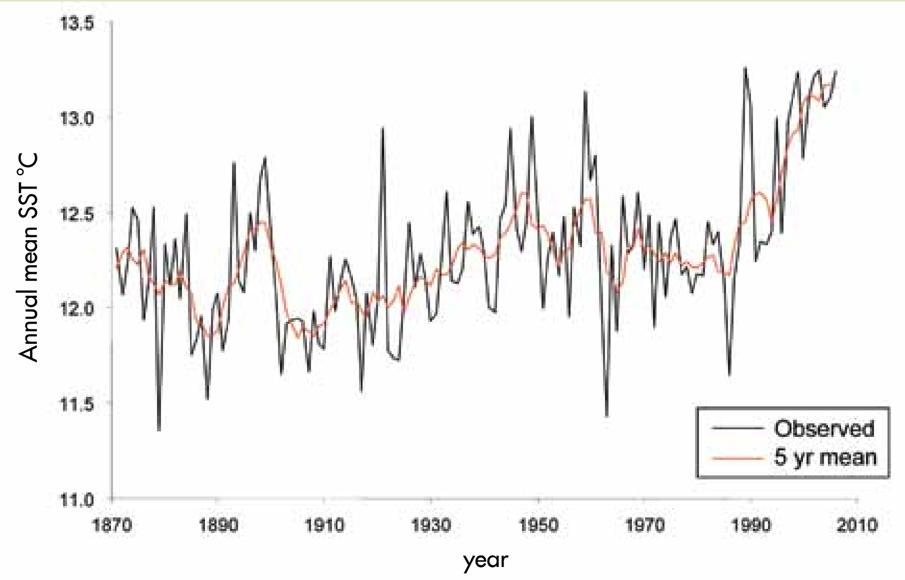


Figure 17.1 *Mean annual sea surface temperature for the coastal waters of the English Channel. Note that the off-shore surface temperature is very similar to that recorded in St Peter Port harbour (Figure 15.2, page 41), but showing the same upward trend. Data kindly supplied to the MarClim project by kind permission of the British Atmospheric Data Centre.*

Change over time

Analysis of data from the 1950s, 1960s, 1980s and 2000s showed the following changes to intertidal species in the English Channel in response to climate warming:

- Warm water 'southern' species of topshells, limpets, barnacles and seaweeds have extended their eastern range limits in the English Channel by up to 120km.
- Population abundances for southern topshells have increased six fold as sea temperatures have warmed. Similar changes have occurred in southern barnacles.
- Cold-water 'northern' species of limpets, barnacles and seaweeds have shown reductions in abundance and some retraction in their southern limits.
- These changes in northern species are not as marked as the increases recorded in southern species.

Experimental research showed that these changes appear to be driven by increased reproductive success of adult organisms as spring and summer temperatures have risen, and increased over-winter survival of juveniles for southern species in response to milder winters. In addition, indirect effects of climate change occurring via competition are affecting the relative abundances of northern versus southern species of barnacles and limpets.

A major study of the impacts of climate change on marine biodiversity in Britain and Ireland over the last 50 years (the MarClim project [3]), has been undertaken with a view to predicting likely future climate impacts . The MarClim team has predicted the following changes:

- Further pole-wards expansion of warm water species.
- Continued contractions in the southern range limits and abundance of northern species.
- Increased invasions of non-native species are likely to occur, and expand their range if already established.
- A short-term increase in biodiversity may occur followed by a longer-term decline in biodiversity as native species of northern, cold water origins are lost from an increasing number of shores.
- There is the potential for huge changes to British marine inter-tidal ecosystems within the next 50-80 years, and Guernsey will not be exempt from this.

Likely Impact in Guernsey

The shores in Guernsey host southern, warm-water species of intertidal species including the topshell Gibbula pennanti that are not currently found on the British mainland. Such species are predicted to colonise shores in southwest England as future climate warming opens up new regions of suitable thermal habitat. The island is thus an important 'stepping stone' for the spread of non-native species onto the British mainland. Northern cold-water species that are currently present on the island, including kelps that provide nursery grounds for juvenile fish are predicted to decline in abundance as temperatures continue to increase. Non-native species including the Japanese seaweed Sargassum muticum (Figure 17.2) and Australasian barnacle Elminius modestus (Figure 17.3) have already invaded Guernsey and are predicted to increase in abundance as the climate continues to warm.

Figure 17.2 *The invasive Japanese seaweed Sargassum muticum, transported to British coastal waters in the ballast water of international ships.*

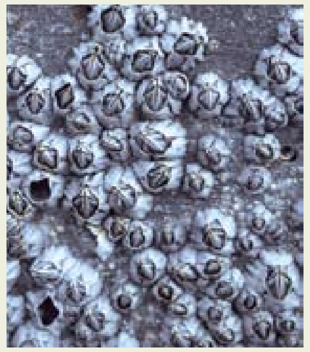


Figure 17.3 *The invasive Australasian barnacle Elminius modestus, transported to British coastal waters in ballast water of international ships.*

Figure 17.4 *Limpet counts are randomly estimated by means of a quadrant.*

References
1. Prof. Steve Hawkins, Nova Mieszkowska & Rebecca Leaper of the Marine Biological Association have been regular visitors to Guernsey, Jersey and the English Channel coastlines of England and France carrying out research on intertidal species.

2. Marine Biological Association of the UK - http://www.mba.ac.uk/.

3. Marine Biodiversity and Climate Change (the MarClim project) http://www.mba.ac.uk/marclim/.

18. THE IMPACT OF THE CHANGING CLIMATE ON AGRICULTURE

Andrew Casebow

Figure 18.1 *Heifers grazing in a St Saviour's wet meadow.*

Changes in the climate have had a dramatic effect on agriculture and the growth of crops, and this will cause greater change in the future.

Increasing winter soil temperatures

When the soil temperature is above 3°C, bacteria break down organic matter in the soil to compounds of nitrogen and carbon. Some of these compounds are used for plant growth, such as nitrates, whilst others, such as nitrous oxide and carbon dioxide, are released into the atmosphere. These are greenhouse gases and are part of a natural release as soils warm, but which, as part of a positive feedback loop, may contribute to further warming. The trend towards warmer soil temperatures in shown in Figure 18.2

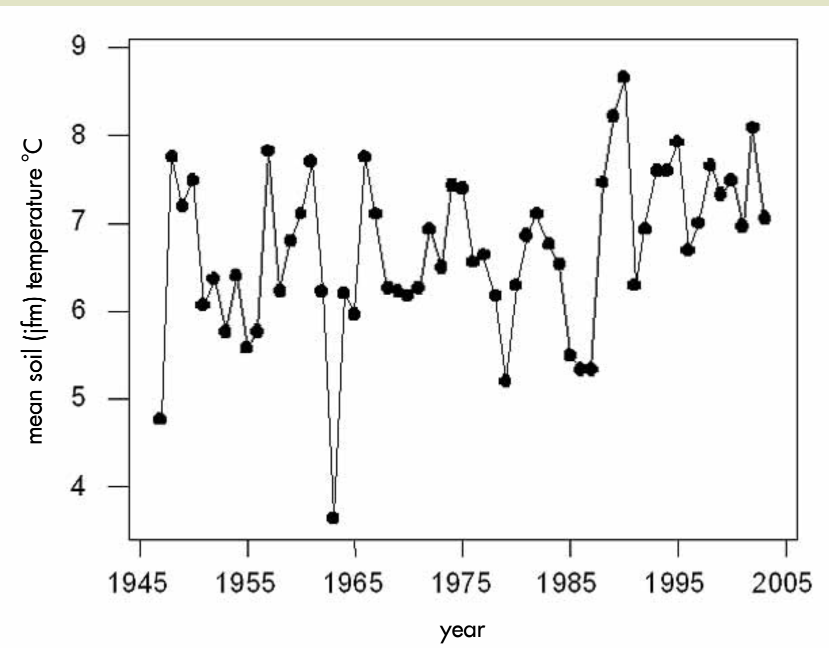


Figure 18.2 *Graph showing the mean soil temperature (in degrees C) during January, February and March (jfm) of each year since 1947.*

Warmer soils also mean that crops continue to grow throughout the winter. Grass growing in our gardens often needs cutting throughout the winter months, but grass is one of the main farm crops grown in Guernsey, specifically for the feeding of cattle and other livestock. The grass is either grazed by cattle in the fields or mechanically harvested and taken back to the farmyard to feed the animals that are housed there.

Wetter soils

As well as becoming warmer the climate has become wetter in the winter months. This means that although grass may continue to grow, the soil in the fields tends to be wetter and may flood. In some fields the soil structure cannot bear the weight of cattle grazing or machinery, and so the fields may become 'poached'.

The soil on the southern plateau in Guernsey is much more free draining than the soil in the north of the island, and so here cattle can often go 'out to grass' earlier than they did before, and also stay out much longer in the autumn before needing to be housed as the weather becomes colder (Figure 18.3).

As long as they have adequate natural shelter, a good coat and plenty of food, cattle are often healthier outside than in winter housing. The warmer soils mean that sown seeds may germinate earlier; but crop pests and diseases are often able to survive the winter as there are fewer frosts to kill them.

New crops

Some crops that could not be successfully grown in Guernsey 30 years ago are now commonplace. Part of this is due to improved crop breeding but also due to warmer winter and spring temperatures. Maize is grown as a fodder crop since it needs a long growing season to successfully form cobs but the summer is not yet long or hot enough for the cobs to ripen into grain (Figure 18.4). This crop is regularly grown south of the Loire valley in France, and so with warming it is only a matter of time before grain maize could be harvested in Guernsey.

Loss of Markets

Crops such as early potatoes and daffodils that were grown much earlier in the Channel Islands, or in the Isles of Scilly, than was possible in England, can now be grown just as successfully in Cornwall and in parts of Southern England. This means that these crops have lost their market 'edge' and can no longer be sold just on their earliness of production and must be marketed on other characteristics, such as tradition, flavour and quality.

Summer drought

Guernsey is particularly prone to summer drought conditions caused by a lack of rainfall, which seems to affect the island most during August. The growth of plants is significantly reduced by a lack of moisture. A summer drought therefore means that dairy cattle that rely on a large daily supply of fresh grass often need to have extra food provided for them during very dry weather. Many cows are now fed conserved food (such as grass silage) throughout the summer (Figure 18.5).

Potatoes

The yield and quality of potatoes is also affected by rainfall during the mid-summer period. Potatoes are often an irrigated crop in England and drier summers could lead to an increase of irrigation in the future, but water resources are not adequate to permit that in Guernsey.

Figure 18.3 *Cows 'out at grass' overlooking Kings Mills in December.*

Figure 18.4 *Forage maize has become a common sight in Guernsey over the past 20 years.*

Figure 18.5 *After milking, dairy cows on this St Saviours farm eat silage (preserved grass) before going back to the fields in the summer.*

19. INTRODUCED SPECIES OF PLANTS

Bridget Ozanne [1]

Figure 19.1 *The Giant Echium (Echium piniana), although indigenous to the Canary Islands, is found growing throughout the islands of Guernsey.* Image copyright C David, Guernsey Biological Records Centre.

The Channel Islands have long been known for the many attractive and colourful flowering plants that have arrived from foreign parts, perhaps with other cargoes, some perhaps on purpose for gardens, whilst many others have naturalised into the wild areas and become part of the Flora. In Guernsey, horticulture has always been an important part of the economy due to the mild climate compared with most of mainland Britain, so many flowers and plants have been cultivated in the island, both under glass and in nursery gardens for several centuries. Some of these have escaped and are now naturalised successfully in appropriate areas. They have been able to survive here whereas on the mainland a hard winter would have destroyed them. A lot of these species have gradually migrated north and colonised areas of southwest Britain, and many are reaching further, particularly over the last decade or two.

It is very difficult to assess how much of this spread can be attributed to climate change. However, it has become more obvious over the last twenty years or so that many of these novice plants can survive the winters, whereas in earlier years populations would have been severely checked, if not wiped out.

Of course, over time floras change anyway, sometimes without the intervention of man, and plenty of these new arrivals are welcomed as additions to the local communities. Problems occur when alien species become a nuisance. They can become very invasive, as their native predators are not present to check them, and this can cause them to out-compete smaller, rarer native species.

An example of this is the South African succulent species (Figure 19.2), which have increased dramatically in the last twenty years or so, due to milder winters. The Kaffir Fig, and other species of Mesembryanthemums, now cover large areas of the cliffs. They completely cover some of our native Guernsey specialities such as Dwarf Pansy, Sand Crocus and Small Cudweed, as they are far larger and form dense mats of vegetation.

Figure 19.2 *South African succulent species. (a) Kaffir Fig (Carpobrotus edulis), and (b) Rosy Dew-plant (Lampranthus roseus) on cliffs at Le Gouffre.*

Figure 19.3 *(a) New Zealand native Wire Plant (Muehlenbeckia complexa), and (b) Wire Plant covering hedge at Les Fontenelles.*

Images copyright C David, Guernsey Biological Records Centre.

A similar situation can be observed in the Isles of Scilly, where non-native plants from the southern hemisphere appear to outnumber native species. One plant that is very invasive in the Scillies is the Wire Plant from New Zealand (Figure 19.3). It forms huge hillocks on the low cliffs in the larger islands. In Guernsey it was first recorded in the 1950s at one location near Moulin Huet. No more records occurred until the 1970s, but since then it has been slowly increasing, both in localities and in areas in these localities unless tightly controlled.

Other garden plants, which have increased and cause visitors some astonishment, are things like Geraniums from Madeira (Figure 19.4) and the Giant Echium (Main image, figure 19.1) which lives in the Canary Islands. These can reproduce and live on their own in the wild, but are no great nuisance to anyone.

Plants which give Guernsey its "sub-tropical" look include things like the Cabbage Palm (Cordyline) and New Zealand Flax (Phormium), both from the Antipodes, and both of which can seed and grow outside gardens. In the past, gardeners would wrap these plants up in polythene or use other means of protection to ensure that they got through the winter, but this does not now appear to be necessary.

Guernsey botanists who have observed plants and plant communities for more than fifty years in the islands, would all say that there have been clear and obvious changes over that period. It is difficult to be completely confident in explaining the reasons for these changes, or even to state if these are unique in the British Isles (for example compared to Cornwall), but such changes are entirely consistent with a warming climate.

Figure 19.4 *Madeiran Geranium (Geranium maderense).* Image copyright C David, Guernsey Biological Records Centre.

References

1. Until her recent death, Bridget Ozanne was Secretary of the Botany Section of La Societe Guernesiaise and managed the Guernsey Biological Record Centre (gsybiorec@cwgsy.net).

20. RECORDS OF SOUTHERN EUROPEAN BIRD SPECIES IN GUERNSEY

Mark Lawlor [1]

As the climate in Guernsey has been getting warmer, it follows that bird species that prefer warmer climates may become more common here. This chapter focuses on species of birds whose breeding range is generally located to the south of Guernsey, and whether their numbers are increasing.

Little Egret

This species was once a very rare visitor but is now a familiar sight around the coastline of the island and has recently bred. It has also shown a phenomenal increase in numbers in Britain during the last ten years or so. All the birds use just two roost sites on Guernsey so quite accurate estimates of the population can be made. Figure 20.1 shows the dramatic increase in recent years.

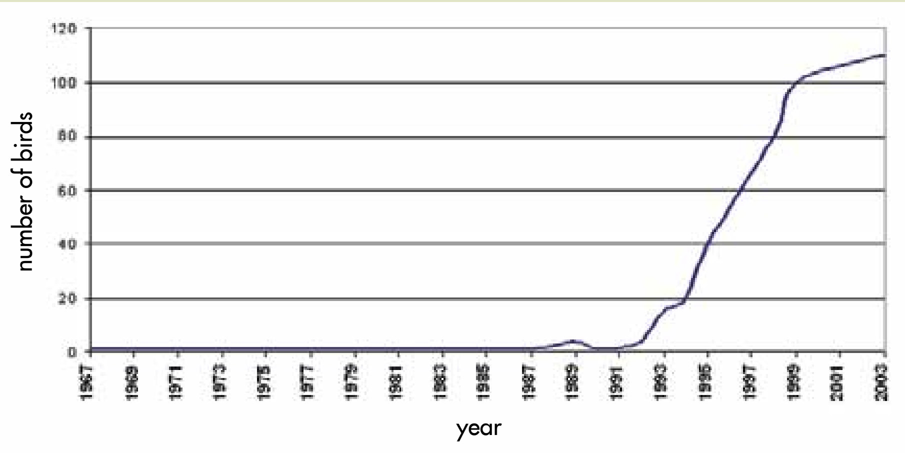


Figure 20.1 *Estimated Little Egret numbers on Guernsey (since first record in 1967).*

Serin & Golden Oriole

These two species are very common in warm parts of Europe including most of France. Both species have shown an increase in records over the years, which can be seen in Figure 20.2.

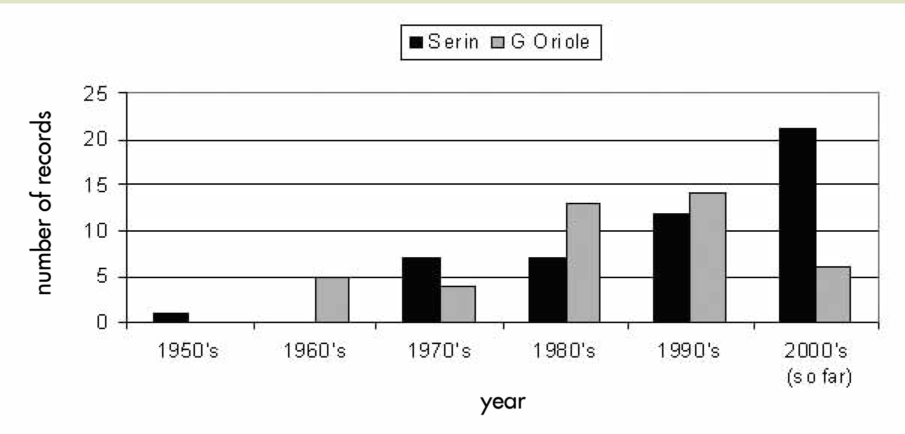


Figure 20.2 *Estimated Serin and Golden Oriole numbers on Guernsey (since 1950).*

Tawny Pipit, Melodious Warbler & Cirl Bunting

These three species are also predominately southern European species. Numbers increased until the 1970's and 80's, but have declined recently (Figure 20.3). There are two possible explanations for this i) both Tawny Pipit and Cirl Bunting are thought to be declining species due to a reduction in suitable habitat. ii) Melodious Warbler and Tawny Pipit are mostly post-breeding autumn visitors to Guernsey.

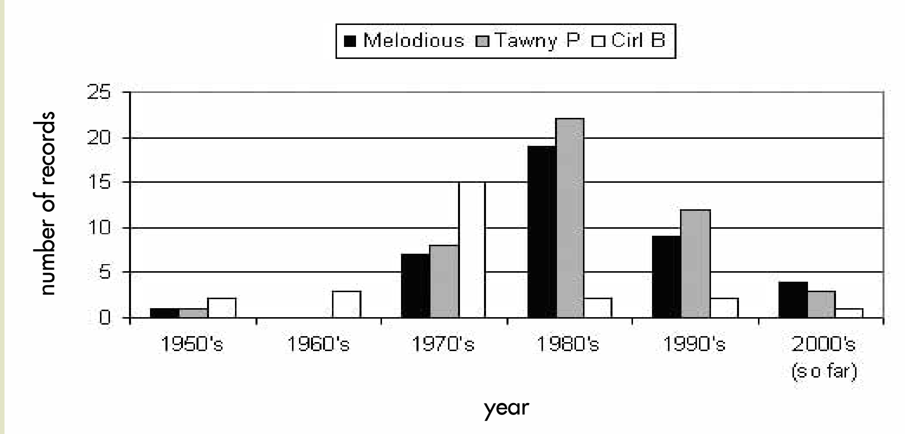


Figure 20.3 *Estimated Tawny Pipit, Melodious Warbler & Cirl Bunting numbers on Guernsey (since 1950) are in decline since the 1980's.*

Cetti's Warbler & Dartford Warbler

Unusually for warblers, these two species do not migrate south for the winter. As they are insect-eating birds, they are reliant on warm conditions and are mainly found in the Mediterranean region. The Dartford Warbler started breeding in Guernsey in 1961 and Cetti's Warbler in 1975. The fact that both these species have successfully colonised the island in the last 50 years indicates that the winters have been warm enough for a plentiful supply of insects, and that there have been few years of extensive freezing conditions that would wipe out their very small populations.

Figure 20.4 *Little Egret photographed by Mark Lawlor.*

Rarer species from Southern Europe

As well as the above-mentioned species there have been 23 other rare species recorded on the island, which can be classed as 'Southern European':

Little Bittern	Night Heron	Squacco Heron
Cattle Egret	Purple Heron	Black Kite
Griffon Vulture	Little Bustard	Black-winged Stilt
Great Spotted Cuckoo	Alpine Swift	Little Swift
Bee-eater	Roller	Short-toed Lark
Red-rumped Swallow	Black-eared Wheatear	Fan-tailed Warbler
Subalpine Warbler	Sardinian Warbler	Bonelli's Warbler

Looking at the records of these species, it appears that rarities from the south are increasingly occurring on Guernsey – even allowing for increasing observer coverage in recent decades.

References

1. Mark Lawlor is the Bird Recorder for La Société Guernesiaise. A Chemistry graduate from Bristol University, he teaches Science at St. Peter Port Secondary School.

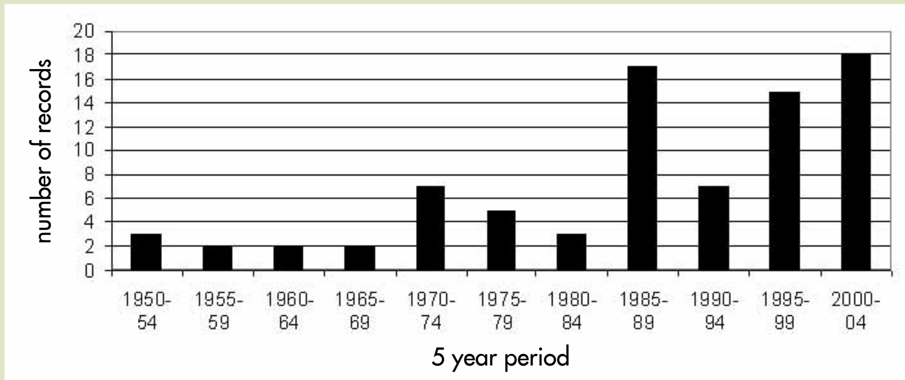


Figure 20.5 *Rare bird records from southern Europe.*

Summary

The majority of southern European bird species that have been recorded in Guernsey have shown an increase in records during the last 50 years or so, which may be due to climate change.

21. SPRING ARRIVAL DATES OF MIGRANT BIRDS

Tim Sparks [1]

Figure 21.1 *Migrant swallow caught for ringing by Jamie Hooper (see Figure 21.2).* Copyright Jamie Hooper.

The dates on which migrant birds return from their wintering locations have been getting earlier across Europe. However these changes are not as great as for plants, or even insects, giving rise to concerns that migrant birds are not adapting sufficiently rapidly to a warming climate. It is now thought that changes in day length trigger migration from Africa, but that temperature modifies migration speed, leading to changes in arrival dates.

We examined the first arrival dates of 20 migrant birds to Guernsey supplied by Barry Wells and Mark Lawlor from La Société Guernesiaise records. The information covers a relatively short period 1985-2004. Whilst the average migrant is now 3 days earlier than 20 years ago, only three species (sand martin, house martin and sedge warbler) are substantially earlier (by 15-30 days). The sand martin has shown great consistency in earlier arrival in Europe. A growing number of observations of migrants in February suggest these birds are wintering closer to Guernsey than the tropics, for example the Mediterranean in the case of house martin, and may in the future over winter on Guernsey itself.

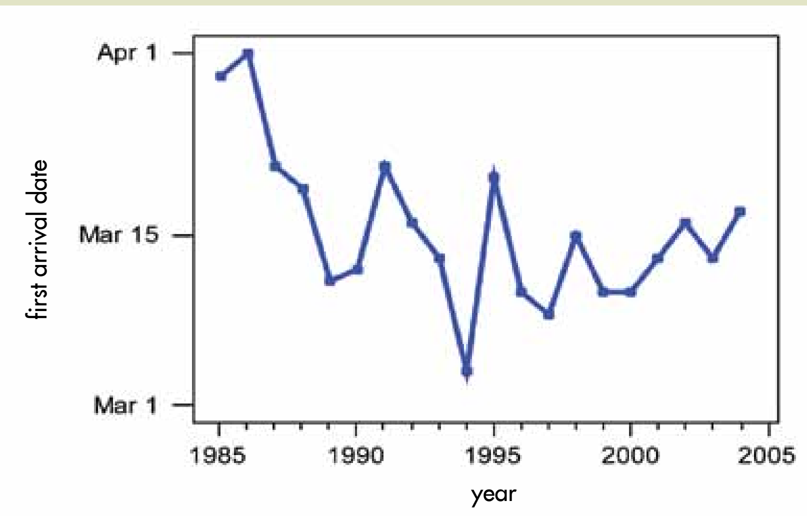


Figure 21.2 *First mean arrival dates for migrant birds to Guernsey from 1985 to 2004.*

The ornithological section of La Société has been active in recording birds in Guernsey throughout its 125 year history. There have been some remarkable changes in migrant birds during this period; including declines in species such as nightjar, corncrake and nightingale; increased frequency of records of species such as sand martin, spotted flycatcher and several warblers; and winter records of species such as blackcap, chiffchaff and turtle dove. In this section we compare first arrival dates of nine commonly recorded species in two periods for which records are reasonably abundant; 1903-1945 and 1985-2005.

The table below shows mean dates for these two periods. Species are arranged in date order of the earlier period.

Mean first dates

Species	1903-1945	1985-2005	Days earlier
Wheatear	March 24	March 6	18
Ring ouzel	April 8	April 2	6
Swallow	April 8	March 23	16
Willow warbler	April 13	March 26	18
Cuckoo	April 15	April 15	0
House martin	April 20	March 25	27
Sand martin	April 22	March 17	36
Swift	April 30	April 22	8
Turtle dove	May 7	April 28	9

These changes are statistically significant except for ring ouzel and cuckoo. Part of the change may be an artefact of sampling, i.e. because more people are now looking for first migrants than previously and hence observing them earlier. There may be some truth to this, but it is unlikely to have much influence on numerous, obvious species such as swallow and, furthermore, these changes have been recorded across Europe from bird observatories operating 'constant effort' sampling.

Can these changes be attributed to a warming climate? We have taken the analysis one step further by comparing arrival dates in Guernsey with temperatures further south, from Spain. For all species, except ring ouzel and cuckoo, we can find a significant relationship with temperature such that earlier arrival in Guernsey by between 3.3 and 9.4 days (depending on species) is associated with a 1°C increase in temperature in Spain (see Figure 21.3). Cuckoo, and possibly ring ouzel, follows a different migration across France, but we did not find agreement with French temperatures for these species. Both species are in decline which may mask climate influences on their arrival dates. Mean March temperatures in Spain were 8.5°C in 1903-1945 and 10.3°C in 1985-2005.

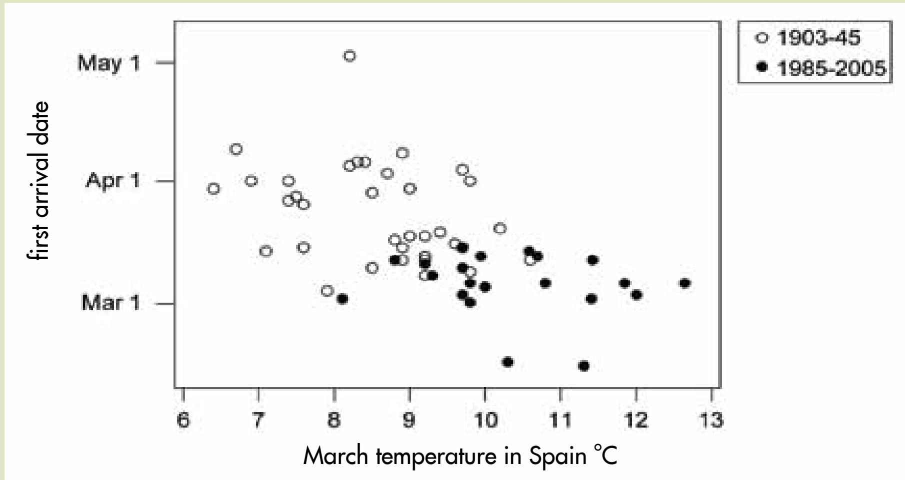


Figure 21.3 *the relationship between wheatear first arrival date and Spanish temperatures in March.*

These results provide strong evidence for a change in spring arrival dates of migrant birds linked to migration route temperatures. In future years it will also be possible to make use of more Guernsey data, for example on the numbers of birds on spring and autumn migration, e.g. through ringing schemes and roost counts, but currently the data hasn't been recorded for long enough to draw conclusions on the influence of climate on these.

References

1. Dr Tim Sparks is an environmental scientist with the Centre for Ecology and Hydrology.

22. FLOWERING DATES OF GUERNSEY WILD PLANTS

Tim Sparks and Andrew Casebow

Figure 22.1 *Early spring flowering daffodils in a Guernsey farmhouse garden.*

The dates on which plants come into flower are determined by a number of factors. With one or two exceptions, plant species flower in specific seasons, for example daffodils in spring and ivy in autumn. This suggests that temperature and day-length are key to inducing flowering. In some desert systems, rainfall is the main driver, but this is unlikely to be an issue on Guernsey. Day-length does not vary from year to year so variation in plant flowering time (within seasonal limits) can be largely and directly attributed to temperature. In fact, plants in Europe are very responsive to temperature, which induces earlier leafing, flowering and fruiting, and can allow later leaf fall. In a warming climate we would expect to see gradually earlier flowering. This is, in fact, what has been observed across Europe and elsewhere in the Northern Hemisphere where records exist. But what has been happening on Guernsey?

Nigel Jee has been recording the first flowering dates of 46 plant species in his Castel garden since 1985. In addition, Peter Danks has recorded the flowering date of his apple trees in St Martins over the same period. We have examined these 47 events to see if there is any evidence of a response to temperature, and indeed if they have been getting earlier in recent years.

Analysis shows that, on average, a 1°C increase in temperature in the three months leading up to flowering causes these flowers to appear ten days earlier. This figure is much higher than some colder parts of Europe. The average masks a range of values from plants showing little influence of temperature, such as sycamore trees, to those with a much greater response, such as lesser celandine. This suggests that any preconceptions we may have about there being a normal order of plants coming into flower may be overturned in the future (under increasing temperatures). The repercussions for insects and other animals feeding on these plants are not yet known.

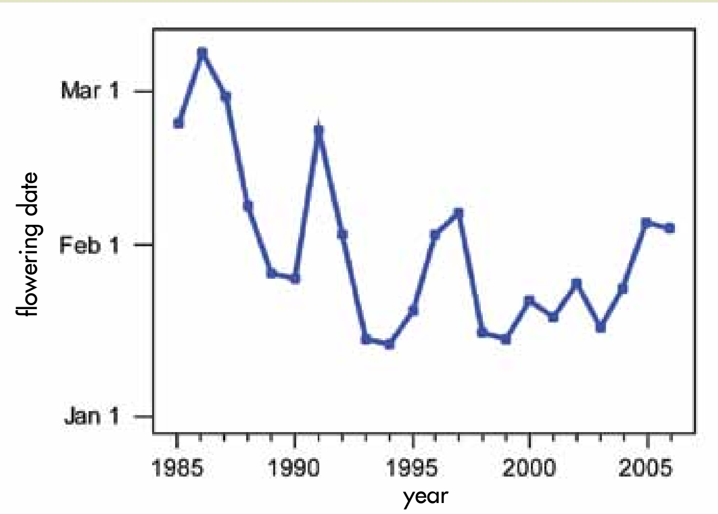


Figure 22.2 *Changes in first flowering of snowdrop: note the lateness in 2005/2006.*

On average these plants have advanced flowering by 13 days since 1985. This figure would have been considerably higher had not flowering been much later in 2006 as a consequence of that year's unimpressively cold spring weather. Nine species, including snowdrop and clematis, have seen substantial advances in flowering, for instance see Figures 22.2, 22.5 and 22.6.

Quite clearly, flowering plants on Guernsey are strongly influenced by temperature and several have already become substantially earlier. In general terms the early spring flowers show this temperature response most and will be the species that will become even earlier as Guernsey's winter temperatures become even milder. As plants exist as part of a food chain, for example, supplying nectar to insects and being pollinated by them, then there is a need to maintain synchrony with those insects. The fact that plant flowering dates are changing at different rates will present a challenge to wildlife in the future.

The timing of biological events, known as phenology, has been widely used to demonstrate changes in wildlife (see page 38). Some historical data exist for Guernsey, but records like Nigel Jee's are invaluable in demonstrating change under the warming that Guernsey has started to experience.

Late flowering is associated with cooler spring temperatures, and warmer winter temperatures cause earlier flowering. This clearly shows how the spring flowering of plants is made much earlier by climate warming.

Figure 22.3 *The common snowdrop (Galanthus nivalis), among the first bulbs to bloom in spring.*

Figure 22.4 *The vigorous climber Clematis montana, a species with advanced flowering dates since 1985.*

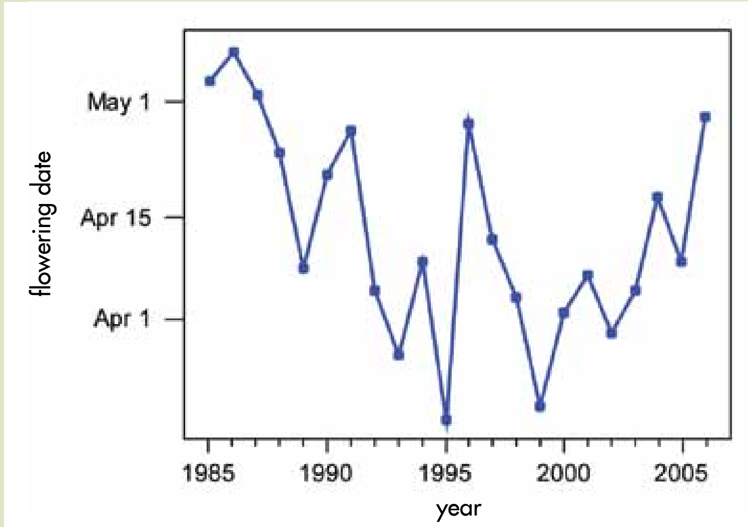


Figure 22.5 *Changes in first flowering of Clematis montana: note the lateness of 2006.*

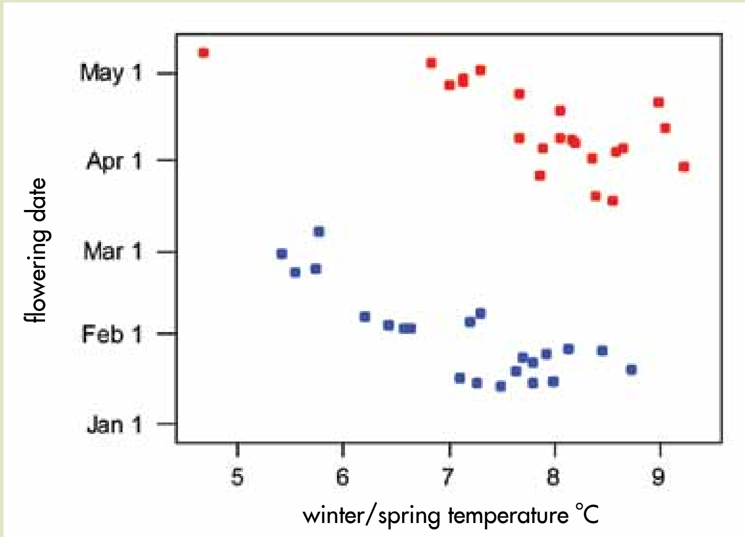


Figure 22.6 *Changes in average temperature of the three months preceding the first flowering dates of Snowdrop (blue) and Clematis montana (red). Note how lateness of flowering is associated with cooler spring temperatures.*

23. CHANGES IN INSECT SPECIES IN GUERNSEY

Charles T. David [1]

Figure 23.1 *The Firebug Pyrrhocoris apterus has become much more abundant in Guernsey in the last ten years.* *Image copyright C David, Guernsey Biological Records Centre.*

As global warming occurs the distributions of species in the Northern Hemisphere would be expected to drift northward, and some previously southern species would be expected to reach Guernsey. There is a lot of evidence that this is occurring. However, one must exercise caution when recording a species as new. Many insects are under-recorded. A species may only appear to be a recent immigrant but could have been present undetected for many years. Even if one is convinced a species is a new arrival it is difficult to determine whether it arrived due to climate change making the island a suitable habitat or because many ecological nichés in the island remain unfilled compared to those on the adjoining coasts of France so that species from the continent can easily establish.

An example of both of these types of colonisation is provided by the fauna of Alder trees. Alder was very scarce in the island until the recent States 'Free Tree Planting Scheme'. Now it is common. In recent years several species of insect new to the island have been recorded from Alder; all but one of these species occur in the UK and Normandy and have presumably migrated from France and established themselves in an unfilled niche. However, one of the new arrivals is the bug Arocatus roeselii (Figure 23.2). This species is apparently spreading northwards in France, but has not yet been recorded in North Brittany or Normandy; presumably this species has managed to establish itself in Guernsey because the climate is now suitable.

Figure 23.2 *The Alder bug Arocatus roeselii.* *Images copyright C David, Guernsey Biological Records Centre.*

Figure 23.3 *The Tachinid fly Ectophasia crassipennis.*

Other southern species arrive without apparent changes in habitat. The impressive fly Ectophasia crassipennis (Figure 23.3), a parasite of shield bugs, was first recorded in Guernsey in 1998. It is now common and has been found in all the other large Channel Islands. Ant lions Euroleon nostras (Figure 23.4) were first found in Guernsey and Herm in 1997 and were discovered in Suffolk at about the same time, though they had been known in Jersey since the 1940s. They are now found all over the southern part of the island and in two places in the Vale. These two species are large and because they are obvious they do seem to be genuine recent immigrants, which would have been recorded before if they had been present. There are many other cases of southern insects establishing populations in the island in recent years. These include distinctive species such as the bug Ceraleptus gracilicornis and the bee Halictus quadricinctus neither recorded in Normandy, and the flies Peleteria varia, Blepharipa pratensis and B. schineri.

As global warming occurs species with a more southerly distribution would be expected to increase in abundance in the island compared to species with a more northerly distribution whose populations may decline. A southern species that has increased enormously in abundance in the last ten years is the Firebug Pyrrhocoris apterus (Main image Figure 23.1). This was recorded in the 1890s but not seen again till 1995. The current population may have been re-established by immigrants in the 1990s. Evidence of the loss or decline in abundance of Northern species is harder to come by. Many species present in the islands have only been recorded in the literature a few times, and it is difficult to tell if they are now extinct, or are simply under-recorded. It is even harder to determine if their populations have diminished, and if so, why.

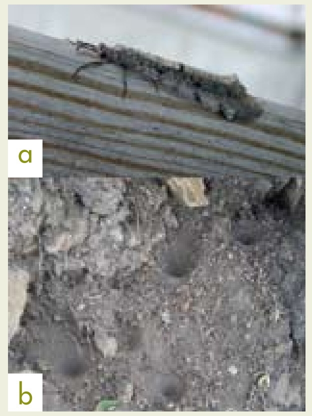


Figure 23.4 *(a) Ant-lions Euroleon nostras, (b) ant-lion pits.* *Images copyright C David, Guernsey Biological Records Centre.*

References

1. Dr Charles David is an enthusiastic entomologist who lives and works in Guernsey. He is a past President of La Société Guernesiaise and Joint Manager of the Guernsey Biological Records Centre.

24. EFFECT OF CLIMATE CHANGE ON MOTH SPECIES AND ACTIVITY IN GUERNSEY

Tim Sparks, Ian Woiwod [1] and Andrew Casebow

Figure 24.1 *Moth trap at Raymond Falla House in Guernsey.*

There are few groups of insects that are recorded on a systematic basis, the exception being moths.

Because most moths fly at night and are attracted to light they can be caught in a 'light trap', and for the past 33 years a light trap has been operated each night in St Martins. The moths that are caught are identified and a list of each night's catch is sent to Rothampstead Research Station, where the information is collated with data from other light traps operating throughout the British Isles. These results have been used to assess moth activity in terms of overall abundance, changes in timing (phenology), and changes in the species complement over time.

The relationship between temperature and moth activity

There are more regular continental visitors to Guernsey, and many more occasional Mediterranean visitors than in earlier years. Although a strong relationship with summer temperatures can be seen, there has been no overall increase in the numbers of moths caught on Guernsey. From this we may deduce that:

- warming temperatures have compensated for what might otherwise have been a decline in moths.
- more moths might be seen in the future.
- alternatively the total moth population might remain in balance as some species increase while others decline.

The relationship between temperature and moth numbers suggests that a 1°C increase in summer temperatures would increase numbers caught in this trap by about 300 moths, although this might just reflect greater moth activity at higher temperatures rather than an increase in moth populations (Figure 24.2).

Changes in the timing of moth flight dates

We have examined changes in the timing of moths by looking at the mean capture dates of nine common species in each year (Figure 24.3). Five of these species have been getting earlier over the last 33 years, and this change is greater for spring flying moths than summer flying moths. This is consistent with changes in a large number of insect species across the Northern Hemisphere. Change in the average of these 9 moth species is shown in the following graph. Overall, the mean flight period of these species has advanced by seven days, but varies between species from almost no change to thirteen days. The average flight period of the nine species is related to mean temperatures from January to September with a five-day advance in flight period for each 1°C warming.

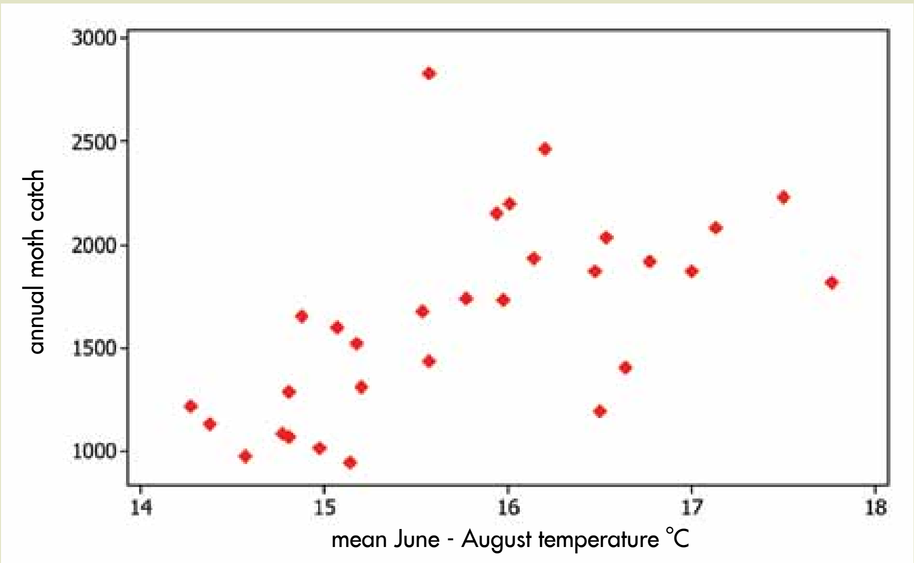


Figure 24.2 *Relationship between the mean June – August Temperature and the Annual Catch of Moths in the St Martins, Guernsey Moth Trap.*

We can conclude that both abundance and activity, and timing of moths on Guernsey, is influenced by temperature. There has already been significant change and both are anticipated to change further in the future.

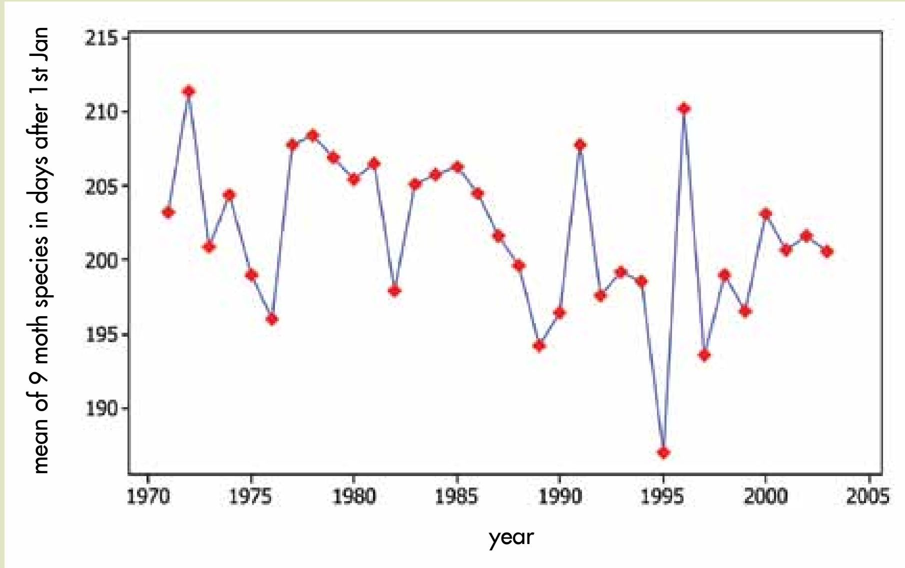


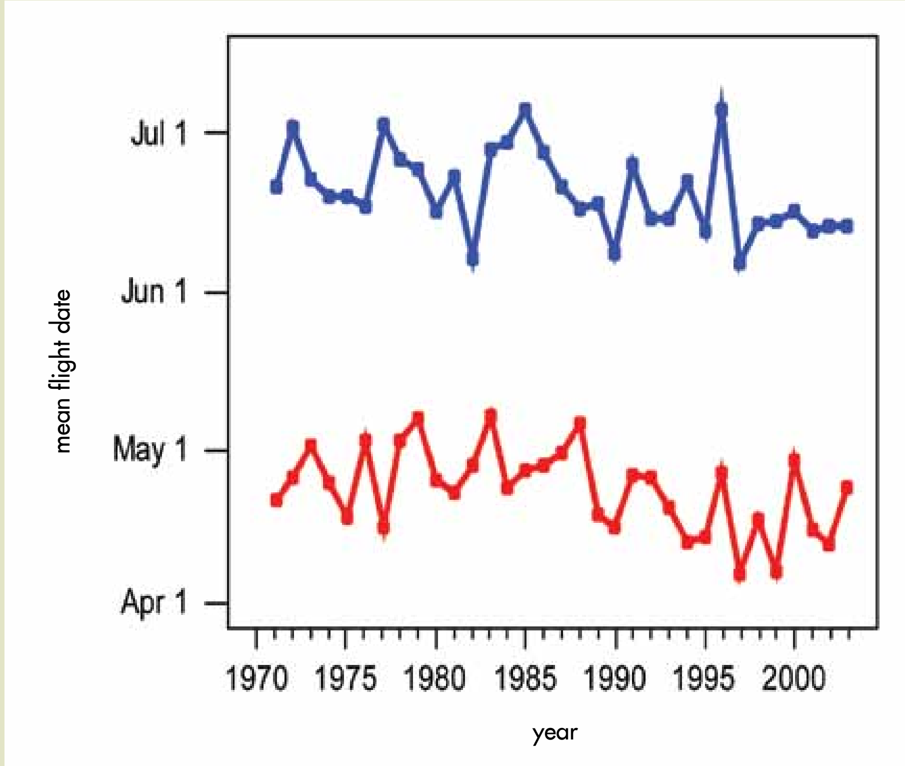
Figure 24.3 *'Mean flight time is getting earlier' (in days after 1st January) of 9 Species of Moths caught in Guernsey.*

Changes in two common species found in Guernsey

Two of our most common species are the White Ermine and the Hebrew Character Moth and are used here for illustration (Figure 24.4). The Hebrew Character Moth flies in March and April and its mean flight date has become 13 days earlier over 33 years. The White Ermine Moth flies from late May to July and its mean flight date has become 12 days earlier over the past 33 years.

References
1. Ian Woiwod is the co-ordinator of the Rothamsted Insect Survey UK network of light traps.

Figure 24.4 Common moth species comparison



Mean Flight Date in Each Year of the White Ermine Moth (blue) and the Hebrew Character Moth (red).

White Ermine Moth.

Hebrew Character Moth.

25. PREDICTIONS OF CLIMATE CHANGE

Vicky Pope[1]

Figure 25.1 *An example of negative feedback. Low-lying cumulus cloud reflects sunlight which cools the Earth's surface. We can improve mathematical models used to predict long-term climate change by understanding the Earth's climate system.*

The only way to predict day-to-day weather and changes to the climate over long timescales is to use computer models. These models solve complex mathematical equations that are based on well-established physical laws that define the behaviour of the weather and climate.

Two critical factors have helped to improve these computer models over the years. First, our knowledge of the real world has improved, and second, the speed and power of computers has increased dramatically, allowing us to represent more detail in the models.

Improvements in the science

The climate system is highly complex with many potential interactions and feedbacks. More of this complexity has been included in the models. Our current 'state of the art' climate models now include fully interactive clouds, oceans, land surfaces, and aerosols; as well as detailed chemistry and carbon cycle calculations. It is worth thinking about why these processes are important and a few examples are highlighted here:

1. *Clouds affect the heating and cooling of the atmosphere.*

   On a cloudy day less radiation (heating) from the sun reaches the Earth's surface, but on a cloudy night the heat generated during the day is trapped and the temperature near the surface remains relatively warm. The detailed properties of the clouds are also important. Cirrus cloud high up in the atmosphere lets sunlight through but traps infra-red radiation, which stops heat escaping from the surface. Low-level clouds reflect sunlight and trap little infra-red radiation and so result in a cool surface climate.

2. *The oceans take much longer to warm up than the land.*

   They also move heat around the globe. For example, the gulf-stream brings warm water from the tropics up to northern Europe, and has a strong effect on our temperatures.

3. *The land surface influences how much radiation is absorbed at the surface.*

   Land that is covered in trees will be dark and will absorb more radiation, whilst areas that are covered in ice, or by desert, will both reflect more radiation and absorb less heat.

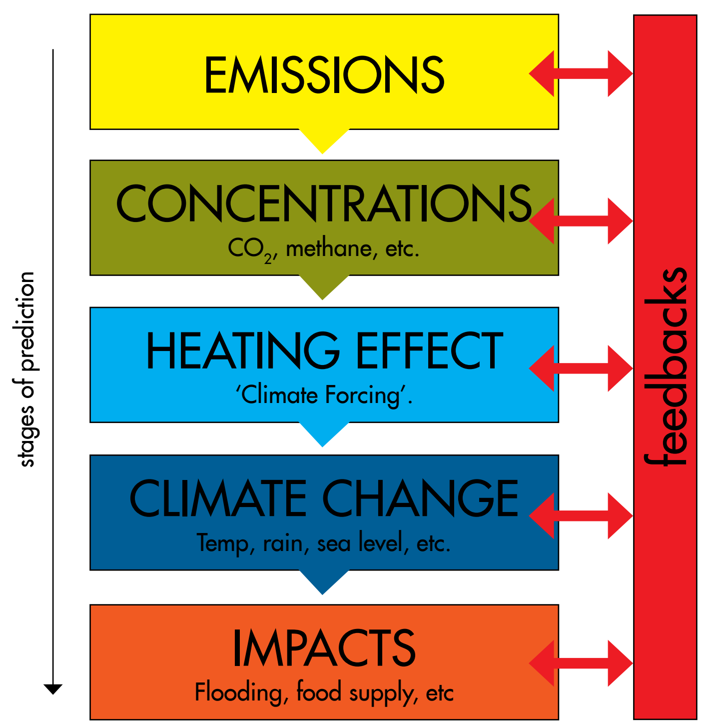
4. *Aerosols.*

   These are atmospheric particles, such as sulphate and black carbon that are produced naturally from volcanoes and forest fires, as well as by humans from fossil fuel power stations and other industrial activity. These have a short term cooling effect by reducing the amount of sunlight reaching the surface (the so-called dimming effect).

5. *The chemistry and carbon cycle determines how much carbon dioxide remains in the atmosphere.*

   Currently the biosphere (plants, soils, and phytoplankton) absorbs half of the carbon dioxide that man produces. However, this will not continue indefinitely as soils could start to release carbon if temperatures rise too much.

Figure 25.2 Stages in predicting climate change



First, estimation of scenarios from population, energy and economics models see how emissions will change.

Then the emissions that remain in the atmosphere are calculated through carbon cycle models for CO_2 and chemistry models for gases such as methane.

Next the heating effect of the increased concentrations of greenhouse gases and aerosols are simply evaluated through their properties.

The complicated effects of the changed heating on the climate can then be calculated by coupled climate models taking feedbacks in to account.

Finally, the impact of climate change can be estimated through impact models.

Adapted from Hadley Centre for Climate Prediction and Research.

The Results

The latest computer models predict similar possible global average temperature changes to models used five or ten years ago, but we are much more confident that they are correct because they are based on so much more information.

Now that man-made climate change is established beyond reasonable doubt and further global warming is inevitable, it is even more important to improve our climate predictions.

References

1. Dr Vicky Pope is head of the climate predictions programme at the UK Met Office's Hadley Centre, which provides independent scientific advice on climate change.

26. CLIMATE CHANGE SCENARIOS FOR GUERNSEY

Peter Cox[1]

Global average temperatures have risen by about 0.7°C over the last 100 years, and most of this change is likely to have been caused by the burning of fossil fuels. We also know that temperatures in Guernsey have risen by more than that, particularly in the past few decades.

Climate models predict a rise of between 1.5°C and 5.8°C in the global annual average temperatures between 1990 and 2100, taking account of both the range of predictions of future emissions of 'greenhouse gases' and different climate models. These models are based on the following emissions and social scenarios:

1. High Scenario - rapid economic growth, continuously increasing populations peaking in mid-21st century and a reliance on fossil fuels (the business as usual scenario);
2. Medium-High Scenario – more self reliance, continuously increasing populations, economic growth;
3. Medium-Low Scenario – Population peaks mid-21st century, clean and efficient technologies, reductions in material use, social and environmental sustainability, improved equity;
4. Low Scenario – Local solutions to sustainability, increasing population but at a lower rate, less rapid technological change.

The climate consequences, in terms of global average temperature, of these four emissions scenarios calculated by the Hadley Centre global climate model is shown in Figures 26.1 – 26.3. Despite the immediate and rapid divergence of future emissions paths, the warming over the next 40 years or so is predicted to be much the same. This is mainly due to the very long effective lifetime of CO_2 in the atmosphere and the inertia of the climate system. Warming over the next few decades is already built into the climate system from current emissions and those over the past few decades. On the other hand, warming by the end of the century does depend on how emissions change in the future; roughly 2°C for the lowest emissions scenarios and 5°C for the highest.

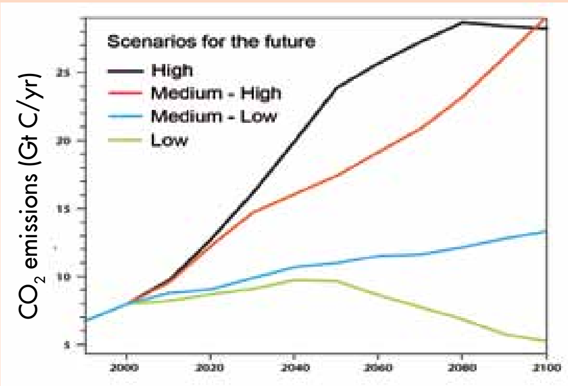


Figure 26.1 *Emissions of carbon dioxide, 1990-2100, in the four SRES emissions scenarios.*

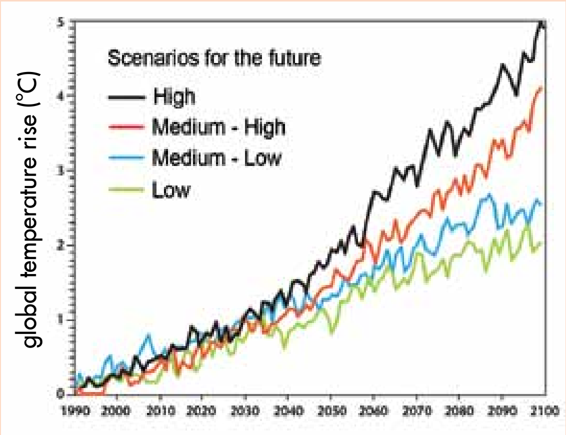


Figure 26.2 *Global mean temperature change, relative to 1990, predicted by the Hadley Centre global climate model (HadCM3), for each of the four SRES emissions scenarios.*

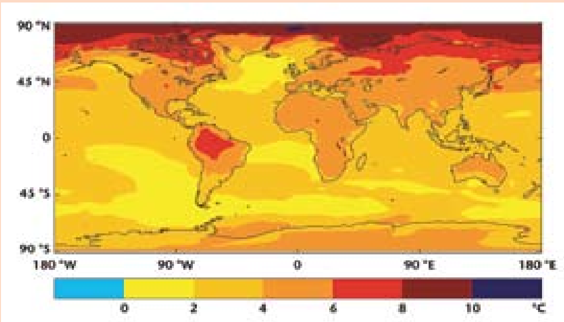


Figure 26.3 *Temperature rise between 1961-90 and 2071-2100 predicted by the Hadley Centre global climate model with Medium-High emissions.*

Seasonal Scenarios for Guernsey (the Channel Islands)

The scenarios of temperature (maximum and minimum) and precipitation (rainfall) are presented in map form (Figure 26.4 - 26.7). Maps are shown for all four emissions scenarios, and for all three 30 year time periods - 2020s (2011 – 2040), 2050s (2041-2070), and 2080s (2071-2100). The maps that follow identify by their box outline a grid square covering the land and sea area of the islands. A single 25km grid square, located for the purposes of the map mid-way between the two islands, has been taken to represent both Jersey and Guernsey.

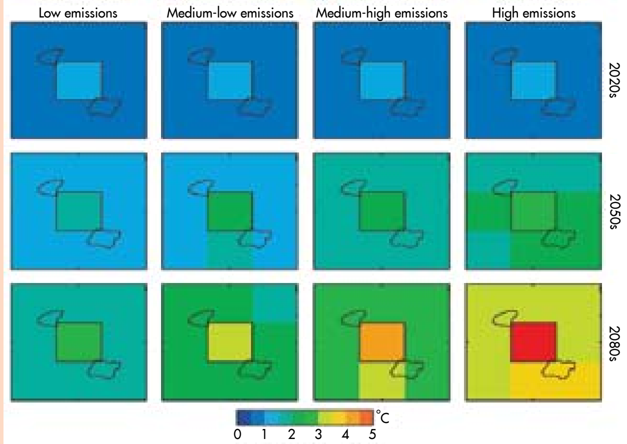


Figure 26.4 *Change in summer-average maximum temperature.*

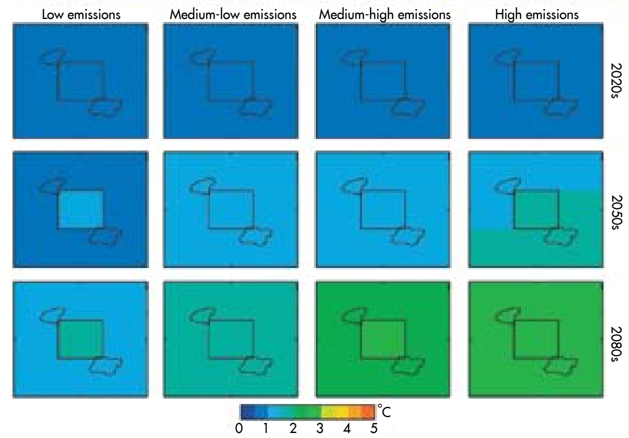


Figure 26.5 *Change in winter-average minimum temperature.*

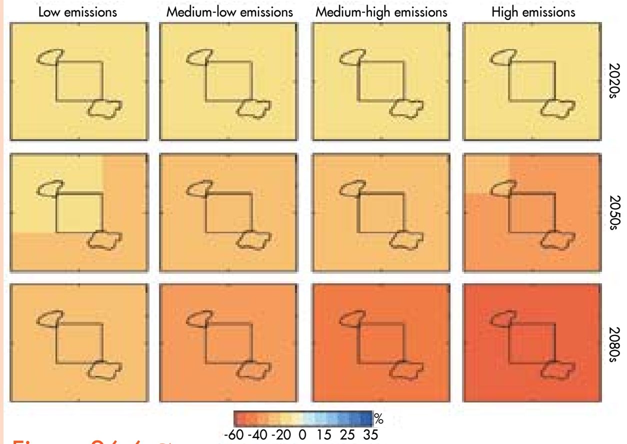


Figure 26.6 *Change in summer-average precipitation.*

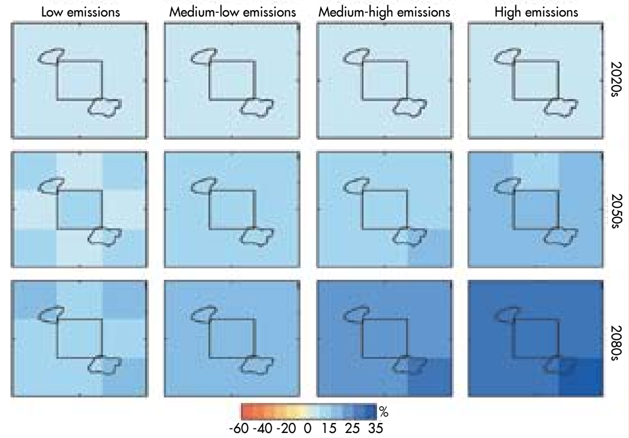
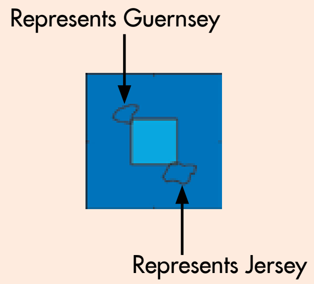


Figure 26.7 *Change in winter-average precipitation.*

Under the medium-high scenario of climate change the average annual temperature in the Channel Islands will increase by 3°C by 2080, but this masks a seasonal change from an average of 3.8°C in the summer to an average of 2.4°C in the winter. A similar seasonal difference is likely to be seen in rainfall (precipitation) that shows a modest 4% annual reduction, but this masks a dramatic 45% reduction in summer rainfall and a 24% increase in winter rainfall.



The frequency of hot days in the Channel Islands is expected to increase 4 or 5 fold by the 2080s under the medium-high emissions scenario, with a 70-85% reduction in frosts. The number of heavy rainfall days is expected to increase by 30-50% in winter but to decrease by 40-50% in summer.

Sea level is expected to increase by between 9 and 69cm by the 2080s; taking account of the different future emissions. When the effect of land movement is added the net rise varies from 14 to 74cm. With a sea level rise of 30cm the change in height of a once-in-50-years storm surge is predicted to be up to 0.5m.

The North Atlantic Ocean circulation, which includes the gulf stream, is predicted to decrease in strength by about 20% over the next 100 years, but not to switch off during that period. The temperature predictions above take account of the reduced heating due to these gulf stream changes.

Use of Climate Change Scenarios

The main use of climate change scenarios is in carrying out assessments of the impacts that climate change may have on socio-economic sectors such as infrastructure, agriculture, water resources, and coastal and river flood defences. In this way, adaptation can be planned well in advance, so that damages and costs can be minimised, and perhaps some potential benefits realised.

References

1. Dr Peter Cox is Director of the UK Met Office's Hadley Centre, which provides independent scientific advice on climate change.

27. WHAT HAPPENS IF THE WORLD GETS EVEN WARMER?

Predictions: how it could affect your family

0°c - 1°c Guernsey temperature increase, assuming high CO_2 emissions

2025

In your lifetime

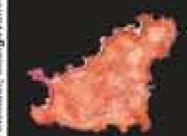
- Water bills double as new reservoirs commissioned for Guernsey
- Malaria pills needed for most south European destinations
- Air transport quotas introduced
- Pistachio and olive trees become garden centre favourites
- Flash floods devastate communities

1°c - 2°c

2050

In your children's lifetime

- Malaria pills imported on mass after major outbreak
- Environmental refugees arrive in strength at St Peter Port
- Flying becomes a luxury for the super rich
- London downsizes as summer temperatures become unbearable for millions
- Permanent island wide hosepipe ban



4°c - 5°c

2080

In your grandchildren's lifetime

- New northern sea wall barriers fail after storm surge
- First case of elephantiasis, caught from infested dout
- Light crude oil becomes more expensive, litre for litre, than claret
- Many west coast beaches disappear because of sea level rises

Source: Hadley Centre, Energy Saving Trust, World Resources Institute, Intergovernmental Panel on Climate Change, Worldwatch Institute, Energy Information Administration, UK Climate Impacts Programme, Arctic Climate Impact Assessment, UNEP

Life in 2050

Sea-level rise

Predicted to rise by up to 36 cm by 2050 and by 69 cm by 2080. Stabilising emissions by the year 2025 could cut the rate of sea level rise in half

Deforestation

Could account for 15 per cent of the CO_2 in the atmosphere by 2050, mostly from the Amazon. After 2050, this contribution will decline because there will not be many forests left. 73 per cent of the world's tropical forests will have been felled by the year 2100. The last tropical evergreen tree will fall before 2045

Crops collapse

By 2050, current crop yields must double in order to keep pace with increasing populations. Research suggests a 50 percent loss in crop yield under constant 2050 levels of CO_2

Water conflict

Humans are already using more than half the planet's fresh water. By 2025, this could be more than 70%. Some of the fastest growing human populations live along rivers shared between two or more countries –the Nile, the Ganges, the Jordan and the Tigris–Euphrates

Tropical storms

Around 50 tropical storms reach hurricane status each year. Warmer oceans mean that figure could double. Tropical atolls like the Maldives – which rise less than 1.8m above sea level – could disappear forever

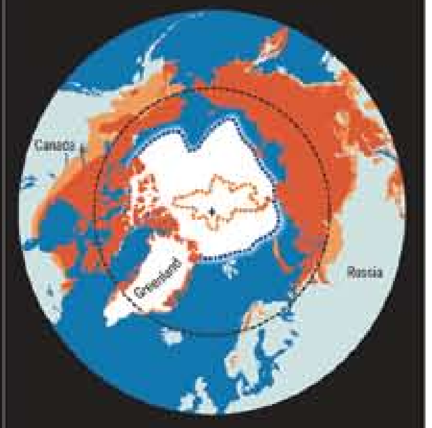
Fishing

Two–thirds of fish species, including cod and haddock, in the North Sea have moved north in search of colder waters as temperatures rise – average surface temperatures of the North Sea could rise by up to 4°C by 2080

Disease

The percentage of the earth where mosquitoes transmit malaria is likely to rise from 45% today to about 60% sometime after 2050. Increases in cholera, salmonellosis. Increased asthma, allergic disorders, and cardiorespiratory diseases

Permafrost: the world's CO_2 store



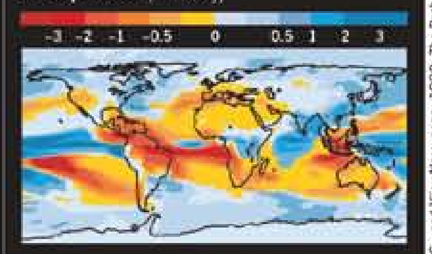
What is permafrost?
It's the name given to frozen soil, which occurs in Arctic regions and on high mountain ranges – and it can contain over 30% ice, or practically no ice at all. It covers 27% of the world's land surface and can be as much as 1000 metres deep. It contains 14% of the world's carbon trapped in the frozen soil and a mimimum of 100,000 trillon cubic feet of methane

What happens when it melts?
Across much of Canada, Alaska, Russia, Norway, China and Greenland permafrost is melting with alarming results. Houses, roads, pipelines and railways built on the assumption that permafrost was permenant are collapsing. In Switzerland some mountain tops are literally crumbling. The melting releases vast quantities of carbon and methane into the atmosphere

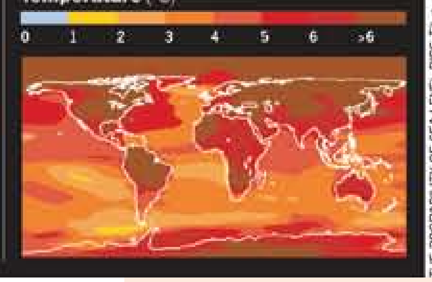
2080 the weather

Annual changes from the present day to the 2080s with the continuation of fossil fuels as the main source of energy

Precipitation (mm/day)



Temperature (°C)



THE PROBABILITY OF SEA LEVEL RISE Titus, James G., and Vijay Narayanan. 1998. The Probability of Sea Level Rise, Environmental Protection Agency, Washington, D.C..

Adapted from Guardian News and Media Ltd 2007.

28. MODELS OF PROJECTED SEA LEVEL RISE IN GUERNSEY

Andrew Casebow

Sea levels appear constant to us during the course of our lives but, as John Renouf showed in chapter 5, the sea level around the coast of Guernsey has risen by over 100 metres in the last 20,000 years. Against such a backdrop the sea level rises that are now being predicted appear small, but they could have a dramatic effect on the island and on the lives of the inhabitants.

The recent Intergovernmental Panel on Climate Change report states that "Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000m and that the ocean has been absorbing more than 80% of the heat added to the climate system."[1] Heated water expands and, as a consequence, sea levels are projected to rise as water temperatures increase. This will occur even without any increase in glacial melting. Information from Cherbourg suggests that sea level rise is already happening in this part of the Channel, and that the sea level has risen by over 40 mm in the thirty years to 2004.

Future projections of sea level rise suggest that the Channel Islands are in one of the worst regions of the British Isles, with a potential sea level rise of up to 0.7 metres by 2080 (see Figure 28.1).

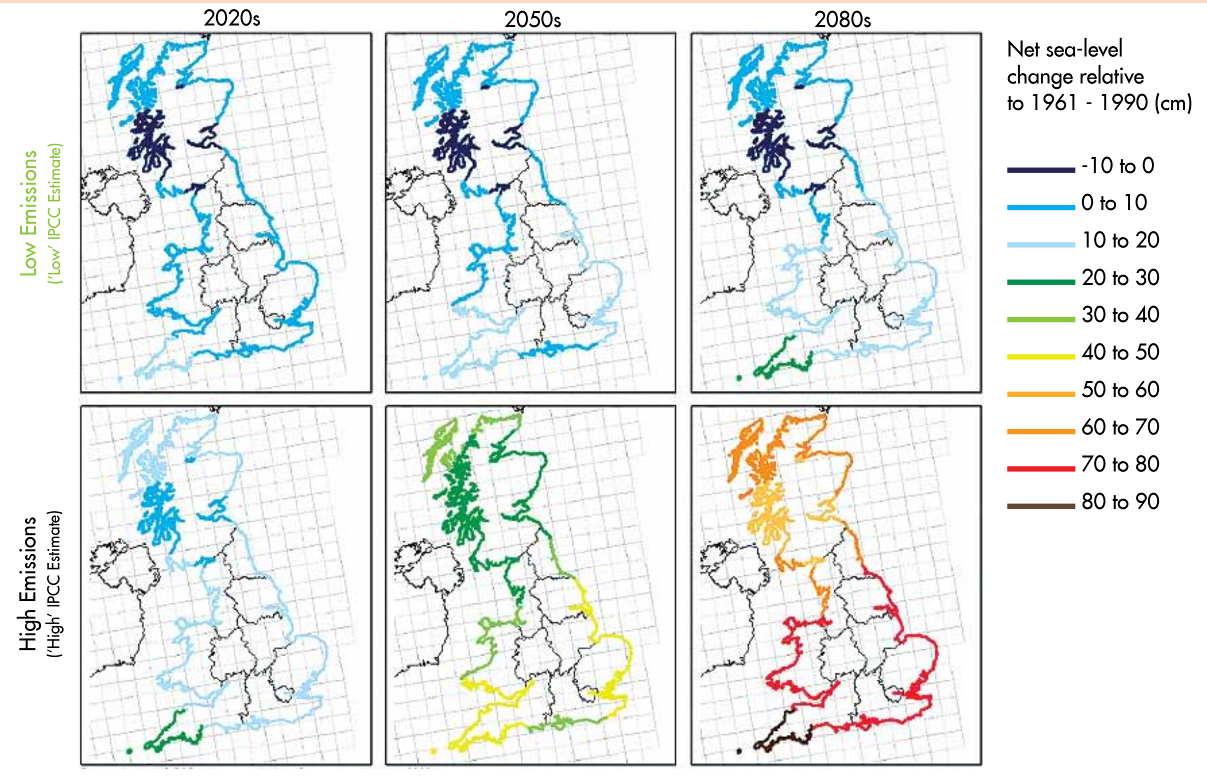


Figure 28.1 *UKCIP 2002 Projected average sea level rise under different SRES scenarios (mm)* [2].

Some individual scientists suggest that if glaciers melt more quickly than predicted then sea levels will be higher, whilst if appropriate action to curb carbon dioxide emissions can be taken then potential sea level rise might be considerably less. In the longer term sea level rise could be substantially more than this and 'business as usual' predictions suggest that a level about 10 metres higher than the present might be expected within 1000 years following the melting of the Greenland ice cap and expansion of the world's oceans (Chapter 29).

It will be noted in the following Digimap representations that a considerable area of the island would already be subject to flooding at high water spring tides if it were not for the island's existing sea defences. As a consequence, a small rise in sea levels might make little difference to the current situation; whereas if sea levels rose further than predicted, possibly in a longer time frame, or during the occasional (once in 50 year) storm surge, then there might be more extensive flooding. Fortunately the most adverse effects can be avoided if timely actions are taken in anticipation of sea level rise. Where appropriate, actions can be initiated to strengthen sea defences and protect vulnerable areas, at least for the foreseeable future.

A rising sea could also increase the salinity of coastal marshes and aquifers, disrupt marine life and threaten some private drinking water supplies.

In addition to the 'headline' risk of inundation by sea-water, there is a risk of greater flooding in low lying areas of the island due to the higher winter rainfall that is predicted. Considerable areas of open agricultural land already flood following prolonged heavy rainfall. This could be particularly important in the future as urban and infrastructural development (sewage, roads, housing and educational facilities) have been undertaken in low-lying areas, and greater areas of roofs, paved areas and tarmac roads lead to more rapid run-off. Flooding in some of these areas is already mitigated by pumping, and flooding has occurred in the past when remedial pumping of water has not occurred.

Figure 28.2 shows 'Digimap' representations of Guernsey areas that would currently be vulnerable to flooding at high water if it were not for the existing sea defences. The map showing potential flooding if the sea level was up to one metre higher is little changed, but a more substantial sea level rise could affect greater areas, particularly in the north of the island. Fortunately this is unlikely to occur this century, although as sea levels rise these areas will become more vulnerable to flooding following a storm surge.

References

1. Summary for Policymakers: IPCC Fourth Assessment report of the IPCC, Working Group 1, 2007.

2. M Hulme et al (2002) Climate Change Scenarios for the United Kingdom: UKCIP 02 Scientific Report. Tyndall Centre for Climate Change Research, UEA, Norwich.

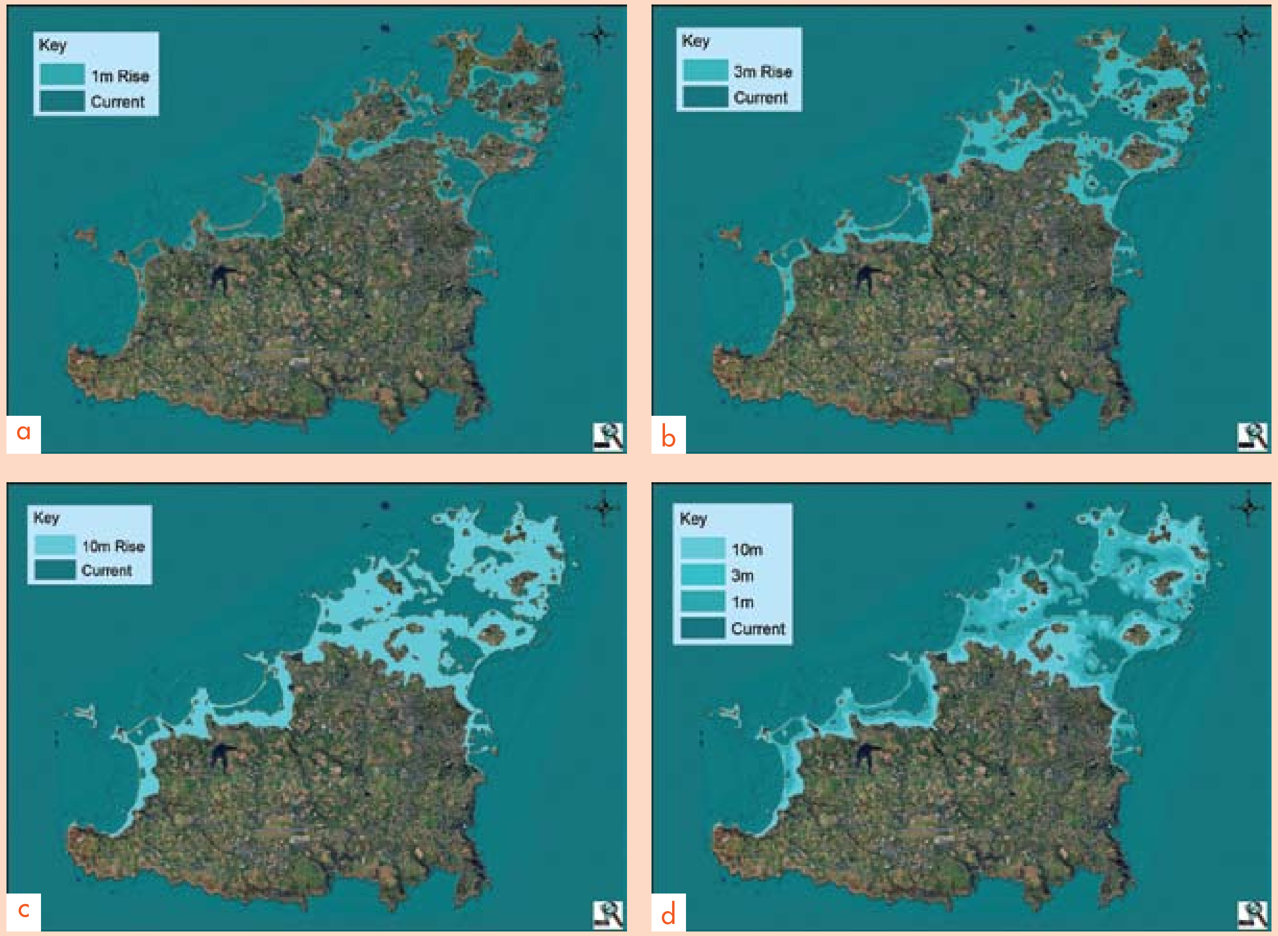


Figure 28.2 *Representations of potential flooding in Guernsey if it were not for our existing sea defences; (a) after 1m sea level rise, (b) after 3m sea level rise, (c) after 10m sea level rise, and (d) all three levels superimposed on top of each other.* *"Mapping © States of Guernsey 2007, supplied by Digimap".*

29. CLIMATE CHANGES OVER A MILLENNIAL TIMESCALE

Andrew Casebow

Figure 29.1 *Continual increase in emissions could lead to total depletion of ice in the Northern Hemisphere.*

Most projections of future climate change focus on this century. The obvious reason for this is that beyond this period relatively accurate predictions become more and more difficult. They also become less meaningful to most of us when the predictions are for a period of time beyond human contemplation, and beyond the possible lifetimes of our immediate descendants.

Projections for the period 2080 – 2100 leave the near surface air temperature and sea level still rising, and in some models the rate of change seems to be still increasing. However, climate changes will not stop occurring. If, as many predictions indicate, greenhouse emissions are still increasing, albeit at a slower rate, and temperature increases are still occurring, then where will all this lead?

The Tyndall Report

The UK Environment Agency commissioned a report into climate change over the next 1000 years from the Tyndall Centre for Climate Change Research.[1] This shows that decisions over the next few years by the major greenhouse gas emitting nations (and by us all), will leave a legacy of increasing climate change over the next millennium unless there is a major reduction in emissions.

Obviously the storylines, or possible scenarios, that lie behind the climate change models will vary enormously, and as a consequence the change in the earth's climate could be quite minimal if appropriate long term action is taken immediately, or severe if humanity adopts a 'business-as-usual' approach. The report notes that:

"The most important potential contributor to the long term forcing of the climate system by human activities is the amount of fossil fuel carbon we emit to the atmosphere as the greenhouse gas carbon dioxide (CO_2). The reasons are that the potential emissions of CO_2 are huge and it has a long lifetime in the atmosphere; even after ~1000 years, at least ~15% of CO_2 emitted will remain in the atmosphere."

The report says that by the year 3000:[2]

- Temperatures could rise from 1.5°C if emissions are minimised to as much as 15°C if we continue burning fossil fuels, which is more than double what the IPCC predict on the centennial timescale.
- Only the minimum emissions scenario can prevent global temperatures from rising more than 2°C above pre-industrial levels. This is thought to be the maximum warming acceptable without the risk of long-term dangerous consequences (defined in the report as 'a global sea level rise of 2m, because it would flood many low lying cities and displace hundreds of millions of people').
- Sea levels will still be rising at the end of the millennium and could reach 11.4m above the pre-industrial level by 3000. Low lying areas of Guernsey and the UK, including London and many major cities, could be threatened by sea level rise.
- Ocean pH is predicted to fall dramatically (increasing acidity), posing a threat to marine organisms.
- Abrupt climate change events could occur (see Figures 29.2 and 29.3). Business-as-usual emissions could lead to "*a rapid climate change event in the 22nd century.*" One model predicts a southward shift in a diminished gulf-stream caused by the melting of the Greenland ice sheet, that might result in a reduction in the surface temperature of the Atlantic Ocean. Another prediction suggests that a rapid increase in global temperature could occur in the 2600s / 2800s. Arctic ice could disappear all year round with the "*thermo-haline circulation (the gulf stream) becoming very vigorous*" causing North Atlantic seas to heat by up to 8°C, accompanied by UK land temperature increases of up to 5°C. However, the Report notes that "*This should not be treated as a prediction but rather as an indication that continual increase in emissions could lead to an event of this type*".

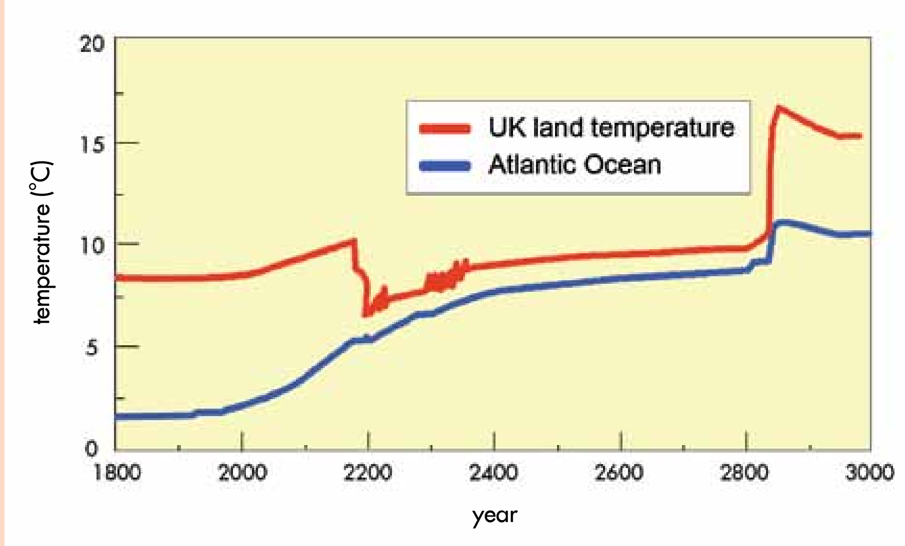


Figure 29.2 *Abrupt climate change events as seen in the North Atlantic region. Surface temperatures drop about 3°C at around 2200 as the Greenland ice sheet completely melts. At around 2800 Arctic ice disappears and the gulf stream becomes vigorous causing North Atlantic seas to heat by up to 8°C.*

('UK' refers to continent at UK latitude).

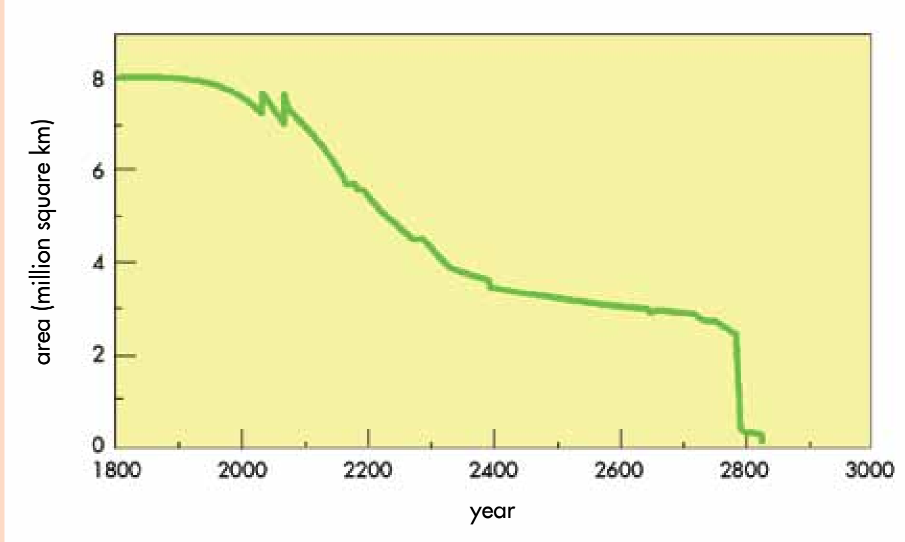


Figure 29.3 *Northern Hemisphere sea-ice area in million square km. Sea-ice rapidly retreats from the Arctic Ocean and at around 2800 it disappears completely. For recent reduction in the extent of sea ice in 2007 (see page 25).*

"Only by minimising emissions can dangerous climate change be avoided: in all except the most stringent emissions reduction scenario, Greenland ice sheet melt begins between the early 22nd and early 23rd century".

Conclusion

"We have presented a sobering picture of potential climate change on the millennial timescale. Whilst great uncertainties remain, our relatively conservative assumptions still produce the result that only by starting to reduce CO_2 emissions in the very near future, and continuing to reduce them so that they are zero by 2200, can we avoid dangerous climate change on the millennial timescale."

References

1. Climate Change on the Millennial Timescale (2006). Tyndall Centre for Climate Change Research, Norwich, UK. (www.tyndall.ac.uk).

2. Environment Agency: http://www.environment-agency.gov.uk/news/1299456.

30. THE ECONOMICS OF CLIMATE CHANGE[1]

Andrew Casebow

Sir Nicholas Stern was commissioned by HM Chancellor of the Exchequer to produce an Independent Report on the Economics of Climate Change.

The Review examined the evidence of the economic impacts of climate change, itself, and explored the economics of stabilising greenhouse gases in the atmosphere. The second half of the Review considered *"the complex policy challenges involved in managing the transition to a low-carbon economy and in ensuring that societies can adapt to the consequences of climate change that can no longer be avoided."*

Scientific evidence

The scientific evidence points to increasing risks of serious, irreversible impacts from climate change associated with business-as-usual paths for emissions:

- The scientific evidence on the causes and future paths of climate change is strengthening all the time.
- The stocks of greenhouse gases in the atmosphere (including carbon dioxide, methane, nitrous oxides) are rising, as a result of human activity.
- The current level of greenhouse gases in the atmosphere is equivalent to around 430 parts per million (ppm) CO_2 , compared with only 280ppm before the Industrial Revolution.
- Even if the annual flow of emissions did not increase beyond today's rate, the stock of greenhouse gases in the atmosphere would reach twice the pre-industrial levels by 2050, that is 550ppm CO_2 equivalent, and would continue growing thereafter. But the annual flow of emissions is accelerating, as fast growing economies invest in high-carbon infrastructure and as demand for energy and transport increases around the world. The level of 550ppm CO_2 could be reached as early as 2035. At this level there is at least a 77% chance – perhaps up to 99% chance, depending on the climate model used – of a global average temperature rise exceeding 2°C.
- Under a 'Business as Usual' scenario, the stock of greenhouse gases could more than treble by 2100, giving at least a 50% risk of exceeding a 5°C global average temperature change during the following decades. This would take humans into unknown territory. An illustration of the scale of such an increase is that the present global average temperature is only around 5°C warmer than in the middle of the last ice age.

Economic conclusions

The Stern Review concluded that: "*The benefits of strong, early action on climate change outweighs the costs.*"

"Emissions have been, and continue to be, driven by economic growth; yet stabilisation of greenhouse gas concentrations in the atmosphere is feasible and consistent with continued growth."

"The effects of our actions now on future changes in the climate have long lead times. What we do now can have only a limited effect on the climate over the next 40 or 50 years. On the other hand what we do in the next 10 or 20 years can have a profound effect on the climate in the second half of this century and in the next."

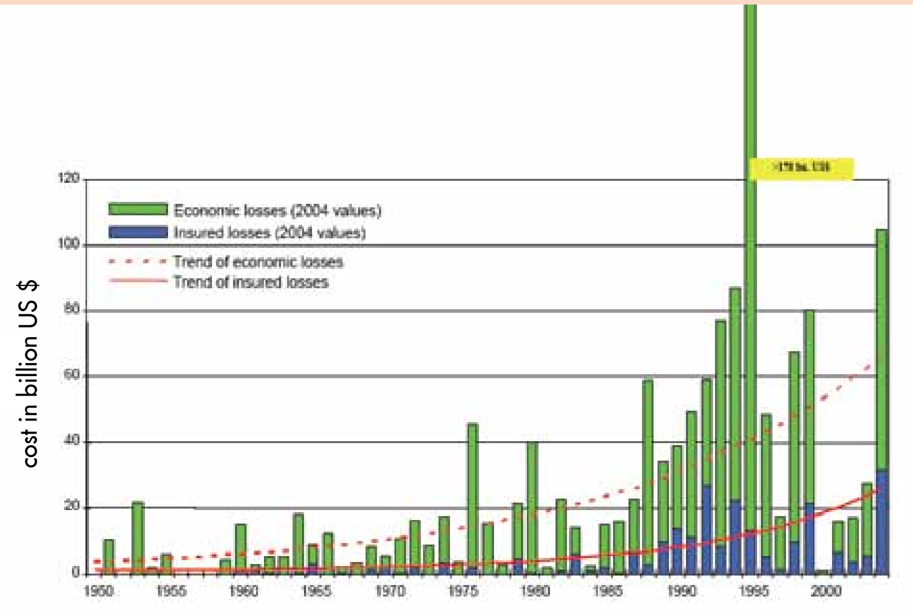


Figure 30.1 *Great Natural Disasters 1950 -2004. Economic and insured losses*

"Policies are required to support the development of a range of low-carbon and high-efficiency technologies on an urgent timescale."

"No-one can predict the consequences of climate change with complete certainty; but we know enough to understand the risks. Mitigation – taking strong action to reduce emissions – must be viewed as an investment, a cost incurred now and in the coming few decades to avoid the risks of very severe consequences in the future."

"Building and sustaining collective action is now an urgent challenge."

"There is still time to avoid the worst impacts of climate change if strong collective action starts now."

Conclusion

"The evidence gathered by the Review leads to a simple conclusion: the benefits of strong early action considerably outweigh the costs."

THE STERN SCENARIOS: WHAT MAY HAPPEN

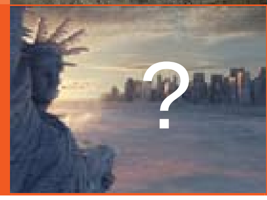
TEMPERATURE RISE		WATER	FOOD	HEALTH	LAND	NATURE	LARGE-SCALE IMPACT
1°C		Glaciers in the Andes disappear threatening water supplies for 50 million people.	Modest increases in cereal yields in temperate regions.	At least 300,000 people each year die from climate related diseases; N Europe and US winter mortality rates drop.	Thawing in Canada and Russia damages buildings and roads.	An estimated 10% of land species face extinction; coral reefs suffer 80% bleaching.	Atlantic Thermo-haline Circulation (gulf stream) starts to weaken.
2°C		20 - 30% less water availability in Southern Africa and the Mediterranean.	Crop yields drop in tropical regions (by up to 10% in Africa).	Up to 60 million more Africans would be exposed to malaria.	Coastal flooding affects up to 10 million more people each year.	An estimated 15 - 40% of species face extinction. Among those most at risk are the polar bear and caribou.	Greenland ice sheet at risk of melting irreversibly, sea levels rise seven meters.
3°C		Serious droughts in southern Europe; up to 4 billion more people suffer water shortages.	Up to 550 million more people are likely to go hungry.	Up to 3 million more people would die from malnutrition (if carbon fertilisation weak).	Coastal flooding affects up to 170 million more people each year.	An estimated 20 - 50% of species face extinction; the Amazon rainforest begins to die.	Severe atmosphere changes. West Antarctic ice sheet threatened with collapse.
4°C		Up to 50% less water available in the Mediterranean and southern Africa.	Agriculture stops in parts of Australia and up to 35% less crops in Africa.	Up to 80 million more Africans would be exposed to malaria.	Coastal flooding affects up to 300 million more people each year.	Half of the arctic Tundra disappears and the half of the world's nature reserves cannot fulfil objectives.	Atlantic Thermo-haline Circulation stops.
5°C		Possible disappearance of large glaciers in the Himalayas, affecting 100's of millions of people in China & India.	Ocean acidity disrupts marine ecosystems and possibly fish stocks.		Main cities such as London, NY and Tokyo and low-lying coastal areas threatened by rising sea levels.		
6°C +		Disaster on an unimaginable scale. Such a change in temperature would be the equivalent to the rise that occurred between the last Ice Age and today. The exact effects are hard to gauge with current models because the temperatures are so far outside human experience. Note: The table shows illustrative impacts at different degrees of warming. Temperatures represent increases relative to pre-industrial levels. The impacts are expressed for a 1°C band around the central temperature, e.g. 1°C represents the range 0.5°C - 1.5°C.					

Figure 30.2 *Climate change scenarios. Source: Stern review.*

References
1. Stern Review 2006. The Economics of Climate Change, Executive Summary.

31. CONSEQUENCES OF FUTURE CLIMATE CHANGE IN GUERNSEY

Andrew Casebow

Figure 31.1 *Sunset at Cobo Bay. In the short term Guernsey could become a popular holiday destination, whilst other European destinations are deemed too hot. However, long-term consequences of climate change are not so positive.* *Image courtesy of VisitGuernsey.*

Guernsey is in a remarkably favourable position. The islands appear set to become warmer throughout the year, but should not succumb to any of the more severe problems in the short-term. However, it is important to make a distinction between possible short-term 'gains' and the long-term impacts that could well involve serious flooding if the more dire predictions of sea level rise come to fruition.

Improving climate

In the 'short term' the temperature in Guernsey could increase, providing a climate more like that of central France today, which many would welcome. The island may even become a more sought after holiday destination if the summer-time climate 'improves' for holiday-makers, with hotter, sunnier days, and less rainfall; whilst other destinations are considered too hot.

Agriculture and gardening

For farming and horticulture this is likely to mean lower crop yields in the absence of irrigation but also the possibility that different crops might be viable; whilst in our gardens it may lead to a change to more Mediterranean planting schemes.

Energy and food security will become more important. Agricultural land is being used to grow crops for the production of biofuels. This is already leading to higher food prices and predictions that the era of 'cheap food' has come to an end. With an increasing world human population food 'security' and availability will become important once again. One of the island's weaknesses in the future will be its inability to feed its population and its reliance on imported produce.

Water resources

Water is one of the most valuable commodities. With much drier summers it will be even more important to conserve water and to avoid water pollution, and we will depend even more on water that has been stored from the previous winter rainfall. We are fortunate that Guernsey Water already has considerable water storage capacity.

Climate predictions suggest that the island will receive much more of its annual rainfall during the winter months in the future. Whilst this will place even greater stress on the need to conserve and store water, it will also mean that the flooding of low-lying areas is more likely. Greater consideration will need to be given to the possibility of flooding before building new developments. The risk of flooding could also have a considerable impact upon the island's infrastructure, its foul water drainage system and sewage treatment facilities. As the island depends on collecting clean fresh water from the whole island catchment, serious flooding could well cause pollution of the fresh water supplies.

Insurance

Insurance against the financial losses caused by the greater risk of fire, storms and flooding, is of increasing importance, and just one area where the human and financial expertise contained within our island could benefit Guernsey.

Human and animal health

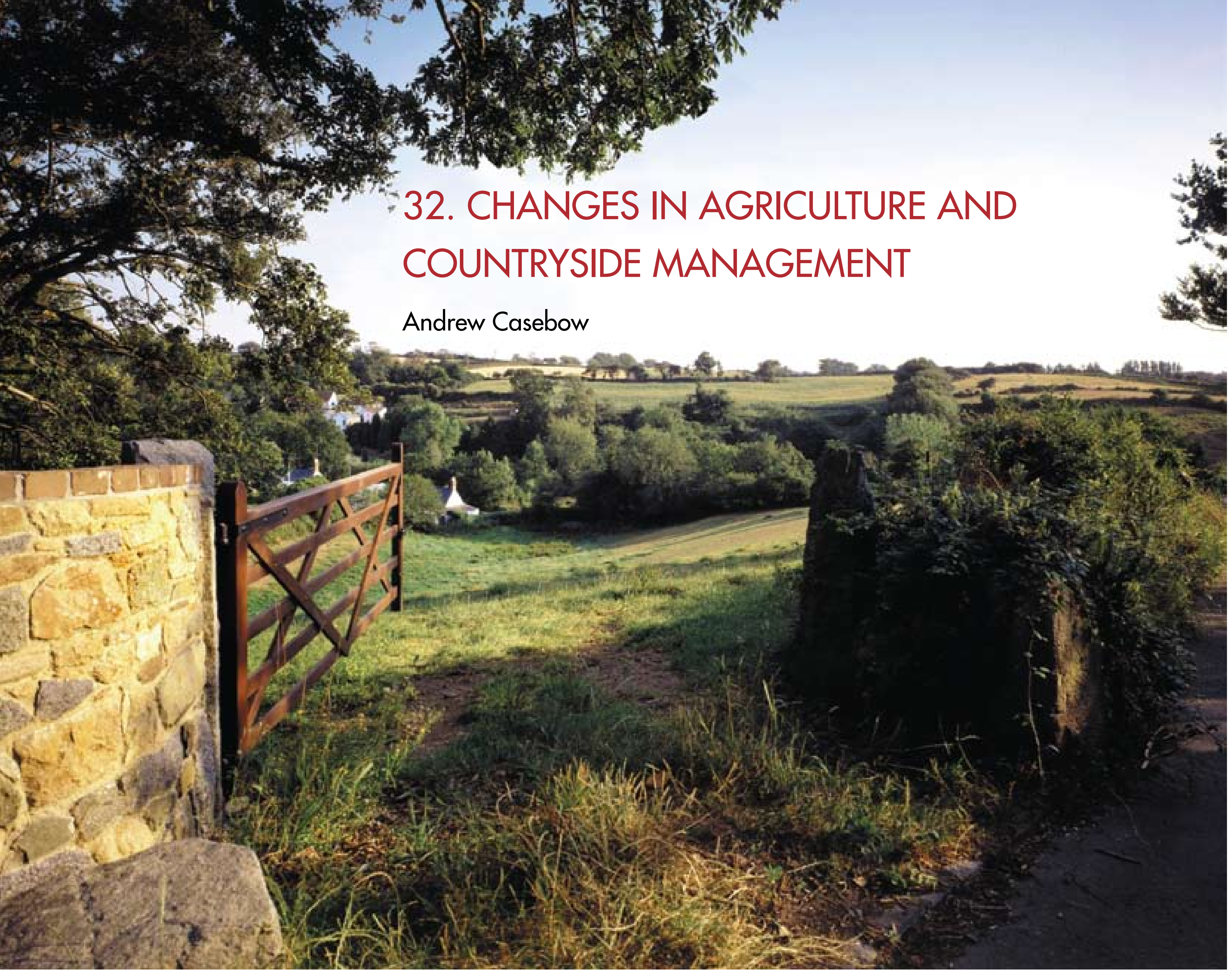
Pests and diseases, particularly those carried by insect vectors, will have an impact on our human and animal population. Higher summer temperatures may become uncomfortable or kill vulnerable people and animals, whilst we will need to ensure that livestock have sufficient water to drink and shade from the sun.

Wildlife

Higher temperatures and the drying of many wetland habitats during the summertime will have consequences for the island's wildlife, and the changing seasons will affect the migration and breeding success of many species of birds. Some plants and birds at the southern extremity of their normal range might well die out, move northwards or not return, whilst others that are occasional visitors now may come in greater numbers, or breed within the island. Others may stay over-winter and not migrate southwards.

Conclusion

With the availability of good medical and veterinary treatment, ready supplies of food at a reasonable cost, sufficient water supplies and a beautiful environment, our island is likely to remain one of the most delightful and favourable places in which to live and work for many years to come.



32. CHANGES IN AGRICULTURE AND COUNTRYSIDE MANAGEMENT

Andrew Casebow

Figure 32.1 *Guernsey's undulating countryside, just one of the island's many picturesque landscapes. Image courtesy of VisitGuernsey.*

Whilst farming is the cornerstone of Guernsey's rural economy, it is widely accepted that agriculture has a multi-functional role, delivering not just food but other benefits, such as the responsible management of an increasingly endangered breed of dairy cattle, and the protection and enhancement of the Guernsey countryside.

Biodiversity

The biodiversity of the countryside, consisting mainly of farmed land, is likely to change. Wildlife will be put under stress by the reducing rainfall and higher temperatures, that will cause wetland habitats to dry up in the summer; whilst the increasing winter rainfall could lead to greater flooding of farmed land in some areas.

Crop yields

In the early phases of climate change, crop yield could increase due to the warmer temperatures, the longer growing season and higher carbon dioxide concentration in the atmosphere. But yields are likely to decline as crops begin to suffer from a mixture of drier soils in the summer and earlier maturity, which reduces the amount of solar radiation that growing crops receive. Whilst early potatoes may become earlier and higher yielding, main crop potatoes may only be viable where irrigation is available due to drier summers. Similarly some vegetable crops may only be viable if they are irrigated.

New crops and husbandry

Farmers and growers wishing to capitalise on niché markets will grow new crops. An example of this is the English winemaking industry, which is expected to expand. Whereas the climate was only suitable until recently for white wine production, champagne producers are now moving to England from France and red grape varieties are being planted. It would be surprising if local Guernsey growers did not plant vineyards and start making Guernsey wine. There are also opportunities for many different niché crops, such as outdoor herbs, and unusual fruits and nuts such as apricots and almonds, which thrive in frost free environments. Some gardeners are already growing outdoor olive trees and it is only a matter of time before some enterprising grower starts to plant citrus fruit, although it is doubtful whether these would be commercially viable.

Livestock may increasingly be housed during the mid-summer. Pigs suffer badly from sunburn and whilst the Guernsey breed of dairy cattle thrives in hot climatic conditions, they welcome shelter from the sun and sprays of cooling water. The availability of a constant fresh water supply during the heat of the summer is particularly necessary for all animals.

Safeguarding agricultural land and wildlife habitats

Although the available agricultural land in Guernsey could not feed the island's population, safeguarding agricultural land for future food production could be vital as world population increases, food crops become more expensive, and food security becomes important once again. Wildlife, too, needs space and suitable habitat in which to thrive.

Figure 32.2 *Camomile and Corn Marigold in a wild flower meadow.*

The importance of refrigeration

Increasing temperatures will also affect the durability of farm crops and food, and wastage during storage and transport will be an increasing concern. Food freshness is maintained by refrigeration in the human food chain, and this will be increasingly important to maintain food quality.

Due to increasing temperatures and demand for longer shelf life, refrigeration will become essential for many foodstuffs. For instance, milk must be cooled quickly after production at the farm and it is important to ensure that there is a consistent cold-chain from the farm, to the dairy, to the customer, and to the point of consumption to ensure that fresh milk and dairy products retain their quality.

33. THE CHALLENGE OF GLOBAL WARMING FOR GARDENERS

Peter Danks [1] and Andrew Casebow

Figure 33.1 *Gravelled garden at Jerbourg. In the event of further global warming, and increasing droughts, maintaining a lawn may prove difficult.*

The drier summers and wetter winters that are predicted in the future will not prevent us from gardening. However, we will probably need to change the varieties of vegetables and flowers that we grow, and learn to conserve water and use it more sparingly in the future. In some ways it could even be quite exciting as we can experiment with unusual varieties of plants and trees that are not tolerant of frost and are normally considered to be 'Mediterranean'.

Coping in drought conditions

Conserve water by:

- *Using less water, but more effectively.*
- *Using "grey" water, e.g. use bath water / shower water.*
- *Storing as much rain water as possible.*
- *Improving the water-holding capacity of garden soils by increasing their organic matter content. In other words, using more compost.*
- *Reducing the wind-speed over the garden by planting more hedges, both deciduous and evergreen, according to locality.*
- *Hoeing open soil in vegetable plots regularly to create a loose soil mulch and reduce weed competition.*
- *Using a "floating mulch" [2] in vegetable plots. This will reduce evaporation and pest attack.*

Reduce water loss and encourage plant growth

The following may be useful:

- *An old carpet or permeable black plastic mulch, on its own or under gravel, will conserve water and may help to reduce weeds.*
- *Composted bark, garden compost or fresh lawn cuttings. (These materials need to be at least 3-4 inches (7-10 cm) thick if they are to properly smother weed growth.*
- *In the vegetable garden use raised beds, these give a greater depth of soil for deeper root penetration.*
- *Sowing plants in a deep drill and earthing-up after germination gives added rooting depth.*
- *Paths can be loose-paved to conserve moisture.*

Use shade to good effect

This will become more essential in long, dry spells. Living shade will absorb water. Some plants have deep roots whilst others, like Eucalyptus, have massive spreading roots; so choose plant associations carefully. If in doubt, ask your nurseryman for advice on the particular species that you fancy before purchasing.

Lawns and vegetables

Lawns may well need a different balance of grass species, which are more drought tolerant, and maintaining a pristine lawn may prove difficult. The use of water sprinklers to maintain a green lawn may be socially unacceptable when water is a scarce commodity. However, if you are using 'grey' or saved rainwater in the vegetable garden, apply through low level watering lines or a leaky pipe system to place water where it is most needed and reduce evaporation. Fresh food may become more expensive as the climate becomes drier and there are more 'mouths' to feed. There is increasing interest in vegetable growing for personal consumption, and more people may value keeping an 'allotment' and growing at least some of their own food.

Which plants to grow?

Not all plants from warmer/drier climates are likely to do well here, especially some plants that have a particular day length requirement for successful flowering and cropping. Although winters will be warmer than now, they are still unlikely to be suitable for plants from the tropics.

Think more of plants from the Mediterranean, South Africa, Australia, New Zealand and South America, so that many of the palms, southern beech, cistus and citrus and hardier bananas become interesting subjects. Conifers, evergreens and the more drought tolerant succulents could be useful if they can tolerate a wet winter.

Some of the plants that we grow now may not succeed because they require more cold than is likely in the future. Small alpine plants and bulbs come into this category.

Figure 33.2 *Vegetable allotment at St Martin's in Guernsey.*

Conclusion

The secrets to success are to conserve water and use what we have wisely. Protect from wind and sun and, above all, research the plants you think you would like to grow in your garden. Do not rush into things. For gardeners, the future could be an exciting challenge.

References

1. Peter Danks has been gardening in Guernsey since 1968, both professionally and as a hobby. Before retirement he was a horticulture lecturer and adviser.

2. A floating mulch is a very fine polyfibre woven film that allows moisture but not insects to penetrate.

34. CHANGES IN WILDLIFE HABITATS AND SPECIES

Pam Berry[1]

Figure 34.1 *Conditions could become unsuitable for plant species such as the bluebell from the 2050s onwards.*

Observed changes in climate are already having an impact on the biodiversity of Guernsey, but what might be the impacts of the projected climate changes?

Research in the MONARCH project [2] in Britain and Ireland have shown that there are species that could benefit from climate change ("winners"), and those that could lose suitable climate conditions ("losers"), while some species, especially on a small island like Guernsey, may continue to find suitable climate space. Similar work has been carried out for Europe in the BRANCH [3] project and this has been used to inform this chapter.

Woodland, wetland and coastal habitats are important in Guernsey, although they occupy less than 8% of the land area. Grasslands and agricultural land can also contribute to wildlife, especially if they are appropriately managed. Key woodland species include elm, ash and oak. Wych elm, ash and oak show increasing vulnerability to climate change, such that potential suitable climate space could be lost from Guernsey by the 2020s, 2050s and 2080s respectively (Figure 34.2). Key ground flora plants include greater wood rush, bluebell and black bryony and while the former could continue to find potential suitable climate space in Guernsey, conditions could become unsuitable for bluebell from the 2050s onwards.

Wetlands comprise a range of habitats including grazing marsh, salt marsh, brackish water and freshwater ponds. The balance between these fresh, brackish and salt water habitats is likely to change as a result of sea level rise on low-lying parts of the coast. Coastal habitats and their species will try to move inland, but where hard coastal defences and built development limit this movement they may be lost. Key species include: strawberry clover, common saltmarsh grass, greater pond sedge, reed and duckweed. Climate change should not significantly directly affect available climate space for these species, but other more water-level sensitive species may be adversely affected.

Coastal habitats, such as sand dunes, shingle, scrub and some grassland, will be similarly affected by sea level rise. Key species, such as marram grass and gorse, could continue to find potential suitable climate space, although Guernsey could start to become unsuitable for western gorse from the 2050s onwards. The success of species associated with scrub, arable and grassland will depend very much on management, but some associated species, such as blackthorn, bracken, dog violet, common St. John's wort could continue to find suitable climate space, while honeysuckle, bramble, sheep's sorrel and early purple orchid could be adversely affected as climate change progresses.

These suggestions of the potential impacts of climate change are based on climate alone and thus do not include many of the other factors that can affect a species' distribution, including availability of suitable habitat and interactions with other species. They do, however, give an indication of some of the changes that might occur and for which species adaptation actions might be necessary.

Figure 34.2 *Changing potential suitable climate space under the HadCM3 A2 scenario for Wych elm (a to c), ash (d to f) and oak (g to i), where green represents overlap between current and future potential suitable climate space, red represents loss and blue gain*[4].

Wych elm

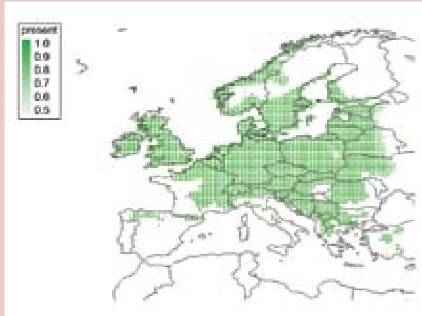


Figure 34.2a *Simulated current European climate space.*

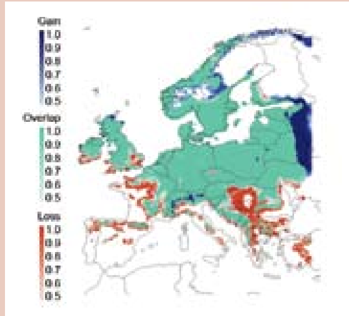


Figure 34.2b *Potential suitable climate space for the 2020s.*

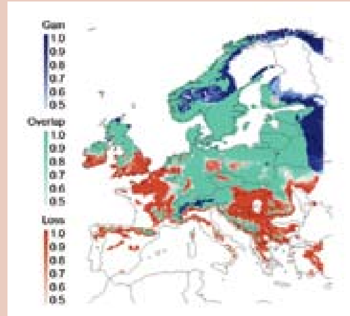


Figure 34.2c *Potential suitable climate space for the 2050s.*

Ash

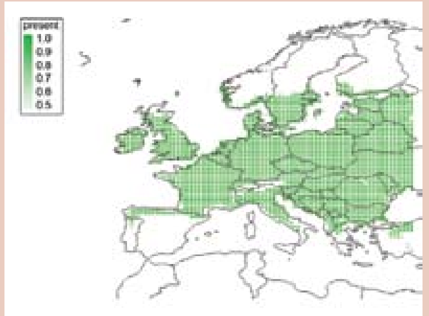


Figure 34.2d *Simulated current European climate space.*

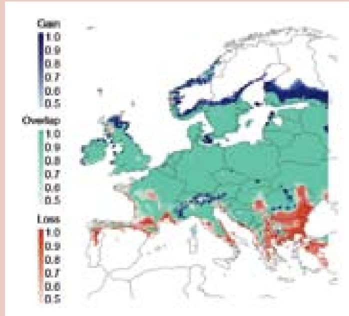


Figure 34.2e *Potential suitable climate space for the 2020s.*

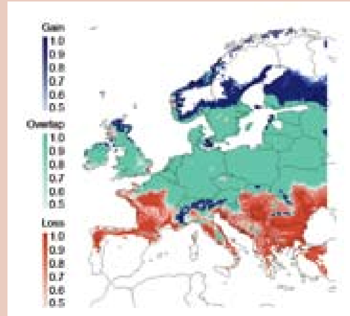


Figure 34.2f *Potential suitable climate space for the 2050s.*

Oak

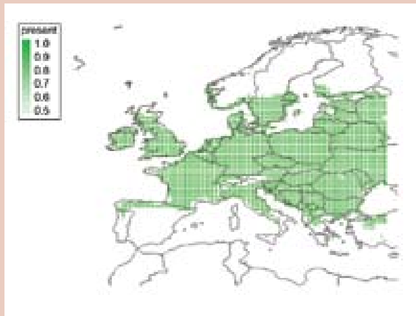


Figure 34.2g *Simulated current European climate space.*

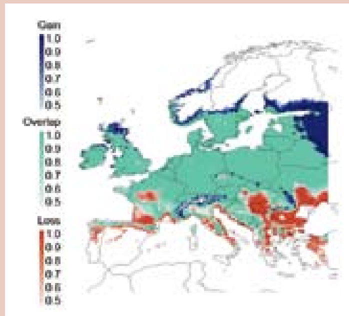


Figure 34.2h *Potential suitable climate space for the 2020s.*

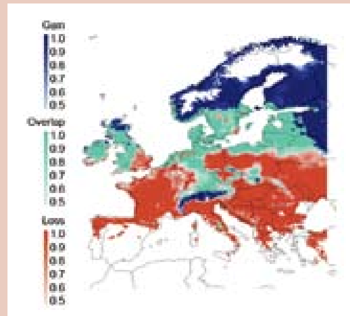


Figure 34.2i *Potential suitable climate space for the 2050s.*

References
1. Dr. Pam Berry, Environmental Change Institute, University of Oxford. Her research interests include various aspects of the potential impact of climate change on landscapes, ecosystems and selected groups of plant species.

2. Berry, P.M et al (2005). Climate change and nature conservation in the UK and Ireland: modelling natural resource responses to climate change (MONARCH2). UKCIP Technical Report, Oxford. (Available from www.ukcip.org.uk).

3. BRANCH (Biodiversity Requires Adaptation in Northwest Europe under a Changing Climate) was funded under the EU Interreg IIIb programme.

4. James Paterson carried out the modelling.

35. POTENTIAL IMPACT ON HUMAN HEALTH IN GUERNSEY

David Jeffs [1]

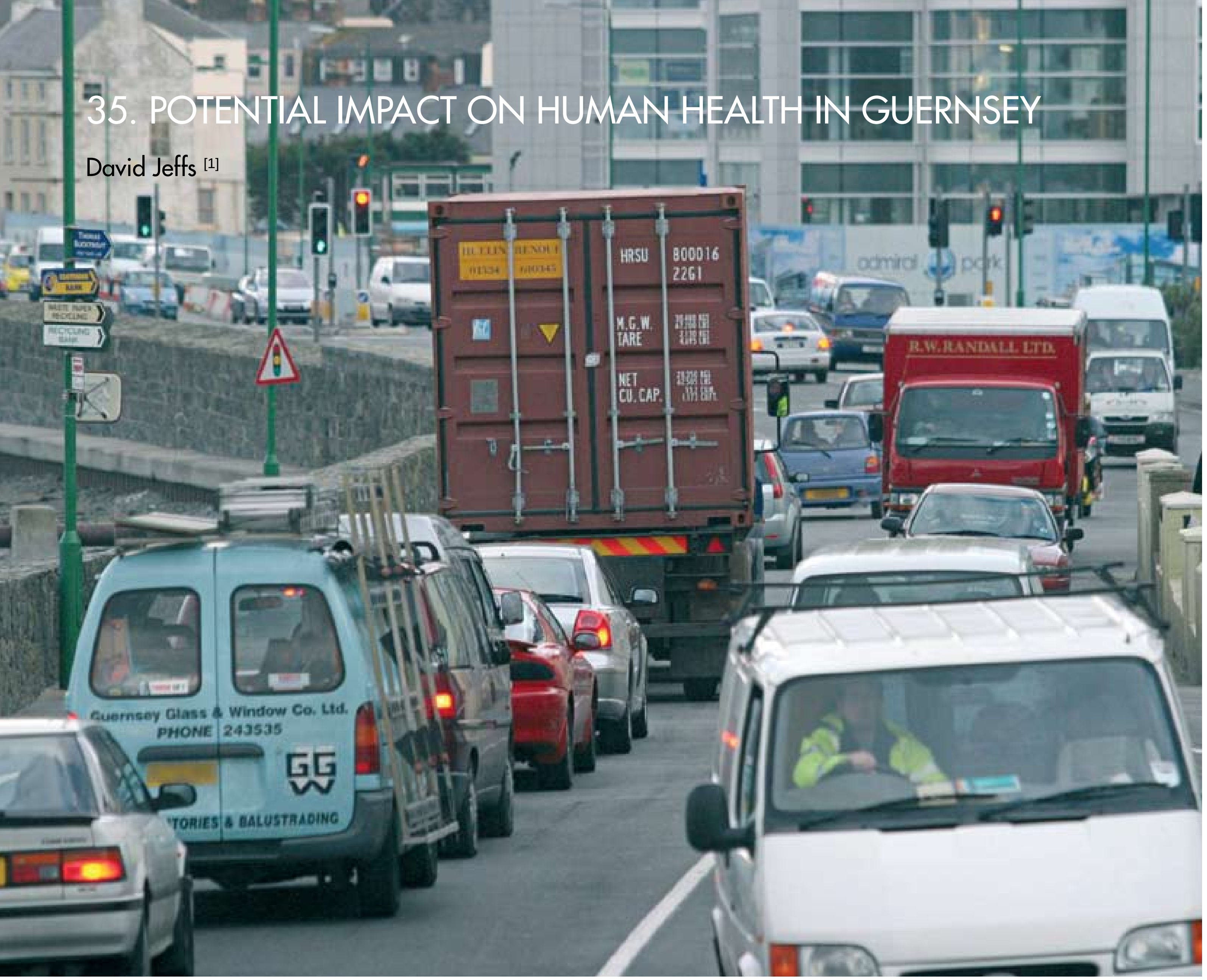


Figure 35.1 *Traffic-jam along Les Banques in Guernsey. Transport pollution is a threat to human health and to the environment.* *Pictures reproduced courtesy The Guernsey Press Co Ltd.*

Guernsey is fortunate that in being a small landmass surrounded by sea, many of the more extreme effects of climate change will be ameliorated. However, rising sea levels will mean that many parts of the island will be more prone to storm surges and flooding, whilst any change in the Gulf Stream could have a major impact on the islands 'microclimate'.

Apart from 'major disaster' scenarios associated with increased risk of storms, flooding and other natural events, impacts on human health are likely to parallel, but be less extreme than those predicted in the UK.

In particular:

- Cold and heat-related winter and summer peaks in mortality are likely to be less extreme.
- Cases of food poisoning can be to some extent controlled by effective environmental health enforcement of food hygiene legislation.
- Without a change in public attitudes towards sun exposure, we are likely to see an increase in sun related skin cancers. At present, the incidence rate of malignant melanoma in Guernsey is some two to three times higher than that of England and Wales overall, although part of this is believed to be due to a more affluent population getting greater non domestic sun exposure.
- With a high level of car ownership and usage, existing peaks of atmospheric pollution associated with high pressure systems are likely to increase, and in the absence of integrated traffic policies, lead to increased respiratory disease, particularly of acute asthma, and of exacerbations of chronic pulmonary disease.

- The likelihood of an increase in vector borne diseases, such as malaria and lyme disease is problematic. Although a rise in temperature may encourage mosquitoes and other potential vectors to breed, much can be done to control this through environmental interventions.
- For example, malaria was common in parts of Italy until the seventeenth century, but was successfully controlled through environmental measures such as draining the marshes in low lying areas.
- Similarly, climatic conditions are very suitable for malaria to be reintroduced into the Darwin Region of Northern Australia, but this is prevented by judicious spraying and other public health measures.
- In Guernsey's much smaller land area, it is hoped that environmental and public health interventions would be more effective in preventing new diseases becoming established.

However, in a jurisdiction of less than 65,000 people, annual deaths and morbidity from any single category are likely to be low, and year to year variability wide. Possible 'indicators' will be 'soft', and what influences them multifactorial.

It will therefore be extremely difficult to formally attribute all or part of any changes to the effects of climate. Nonetheless, we can be certain that climate change on a global scale will impact on human health, but there is much that can be done to minimise these effects, as summarised above.

Figure 35.2 *An increased risk of sunburn due to greater sun exposure will result in a higher rate of sun related skin diseases.*

Further reading:

Human Frontiers, Environments and Disease: Past Patterns, Uncertain Futures, by Tony McMichael, Cambridge University Press, 2001.

References

1. Dr David Jeffs is Director of Public Health, Department of Health and Social Services.

36. POTENTIAL IMPACTS ON ANIMAL HEALTH

Chris Bishop[1]

Figure 36.1 *Exotic diseases in dogs and cats are currently monitored by the UK government.*

Many experts believe that a number of serious diseases in dogs, cats, cattle, sheep, goats and horses, currently only seen in the warmer, more southerly latitudes could establish themselves further north if climate changes predicted by the IPCC were to occur. Some of these diseases are also capable of being transmitted to man.

In dogs and cats the UK government regularly monitors a large number of exotic diseases in a scheme known as DACTARI. From this data we already know that many of these diseases have been detected in animals arriving in the UK from warmer countries on the Pet Passport Scheme.

Exotic diseases of dogs and cats include:

- Babesiosis - a serious disease of dogs caused by a protozoan organism. Various species of tick (Figure 36.2) carry and spread this disease, currently seen in southern and central Europe and Africa.
- Ehrlichiosis - seen in dogs and cats caused by a rickettsial organism. Various species of tick carry and spread the disease, currently seen in Europe. The disease is also transmissible to people.
- Heartworm - a very serious disease mainly of dogs, but also seen in cats, caused by a parasitic worm that lives inside the heart and major blood vessels. The disease is carried and spread by various species of mosquito (Figure 36.3), currently seen in southern and central Europe.
- Leishmaniasis - a very serious disease of dogs caused by a protozoan organism. The sandfly (Figure 36.4) carries and transmits this disease and is seen in southern Europe. The disease is also transmissible to people.

At the moment, species of mosquitoes and ticks that spread these diseases are found mainly in the warmer Mediterranean countries or further south, but with climate change and warmer weather conditions some of these diseases could become endemic further north. In the larger domestic species, cattle, sheep, goats and horses, the situation is similar. The following diseases currently only seen in Mediterranean countries could establish themselves more northerly if climatic change were to occur.

Figure 36.2 *Ticks carrying exotic diseases, currently seen as close as southern Europe.*

Figure 36.3 *A parasite carrying mosquito, currently seen in central and southern Europe.*

Figure 36.4 *Sandflies carry and transmit disease to dogs and humans, currently seen in southern Europe.*

Exotic diseases of cattle, sheep, goats and horses include:

- Bluetongue - a serious disease mainly seen in sheep but also in cattle and goats, caused by a virus. It is spread by several species of midge. Bluetongue spread to Northern France, Belgium, the Netherlands and Germany in 2006. It re-emerged and spread northward in 2007, and there have been over 4000 cases to date. The first case of Bluetongue in the UK was confirmed at Ipswich in Suffolk on 22nd September 2007, and there were 24 cases by early October.
- African Horse Sickness - a serious disease seen in horses caused by a virus and spread by the same midge causing Bluetongue. Currently seen in Spain, Portugal and throughout Africa.

Situation at the moment

Local Vets have already noticed an increase in the number of fleas, ticks, mites, and flies on pets in recent years. The warmer summer months are the normal peak season for infestation but recently this has extended into the winter months too.

Figure 36.5 *Local vets will continue to ensure your pets remain strong and healthy.*

References

1. Chris Bishop, MRCVS, is Guernsey States Veterinary Officer and a partner in Isabelle Vets.

37. POTENTIAL IMPACTS ON PLANT HEALTH

Terry Brokenshire[1]

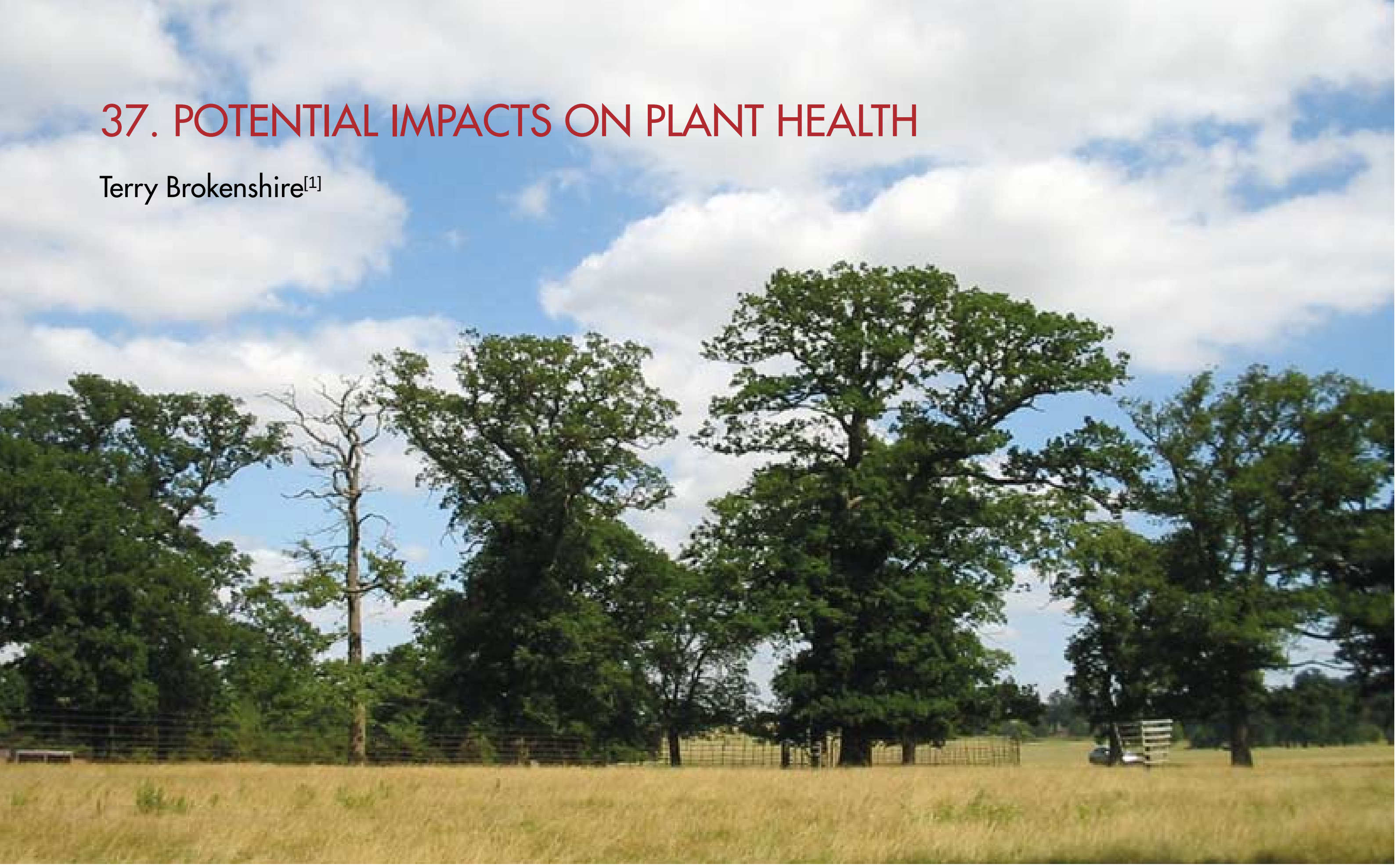


Figure 37.1 *Oak trees with leaf loss caused by pests such as the migrating Oak Processionary Moth. A potential threat for Guernsey in the future. Image courtesy of Forest Research.*

Plant disease is an interaction between the host plant and the pathogen (fungus, bacterium, insect, mite, virus or nematode). Global warming could influence the health status of plants by affecting both the plant and the pathogen.

Plant stress

If climate change causes more extreme growing conditions then this will place stress on plants making them more prone to pest and disease problems. Severe droughts have been implicated in oak decline and in predisposing oak trees to numerous minor pathogens. Increased plant stress has also caused an increase in Honey Fungus on trees and shrubs (Figure 37.2). Notably, the disease has been confirmed on some of the more resistant species like Holly and Yew.

New plant species

There is a significant change in the ornamental species being sold in garden centres. Gardeners are demanding more exotic and drought tolerant species from various parts of the world. This will encourage a different range of plant problems with new pests and diseases arriving and perhaps a few local minor pathogens increasing in importance on plants at the edge of their climatic range.

Increased activity of mites and insects

Global warming will also have a direct effect on the pathogens, in particular, mites and insects that thrive in warmer drier conditions. Glasshouse pests could become significant problems on outdoor plants. The mild Guernsey climate already allows the Glasshouse Whitefly to overwinter outside. The notorious Two-Spotted Spider Mite is normally a glasshouse species but there have been several reports from the UK where the pest is active on outdoor plants in early May, and we have recorded the Glasshouse Thrip on outdoor Viburnum causing serious damage. This is a sub-tropical thrip that cannot survive Northern European winters, but it appears to be living quite happily outdoors for most of the year in Guernsey.

This could extend to more serious pests such as the Tobacco Whitefly and the South American Leaf Miner. These two insects are normally confined to glasshouses where effective controls can be implemented to eradicate them, but if they start to survive outside then control will become problematical. The Tobacco Whitefly (Figure 37.3) is also a vector for numerous serious viruses of a wide range of plants, including the tomato.

There could also be an influx of pests from Southern Europe. Hopefully some of our current pests would migrate north to compensate! A good example of a pest migrating north from Central and Southern Europe is the Oak Processionary Moth, which is a major defoliator of oaks. The moth is also a risk to human health as the caterpillars are covered in irritating hairs that contain a toxin and skin contact can cause irritations and allergic reactions. The moth is now firmly established in Northern France and Holland and outbreaks have been found in parts of London.

Another recent introduction is the Rosemary Beetle, a native of Southern Europe, which is now a significant pest of Rosemary, Lavender and Thyme. It was first found in London in 2000 and since then it has moved throughout Britain including Guernsey.

Fungal diseases

Fungal problems may also be affected by climate change and there may be positive as well as negative effects. For example, drier summers may prove beneficial to reduce the ravages of some of our important wet weather diseases like Potato Blight and Apple Scab. However, the conditions will allow the powdery mildews and rusts to develop fully causing problems on important cereal crops and ornamentals.

Locally, the fungus Corticium rolfsii, the cause of Crown Rot of a wide range of plants, is a problem on crops grown under glass because the fungus is favoured by high soil temperatures. In the future we may see more outbreaks of this soil-borne fungus on outside crops as summer temperatures rise.

Warmer and wetter winters could allow root invading fungi greater opportunity to infect plants. The higher winter soil temperatures and wetter soil conditions could prove ideal for these fungi to become more active. Waterlogged soils could predispose the plant roots to disease.

Bacterial disease

Bacteria are more significant in warmer areas but normally require adequate moisture for infection and dispersal. Moisture availability at specific times of the year may actually limit increased bacterial development. Locally, bacterial problems are relatively few but the range could increase with global warming.

Affects on biological control

We must also consider the affects of global warming on the natural bank of parasites and predators on many of our pests. Global warming should have a positive effect on their activity and could act as a natural 'brake' on pest development. Beneficial insects and mites introduced into glasshouse environments could be used outdoors too. New beneficial species could also spread north adding to our current natural armoury.

Conclusion

The issue of global warming and plant health is highly complex because of the numerous interactions between the host plant, pathogen, predators, parasites and of course, man.

Figure 37.2 *Honey fungus (Armillaria mellea), a problem of stressed trees and shrubs such as the Holly and the Yew.*

Figure 37.3 *The Tobacco Whitefly, a vector for numerous serious viruses of a wide range of plants, including the tomato.*

References
1. Dr Terry Brokenshire, Crop Protection Officer, States of Guernsey.

38. BUSINESS AS USUAL – SIGNIFICANT BUSINESS RISKS

Andrew Casebow

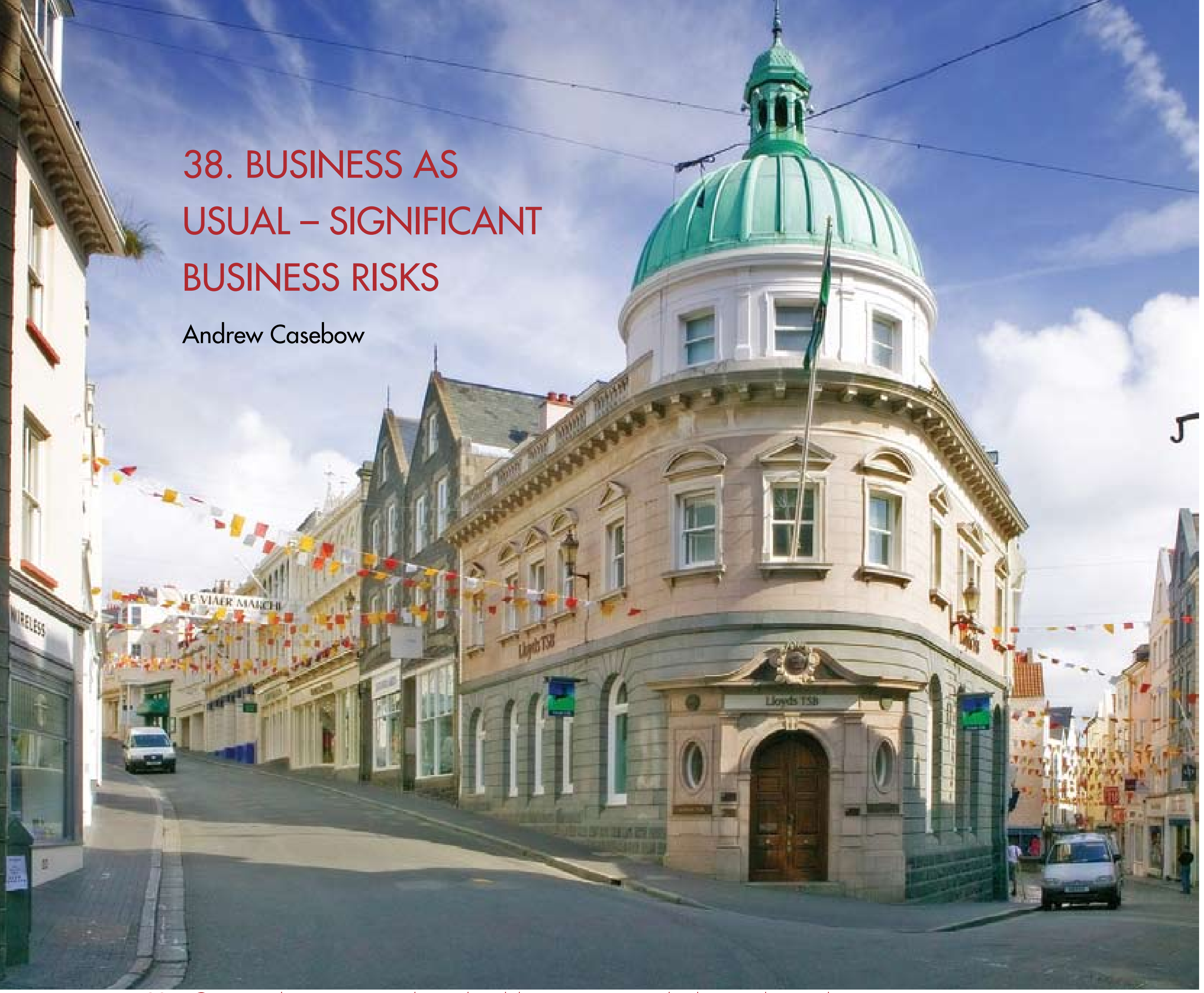


Figure 38.1 *Guernsey businesses must have the ability to mitigate and adapt to climate change.* Image courtesy of GuernseyFinance.

The management of climate change risk and impact should be approached through both mitigation and adaptation measures. Adaptation is action to manage the inevitable effects of climate change, whilst mitigation focuses on reducing greenhouse gas to minimise further climate impacts.

Adaptation has historically had a lesser focus than mitigation. However, it is the lack of adaptation that exposes financial institutions and the assets in which they invest, insure or fund, to extreme weather events, droughts and sea level rise for at least the next 100 years.

Although some financial service sectors (e.g. commercial property insurance) seem more exposed than others, the interconnectivity of the financial interests and the overarching responsibilities of regulators and policy makers, highlights the indirect risk to all financial sectors posed by our changing climate.

A report "Adapting to Climate Change" [1], has been published by the London Climate Change Partnership (LCCP) Finance Group [2], which has members from Insurance (Association of British Insurers), Institutional Investment and Banking (Barclays, Lloyds), Accountancy (KPMG), as well as the Greater London Authority and the Environment Agency.

The report posed a number of key questions aimed at the Insurance, Banking, Pensions, Fund Management, Infrastructure and Utility sectors, to raise awareness and initiate discussion about climate change adaptation risks to business and markets. These all have relevance to Guernsey.

It concluded that adaptation to the inevitable climate change should be embedded within decision-making processes.

What can Business do?

- Businesses can respond to build resilience and climate-proof their interests. Uncertainty about the future is not a reason for inaction.
- There is sufficient information to enable the impacts of a changing climate over the next 40 years to be embedded in decision making at strategic and project levels. Adaptive management is feasible.
- Businesses should review their climate risk management strategies and check that they are responding to both the mitigation and adaptation agendas. Action is required on both – now.
- Taking adaptive action early may be cost-effective when compared with the costs associated with remedial action at a later date (although clearly such investment decision has to be subject to its own financial appraisal). When analysing potential action, companies should consider their fiduciary responsibilities.

Figure 38.2 *'Green Roofs' are effective thermal insulators which can save businesses money whilst being environmentally friendly.*

Conclusion

Changing markets, customer needs and investor expectations will present significant opportunities for those companies that take action to climate-proof their business.

References
1. London Climate Change Partnership (2006). Adapting to Climate Change, Greater London Authority.

2. The London Climate Change Partnership 'Finance Group' has published a number of reports on the implications of climate change for the financial services sector. http://www.london.gov.uk/climatechangepartnership/.

39. INSURANCE RISKS AND BENEFITS

Martin Le Pelley [1]

Figure 39.1 *Storm damage resulting from the 'Great Storm' of 1987. Pictures reproduced courtesy The Guernsey Press Co Ltd.*

The development of insurance products (as a way of mitigating risk) has seen an upward trend since industrialisation. This is because the increasing size and complexity of risks has accelerated the need to spread the risk of catastrophic loss to ensure that there is business continuity in the event of some unforeseen problem or disaster. Without insurance, individuals and businesses could face financial ruin if they are faced by an unforeseen natural disaster which destroys their home or factory.

Storms as insurable events, as well as other natural disasters, are at the heart of insurance. The value and complexity of insurable risks in this modern industrialised world are continuing to escalate. Catastrophic losses arising from weather-related losses such as Hurricanes Katrina and Rita are estimated to be in excess of US$100billion. One of the challenges of the world insurance industry arising from these major losses is to ensure that it has the financial strength to pay the enormous losses, which will arise from major disasters. It is a credit to the industry that it has shown the financial resilience to successfully withstand the shocks from catastrophic losses such as these hurricanes. Guernsey, through its position as the leading European captive insurance centre is playing its part in assisting in, and maintaining, a financially healthy world insurance industry.

Insurance can be a 'game of two halves'

Guernsey's insurance industry is operating in the centre of the market for industrialised risks, and therefore can benefit as much as suffer from these risks! Some of the largest industrial companies in the world own captive insurance companies in Guernsey. Some do not buy insurance from any company other than their own captive insurance company. These companies are both complex and intelligent, they are sophisticated in their approach to assessing the risks to their organisation of global warming, and therefore can price these risks accordingly. This means that as more risks are transferred to Guernsey insurance companies, more premiums are also transferred to these companies to compensate them for taking on the risks. With more premiums coming into the island, the work required of insurance managers and investment managers increases. This has the benefit of improving the prosperity of the island.

At this point you might be wondering whether this implies that global warming and its acceleration might actually be a good thing for the island's economy. This is where a passionate debate might begin, because whilst the island is host to some of the most significant and globally sophisticated insurable risks, it is also vulnerable to these risks in the shape of increasing storms, sea levels, power-cuts and so on.

The insurance managers based on the island, and the Guernsey Financial Services Commission as the insurance regulator, play an invaluable role within the international community in overseeing and upholding the reputation of the island as a world-class insurance market. The island is well placed to embrace the opportunities that might flow from both the increased industrialisation of the planet, but also from the increased awareness and willingness to act to reduce the impact of global warming.

Most of us decide to purchase insurance so that we have the comfort of knowing that if disaster strikes we are confident that the insurance company will pay for a new roof. If the perceived risk or likelihood of your roof blowing off increases, then the insurance premium you will have to pay will also increase. In Guernsey, the risks relating to increasing sea levels, and possibly more severe storms caused by global warming exist, and may result in increased insurance premiums for locals. However, if these risks are outweighed by the benefit derived from a more buoyant economy caused by the increased risks elsewhere in the world, then Guernsey will derive a net gain as premiums flow into its insurance industry.

Figure 39.2 *Tidal flooding at Cobo in Guernsey. Risks relating to events such as increasing sea levels may result in increased insurance premiums for locals. Conversely, increased risks elsewhere in the world may benefit Guernsey's insurance industry.*

Conclusion

Unfortunately there are still many more questions than answers at this stage, and therefore the long-term impact of global warming on the island's insurance economy is simply too uncertain to predict with any degree of accuracy at this time. Reverting to a football comparison, you could say, that the result could go either way!

References

1. Martin Le Pelley is the Assistant Director of Insurance at the Guernsey Financial Services Commission. He has 12 years of experience in the international insurance industry. Prior to moving back to Guernsey in 2005 he worked for PriceWaterhouseCoopers insurance team in London.

40. MANAGING THE PUBLIC WATER SUPPLY IN A CHANGING CLIMATE.

Andrew Redhead [1]

Figure 40.1 *St Saviours reservoir is the only artificially created pumped storage reservoir on the island.* Image courtesy of VisitGuernsey.

Global warming is now accepted as being a reality and many governments around the world are heeding the words of distinguished scientists. Few, if any, are now assuming that the problem will simply disappear.

What does this mean for us in Guernsey? We must take prudent steps to safeguard the public water supply. This can be done by curbing consumption and by engineering systems that are capable of adapting to the new rainfall patterns.

Effective rainfall

The annual average rainfall in Guernsey over the 30 year period 1971-2000 was 824mm, but it has been calculated that some 620mm is lost through a combination of evaporation and transpiration. This means that we enjoy little more than 200mm of effective rainfall, with which to fill our reservoirs, so a reducing rainfall will have a significant impact on water availability.

The ability to capture rainfall when it is available is a function of the rainfall intensity, duration of precipitation and the size of our pipelines and pumping stations. Heightened intensity requires pipelines and pumping stations that are sufficiently sized to cope with the increased flows reliably and efficiently. A significant proportion of the capital expenditure programme, over the next 10 years, is targeted toward improving the raw water pumping stations around the Island.

Figure 40.2 *Map showing areas of the world that will be water stressed by 2025.*

Yellow - Water stress in USA, Southern Europe, China and parts of Africa.

Red - Severe water stress in North Africa, South Africa, Middle-East and Indian Subcontinent.

Reservoirs

In order to meet the growing demand for water in prolonged dry summers we need adequate storage reservoirs. Here in Guernsey there is no underlying permeable aquifer, such as exists in many parts of the UK. Virtually all of our water is surface derived, from streams. Water is then transferred and stored into one of 15 reservoirs.

The St Saviours reservoir is the only artificially created pumped storage reservoir, the remainder being worked-out quarries. Several of the quarries in the north of the island were, until the mid-sixties, used extensively for irrigating horticulture sites. Looking to the future, Guernsey Water has convinced the States of the need to have more water storage and thus La Vardes quarry has been identified for this purpose. Because of the essential nature of water, long term planning is imperative. Desalination, whilst technically achievable, is and will remain relatively expensive to produce drinking water.

Security

Being so heavily reliant upon surface water does expose Guernsey to the risk of contamination and hence the water catchment is continuously monitored. Working closely with horticulture, agriculture, industry and the public we can educate everyone about the risk of releasing harmful chemicals into the aquatic environment. Exceptionally small quantities of chemicals, including many everyday products and fuels, can do immense damage to the potable water supply. Most conventional water treatment processes are unable to remove complex chemical substances such as herbicides, pesticides and hydrocarbons. This is why the whole community needs to play its part.

Water saving

In our modern affluent society water appliances such as dish-washers, power-showers, swimming pools and hot-tubs, are common place. Present water consumption of between 135-155 litres per head per day is forecast to rise as occupancy rates fall and more appliances are installed. At the moment the demand for water is increasing at a rate of 1% per annum. Educating people to try and use less water is important because the natural ecosystems in streams and reservoirs help maintain the quality of our drinking water. In addition, reducing excessive pumping will cut down upon our 'carbon foot-print'.

Waste

No one condones waste and Guernsey Water's engineers continuously monitor the network of pipes that distribute the water throughout the island. Thus leakage can be quickly identified and pipelines repaired. Modern Internet and SMS technology helps the monitoring process.

Customers also play a vital role in reducing the quantity of water needed. Those customers who pay for the water that they use by volume, use on average 12% less than those who are not metered. Not leaving taps running or watering gardens, are just a few of many simple measures that everyone can do to save water.

Figure 40.3 *At the moment the demand for water is increasing at a rate of 1% per annum.*

Summary

We must all be conscious of how much water we use, and use it sensibly. It is not free and there is not an infinite quantity of it! Water is a heavy commodity and it uses considerable energy to move it around. Saving water also saves the fossil fuels necessary to generate electricity and this in turn helps to reduce the effects of global warming.

References

1. Andrew Redhead is Director of Water Services, Guernsey Water.

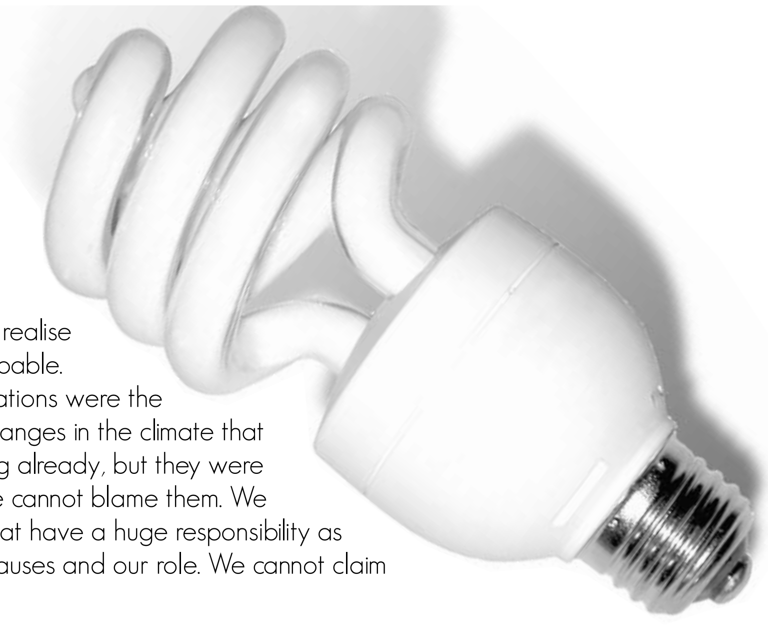
41. RESPONDING TO CLIMATE CHANGE

Brenda Boardman [1]

We are the cause, so we are the solution

There is no doubt now that climate change is occurring and that we, as human beings, are primarily responsible. It is our decisions to put on the light, drive the car, and to fly off on holiday. All our actions, big and small, are causing the rise in carbon dioxide emissions, so we can reduce this threat by similar, more careful decisions. Everything we do can contribute to reducing the problem. All of us can demonstrate greater responsibility both to the disadvantaged of the world and to future generations.

Figure 41.1 *A wind turbine is simply a windmill; it converts kinetic energy in wind into mechanical energy. This energy can then be 'cleanly' converted into electricity.*



We are the first generation to know, categorically, about climate change and to realise that we are culpable. Previous generations were the cause of the changes in the climate that we are suffering already, but they were ignorant, so we cannot blame them. We are the ones that have a huge responsibility as we know the causes and our role. We cannot claim ignorance.

There are major savings to be made in every aspect of our lives, whether through the use of more efficient products, using energy more carefully, switching to lower carbon sources, or changing our lifestyles. A 20% carbon saving by 2020 is the minimum we should be looking to achieve, with at least 60% reduction by 2050.

Some people have major opportunities to bring about change through influential decisions at work – choices that result in the production of more efficient products, enhancing demand for green energy by putting it in the factory or head office or relying on more local sources for components. The options are everywhere.

For the rest of us, the effect of our individual choices will not be so great, but the cumulative impact of our many, small changes will be significant. I believe that gradually all aspects of our lives will change as we understand the ways in which we cause carbon dioxide to be emitted into the atmosphere and decide to limit this effect. And it could well be for the good. We will have less hurried lives, as the conference call replaces the executive trip. The allotment becomes the source of some of our food, rather than flying it half the way round the world. Our well-insulated homes will feel cosy and snug and only need the occasional use of the wood stove to keep warm. We will be fitter as we cycle and walk more, and the dinner table discussion will be about the amount of hot water we have obtained from our solar panels on the roof or the effectiveness of different makes of wind turbine.

I suggest you learn to love your electricity meter and keep inspecting the odometer on your car. Keep a weekly record of how you are consuming energy and try and work out where it all goes.

For a next step.

I suggest you learn to love your electricity (and gas?) meter and keep inspecting the odometer on your car. Keep a weekly record of how you are consuming energy and try and work out where it all goes. Set yourself an achievable target, even if it is to use less this year than last year. More ambitious goals would be even better, but, as with any addiction, deciding to change is the most important step. That way, you will be contributing to a better world for your old age, your children and future generations – and you will also be saving money.

References

1. Dr Brenda Boardman is the head of the Lower Carbon Futures team at Oxford University's Environmental Change Institute, and a co-director of the UK Energy Research Centre. Her main research focus is on how to achieve demand reduction in energy across the UK economy. She was awarded an MBE in 1998 for her work on energy issues.

42. FACING THE PERSONAL CHALLENGE

Andrew Casebow

Figure 42.1 *New sources of renewable energy must be found to ensure energy security.*

Global warming is mainly caused by releases of greenhouse gases. Sir Nicholas Stern, author of the Stern Review, wrote that "the scientific evidence is now overwhelming: climate change demands an urgent global response"[1].

It now falls to us to make a difference.

Towards a low carbon future

Our lead chapter by Dr Brenda Boardman of the Oxford University's Environmental Change Institute, gives us the facts in a forthright way. Remember that most of the energy that we consume is in our homes and for personal transport, and we can and must make a difference. As she says, 'we can no longer claim ignorance'.

Replacing fossil fuels

We must reduce our reliance on fossil fuels. Oil production has already peaked and will decline over the coming decades. Moreover, unstable or hostile governments control much of the remaining reserves of natural gas and oil. This demands greater efficiency and requires that new sources of renewable energy must be found to ensure energy security.

In Guernsey, although we import the majority of our electricity from France, much of which is generated by nuclear power stations, local oil fuelled generators are also used. Unlike our European neighbours, the States currently has no policy to support renewable energy and requires the utilities regulator to act only on economic criteria. The consequence is that there is virtually no renewable energy available to islanders.

Renewable energy

In our next chapters Steve Morris considers the potential for renewable energy in Guernsey, particularly wind, wave and tidal power that can be generated using the tidal flows around our islands; whilst Patrick James discusses the benefits of micro-generation in our homes.

International agriculture can provide renewable fuels, such as ethanol and bio-fuel but much of the drive towards these fuels is based not on a desire to reduce carbon emissions but to provide greater fuel security.

Dianna Bowles from the University of York gives us an insight into how developments in biological science will help to replace fossil fuels.

Low energy homes

Probably the most important thing that most of us could do is to reduce the use of energy in our homes, particularly of oil, coal and gas for heating. This might involve the use of a more efficient boiler or converting our heating systems to electricity, and much better standards of insulation; but for many of us it means just caring sufficiently to turn down the thermostat, and to live in slightly cooler homes and offices. Muir Ashworth discusses opportunities for energy saving in the home and office, whilst Andrew Ozanne considers the potential for new 'eco-housing' projects in Guernsey.

Rebound

We need to guard against 'rebound'. This is the worrying phenomenon whereby someone becomes less careful in their energy usage, following some energy-saving activity. For instance, I may think "it doesn't matter" if I turn up the Thermostat a bit now because I've put some insulation in the roof.

Carbon footprints

Tina Fawcett, from the Environmental Change Institute, helps us to calculate our own personal carbon 'foot-print', and discusses the possibility of personal carbon allowances; whilst Chris Leach considers how Guernsey's businesses can play their part. The recently published British Government's 'Climate Change Bill' set out enabling powers that will allow that government to extend carbon trading across the British economy. In the long term, carbon trading could be extended to individual's own carbon emissions. In Britain every person could have his or her own personal carbon allowance and those whose carbon footprint is less than their allowance might be able to earn money by selling their unused allowances to those who need them.

Offsetting

Another opportunity considered by Nick Day, is for offsetting our use of carbon fuels by investing in third-world energy efficiency projects or forest re-planting.

Transport

Transport and the cost of transporting food to us from around the globe are also considered. For personal transport we might consider purchasing more efficient vehicles with lower carbon emissions, car-sharing to go to the office or to take children to school, linking multiple purposes in one trip, switching to walking or cycling for short trips, using the bus and even re-considering whether we should take long holiday trips.

Local Guernsey case studies

Finally we consider some local Guernsey case studies describing what local Guernsey families have been doing to reduce their use of carbon fuels. This may be by investing in new technologies and better equipment, as outlined by Paul Fletcher, or by the simpler but effective route of just using less energy in our daily lives, as demonstrated by Mandy de la Mare.

Summary

The starting point for Guernsey's transformation into a low-carbon economy is mundane. Energy efficiency starts at home (or office), or to be more specific in the un-insulated walls and roofs that give us a chance to stop wasting energy, save money and help the environment. But that should only be a start!

Energy efficiency is a journey not a destination, and most of us (myself included) have not even started on the road yet.

References

1. Stern Review 2006. The Economics of Climate Change, Executive Summary.

43. RENEWABLE ENERGY – ITS PLACE IN GUERNSEY'S ENERGY 'MIX'

Steve Morris[1]

Figure 43.1 *Home wind turbine.*

The use of renewable energy has been widely promoted across the world to reduce emissions from the combustion of fossil fuels. This chapter focuses on how renewables could contribute to Guernsey's energy mix.

Guernsey's Position in 2007

The only major source of renewable energy is electricity imported from the European grid, where the production base includes renewable sources such as wind and hydro-electricity.

Increasing the Proportion of Renewable Energy

Renewables can be added to the island's energy mix either by large scale development or through the efforts of individuals. This brief resume will consider both scales of development in the context of the local generation of renewables.

Sources of renewable energy are largely the same at either scale, but some sources are more suitable for large scale development whereas others will more readily be deployed at small scale.

Measurement Essentials and a Reference Framework

It is convenient to discuss power output in kilowatts (kW) or megawatts (MW) and energy production in kilowatt hours (kWh) or megawatt hours (MWh).The maximum instantaneous electricity demand of Guernsey is about 72MW and the annual total electricity demand 360 million kWh.

Sources and Application of Renewable Energy

Wind Power

The production of electricity from wind turbines commenced in the 1970s. Given this history of about 30 years there is a wide range of wind turbines available. The output range is from 100 watts up to 3MW. Small machines can be very suitable for use by private individuals when operated in parallel with the electricity grid.

A typical 1kWh turbine on a good site may be expected to produce about 3,500kWh annually. It is most important to place the machine where it will receive a stable flow of wind at the highest possible velocity. The energy output of a wind turbine varies with the cube of the wind speed. Wind turbines must also be sited with regard to potential noise disturbance to neighbouring property.

Larger wind turbines, in the size range 500kW to 3MW, could make a meaningful contribution to Guernsey's energy needs. They are, however, physically very large. A typical 2MW machine requires a tower up to 100 metres tall. Large wind turbines can produce electricity at prices similar to existing local sources but the economics are less favourable for small machine sizes. Similarly, offshore sites would significantly increase the costs.

Solar Power

Modern solar power systems can be divided into two categories - thermal and electric. Both categories are more suitable for small-scale utilisation.

Solar thermal systems are typically used for heating domestic hot water. In Guernsey a household with a solar collector between 2 and $4m^2$ mounted in a reasonable south facing position will be able to reduce energy consumption on water heating by 50%. A typical solar array for water heating will have a capital cost in the order of £2,500 to £5,000.

Electricity can be generated directly from sunlight using photovoltaic cells (PV). There is a wide range of PV cells, ranging in output from about 30W to 5.5kW. A typical 1.5kW (peak) PV array will have an area about $12m^2$ and a cost of about £10,000 plus additional costs to allow its output to be converted to suit the mains. Such an array could be expected to produce about 1,100kWh annually, provided it is sited in a good, unshaded, position.

Figure 43.2 *Thermal solar panel.*

Tidal Power

Energy can be extracted from tidal streams by mounting a device looking rather like a windmill in a suitable place where it will encounter a fast flowing tidal stream. Islanders will be well aware that Guernsey enjoys current flows of 5 to 6 knots.

As with a wind turbine, the amount of energy delivered will increase by the cube of the water velocity. The greater density of water with respect to air makes the size of a water turbine much smaller than a wind turbine for the same output power.

Like the tides, the production of energy from a tidal stream device is largely predictable.

Tidal stream energy is a relatively new concept with only prototypes demonstrated to date. The first commercial scale pre-production machine will be deployed in Northern Ireland in the near future.. Unlike wind and solar, tidal stream energy is only suitable for major developments.

Figure 43.3 *Schematic drawing of an offshore tidal power station.*

Wave Power

Interest in harnessing wave power started in the 1970s and various prototypes have been constructed to demonstrate possible extraction techniques.

Globally the wave power resource is very large. It has been forecast that 25% of the UK's electricity demand could be generated from reasonably economic wave power sites around the coastline. The economics, however, are largely unproven, since the machines are still pre-commercial, but a promising design has recently been tested.

As with tidal power, wave power is really only suitable for large-scale developments.

Figure 43.4 *Wave power station.*

Conclusion

Guernsey is well situated to make use of locally generated renewable energy, with usable wind, tidal and solar resources and an extensive electricity grid with import/export facilities. However, local renewable utilization will require economic stimulus.

References
1. Steve Morris
BSc, C.Eng., MIET. is Engineering Director of Guernsey Electricity.

44. MICRO-GENERATION IN THE BUILT ENVIRONMENT

Patrick James [1]

In Guernsey, the built environment is responsible for most of the energy consumed. A major component of this is associated with housing, notably through space heating, hot water, cooking, lighting and consumer appliances. Micro-generation in the built environment is associated with low carbon technologies such as photovoltaics (PV), solar thermal, combined heat and power (CHP), ground source heat pumps and micro wind turbines which can achieve energy conversion at their point of use. With rising fuel prices and an increasing awareness of the environment, micro-generation is viewed as one of the key ways to reduce the carbon footprint of housing.

Consider the 'de Garis' who live in a 1930s semi-detached house. They have extended their house by the addition of a conservatory, a space which they now heat electrically in the winter months. What can they do reduce their carbon footprint and save themselves money? The house consumes approximately 20,000 kWh of energy per year in terms of space heating (~11p /kWh from gas) and 4,000 kWh of electricity (~12p/kWh normal rate).

The most important factor is to understand the energy flows associated with their building – where are the heat losses and what are the energy hungry appliances? Measures include: enhance the level of loft insulation, eliminate drafts, fit double glazing, install cavity wall insulation (if possible) and replace the thermal barrier (doors) to the conservatory. These measures, which could halve the heating demand, should be undertaken before micro-generation is considered.

The next step is to understand the energy resources essentially the sun, the wind and the ground. Houses in Guernsey have a potentially excellent wind resource and high levels of solar radiation. Solar thermal (evacuated glass tubes) can provide the majority of hot water, roof mounted PV could supply 50% of the electrical demand of the de Garis' house with a wind turbine contributing perhaps 10-20%. However, care must be taken with micro-wind turbine site selection. The power output of the turbine is proportional to the cube of the wind speed. Therefore, wind shadow effects from surrounding buildings or terrain can dramatically reduce the energy yield from a turbine.

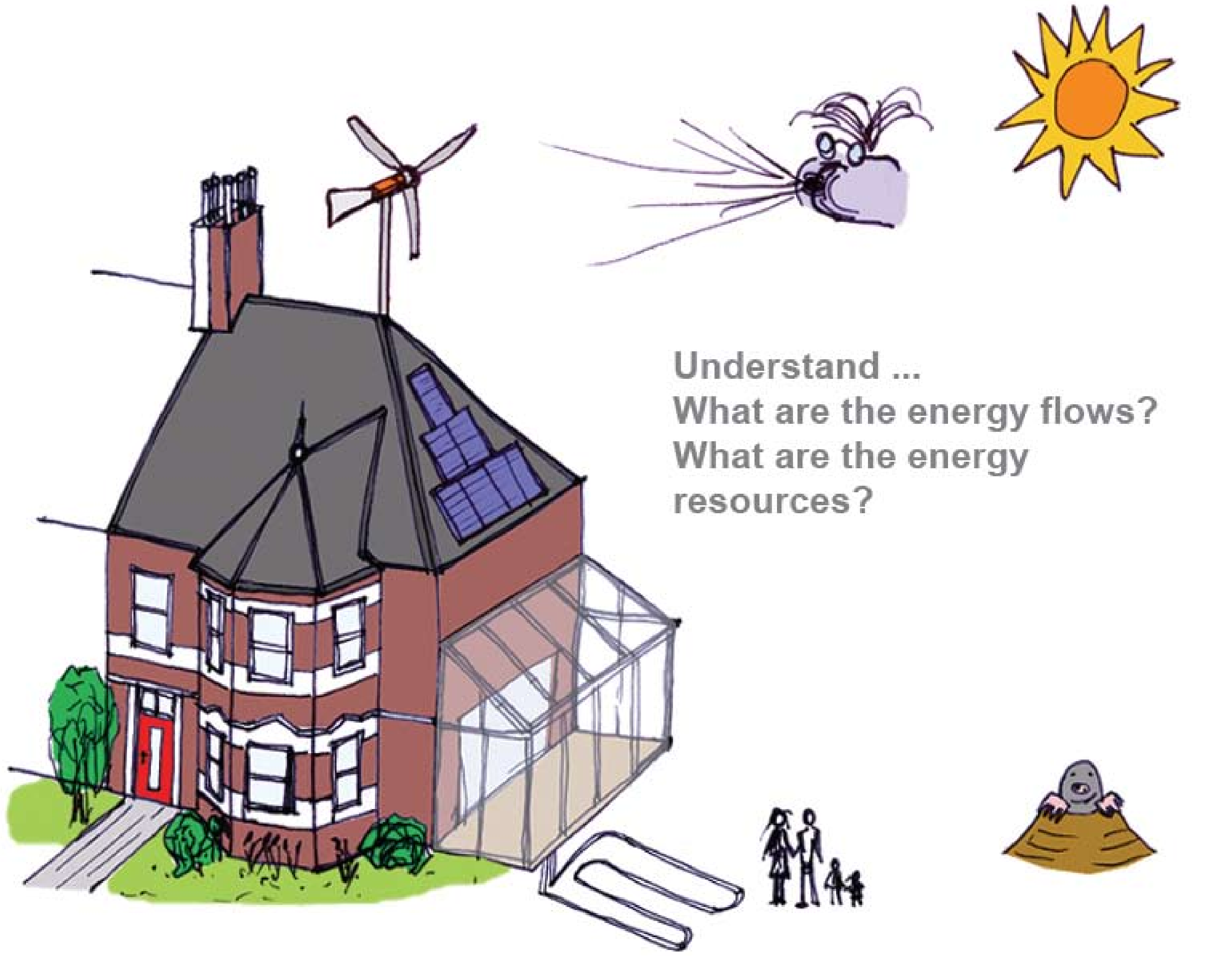
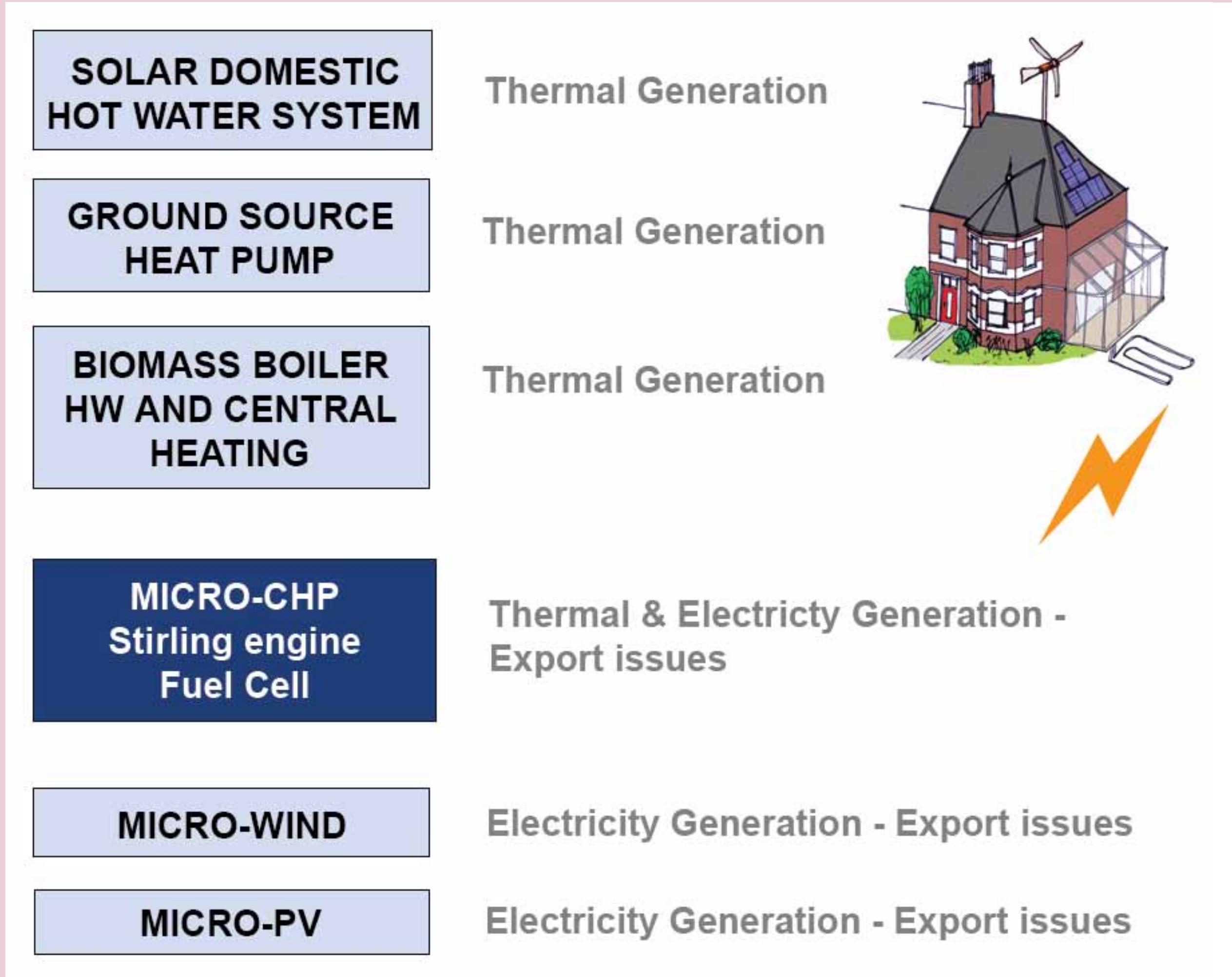


Figure 44.1 *The 'de Garis' live in a 1930's semi . . .*

Ground source heat pumps consist of a network of fluid filled pipes buried in the ground 1-2m below the surface. These systems provide base level heating during the winter and summer cooling with the system operating in reverse. However, they require large gardens and disruptive groundworks to install which reduces their potential application.

Micro-CHP (combined heat and power) is an emerging technology in which the existing boiler in a house is replaced by a unit that produces both heat and electricity at the same time. Whilst this is not a renewable energy, the overall conversion of fuel to 'useful energy' within the home may be better than if the fuel was used to generate electricity in a power station, and heating provided by a gas fuelled domestic boiler. However, the price of gas in Guernsey means that unlike the rest of the UK, micro-CHP is uneconomic for domestic users who mainly use oil-fuelled boilers. CHP at a larger scale may be suited to companies with large heat demands. In Guernsey this could include hotels (especially those with large swimming pools) and heated glasshouses although other alternatives such as ground source heat pumps may result in a lower carbon footprint.

Figure 44.2 Micro-generation Technologies



However, with all these micro-generation technologies the most important criteria is the impact of user behaviour. If, for example, people leave windows open in winter, electrical appliances on standby, or fit an air-conditioning unit to their house, the benefits of having applied micro-generation will have been lost.

To find out more about micro-generation visit our website www.energy.soton.ac.uk.

References

1. Patrick James is a member of the Sustainable Energy Research Group, School of Civil Engineering & Environment, University of Southampton.

45. THE NEW BIO-BASED ECONOMY

Dianna Bowles [1]

Figure 45.1 *Rapeseed fields in the UK. Rapeseed is an alternative to fossil fuel; its pure oil product can be used to generate electricity, and in the manufacture of biodiesel for powering motor vehicles.*

A new era is beginning: the replacement of the current economy based on fossil reserves with a new economy - based on agricultural raw materials and biological resources.

As we all know, fossil reserves are finite and increasingly there are issues of security and cost of supply. Society's dependence on fossil-derived energy to drive our economy is well recognised. Less well known is the dependence of our chemical industries on those fossil reserves. Petrochemicals are used throughout the chemical and pharmaceutical industries as feedstocks for consumer goods such as plastics, health-care and drug products and agrichemicals, including fertilisers.

With fossil reserves of oil and gas diminishing and their costs increasing, global manufacturers are seeking alternative raw material feedstocks for the production of energy, chemicals and materials. These economic drivers complement society's need for sustainable and environmentally-friendly technologies in industrial production, which are together driving a new, emerging commitment to a bio-based economy.

The complete shift in the basis of the global economy will have major impacts on agricultural production. The bio-based economy of the 21st century will rely on the biosciences and their associated technologies. Biology is the science of the natural world. Through the use of our existing knowledge and the new understanding we develop through research, many opportunities can be realised for the sustainable manufacture of bio-products and bio-fuels.

The ability of green plants, whether terrestrial or aquatic, to capture solar energy and use carbon dioxide to manufacture chemicals, is clean technology. This clean technology is sustainable; plants are capable of high capacity production of chemicals such as oils, starches and proteins, as well as complex natural 'scaffolds', well beyond the ability of the global chemical and pharmaceutical industries.

In our current economy, oil is processed in oil refineries to separate different components for different uses. In the bio-based economy, biorefineries will replace the oil refineries and agricultural feedstocks will be separated and processed for many different products and uses.

New opportunities over the coming years for the farming community of Guernsey and elsewhere globally, are immense. Farmers are the producers of the agricultural raw materials that will be used increasingly for industrial production. It will become essential to develop new policy and regulatory frameworks to determine relative land use. Land will be required for food, feed for livestock, and industrial feedstocks for energy and chemicals. Following reform of the Common Agricultural Policy (CAP), markets will play a much greater role in the strategic decisions of farmers, since subsidy will become minimised. Land-based production is important for the bio-based economy, but marine resources are also considerable, with a vast diversity of aquatic organisms also capable of using solar energy to manufacture biomass and biochemicals.

There continue to be bottlenecks in the efficient use of agricultural feedstocks, whether resources from the land or the sea. Efficiency, both in terms of economics and environmental impacts of the process and product, must be considered. Science, particularly bioscience, will play a significant role in helping to overcome these bottlenecks.

In recognition of the need for integration across supply chains from research to deployment and using the products and know-how from the farming, marine, energy and chemicals sectors, the Knowledge Transfer Network (KTN), Bioscience for Business, is taking forward a new UK initiative: the BIOHUB (www.biosciencektn.com). The initiative is industry-led and aims to help ensure UK competitiveness in the new bio-based economy. For further information and regular updates on progress and opportunities, please register at the website.

Figure 45.2 *'All life depends on sunlight and a green leaf'.*

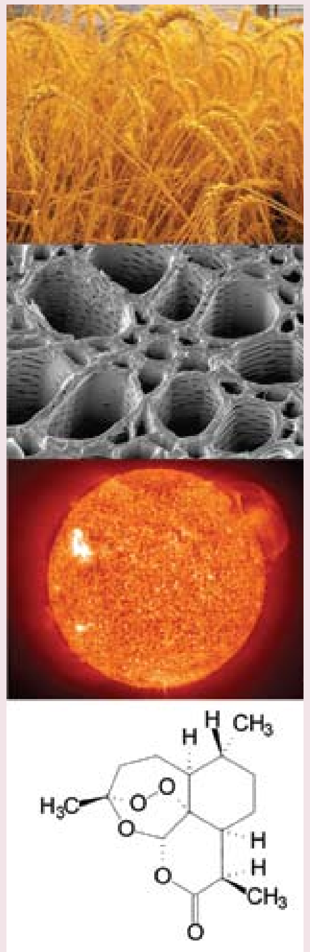


Figure 45.3 *Plant biomass is capable of producing high capacity, complex natural bio-chemicals, fuels and materials by capture of solar energy.*

References

1. Professor Dianna Bowles holds the Weston Chair of Biochemistry at the University of York. She is Director of the Centre for Novel Agricultural Products and Chair of the KTN, Bioscience for Business.

46. RENEWABLE FUELS

Andrew Casebow

Professor Dianna Bowles has described how "the use of agricultural raw materials as feed stocks for industrial production is key to the new bio-based economy." This is based on the ability of green plants to capture solar energy into plant biomass that can be used as the basis for new fuels and bio-chemicals. Just as ancient sunlight created fossil reserves that are processed in oil refineries, the sunlight of today and tomorrow is captured in bio-renewable feedstocks that can be processed in bio-refineries.

Fuel Security

Oil supplies are now at their peak of supply, whilst worldwide demand is increasing (Figure 46.1). The US and European supplies are likely to run out first, meaning that these countries will increasingly depend for their future supplies on potentially unstable or antagonistic governments.

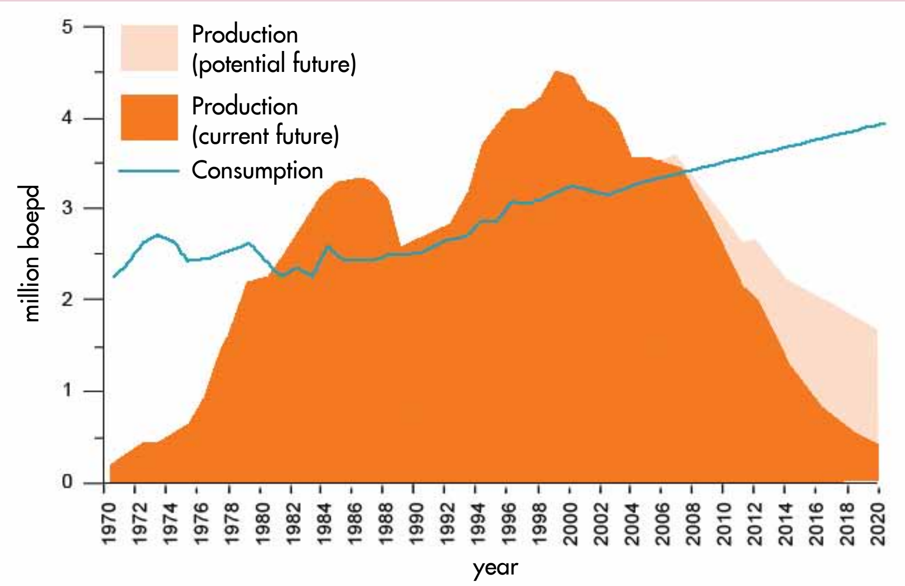


Figure 46.1 *Rate of oil production from 1970 to 2020.*
Source UKOOA / DTI.

The British Government is obligated to obtain 10% of its energy requirements from renewable sources by 2010, and 20% by 2020. The principle driver for this is the 'Renewable Obligation Certificate' (ROC) scheme where by a premium price is paid for electricity generated from renewable resources. Similarly, the British Government enacted a Renewable Fuels Transport Obligation (RTFO) in 2005, which mandated a 5% renewable fuels inclusion in UK transport fuel supply by 2010.

If the UK is to achieve its renewable energy targets, dramatic changes in land use must take place. Energy production, from crops such as willow coppice, will take place alongside food production, wind farms will proliferate on higher ground, and bio-fuels will provide new non-food markets for agricultural crops.

Renewable fuels

Renewable fuels produced by agriculture include:

- **Biogas.** Produced using well-established 'anaerobic digestion' technology that uses farm slurry and food waste as the feedstock to produce gas that is then used to power small-scale electricity generators. There are several thousand farm and community based biogas digesters operating successfully in Germany and Denmark.
- **Biomass.** The growing of coppiced willow, or miscanthus (elephant grass), will be possible on a field scale in Guernsey. Willow grows up to 6m high and is harvested every 3 years (Figure 46.2). It could be successfully grown in wetland areas but could have landscape consequences. Willow plantations are very beneficial to biodiversity and wildlife. The wood chip produced could be used in small-scale micro-generation systems for electricity and heat, such as the heating of schools, business centres, glasshouses or community housing developments. Biomass might also be available from arboriculture (wood chips) and from recycling of waste wood and other products.
- **Bio-fuels (bio-ethanol and bio-diesel).** Bio-ethanol is produced from a variety of agricultural products (maize grain in the USA, sugar cane in Brazil, and feed wheat in Europe) and blended with gasoline (petrol). Vegetable oils are produced in Britain from oil seed rape and blended with diesel oil. There is mounting concern about the clearance of forest to grow palm oil for bio-diesel production in South America and South-east Asia.

There has recently been a massive growth in bio-ethanol plants in the USA where, in the State of Iowa alone, there are currently 56 plants in operation or planned. Similar plants are planned in Britain. This has increased the price of grain, and reduced the amount that is available to alleviate starvation in 'third world' food aid schemes [1].

In Britain a 5% blend of ethanol with gasoline would require the production of about 1 million tonnes of bio-ethanol, which could be manufactured from 3 million tonnes of feed wheat (produced from over 1 million acres of land). This has already increased the price of wheat leaving Britain's farms by 30%, which will have a 'knock-on' effect on food prices. If the vegetable oils for a 5% inclusion in bio-diesel were also produced in the UK, it has been estimated that biofuel production would require up to one third of all arable land in the UK.

Second Generation Fuels

Looking into the future, it is likely that the '2nd generation' renewable fuels will be produced directly from cellulose, which is contained in the cell walls of plants so grasses and other crops could be utilised. A UK Department for Transport (DFT) RFTO feasibility document concludes that once 2nd generation bio-fuels come on stream, the UK could be growing 30% of its transport fuel requirement by 2050. This will have a significant and far reaching effect on food prices and wildlife in Britain.

Conclusion

It is likely that blended ethanol fuels will become available, but the scale of operation means that these could not be produced within Guernsey. Biogas production is unlikely to be viable in Guernsey unless subsidised and required to further reduce waste pollution. A potential use of some agricultural land would be the production of wood chips from willow coppice or miscanthus, if a specific market for micro-generation and heat developed. It is perhaps more likely that, as food prices increase, it will become more profitable for farmers and growers to grow more vegetables and livestock for local consumption.

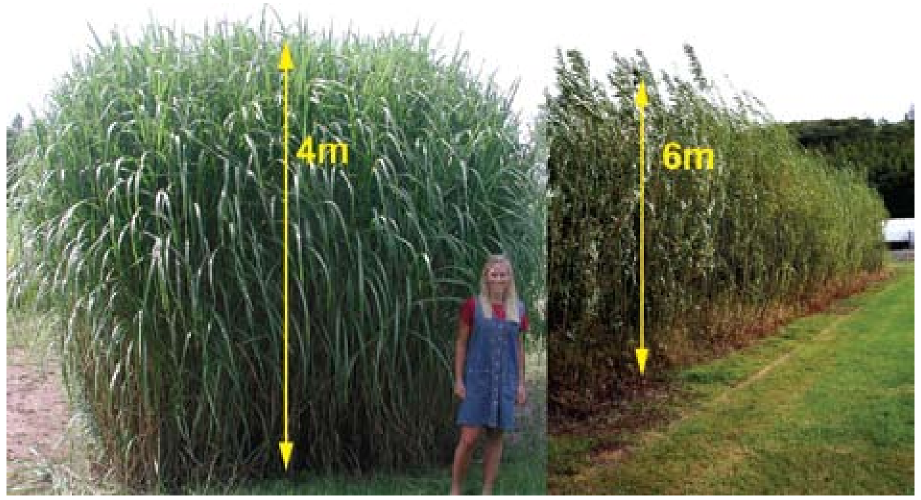


Figure 46.2 *(a) Miscanthus, and (b) Willow plantations.*

References
1. An increasing amount of world grain production is likely to be diverted into ethanol production for fuel in the future. This is likely to cause ever greater food shortages and higher prices. At the same time the human population is predicted to rise by about 50% by 2050, from 6.4 billion to over 9 billion people (which is more than twice the world population in 1970).

47. FOOD MILES AND SUSTAINABILITY

Andrew Casebow

Figure 47.1 *Eat the view! Cows watching a local farmer, wildlife adviser and the author discussing a field bank wildlife habitat.*

Food miles are the measure of the distance that a food travels from field to plate. This has become accepted as a convenient indicator of sustainability; and has led to a general movement towards local production and local consumption.

Most of the food consumed in Guernsey is imported from the UK, and an increasing proportion comes from much further away in the rapidly 'globalising' market.

Agriculture and food now account for nearly 30% of all goods transported on UK roads and 19 million tonnes of carbon dioxide emissions annually. Transport of food by air is increasing. Although it accounts for only 1% of food tonne miles, it produces some 11% of total food transport emissions.

Food Miles as an 'Indicator'

The UK Department of the Environment, Food and Rural Affairs (DEFRA) commissioned a report to look at 'The Validity of Food Miles as an Indicator of Sustainable Development' [1]. The Report identified four dramatic changes in the food production and supply chain that have occurred over the last 50 years. The most striking changes have been:

- Globalisation of the food industry with increased imports and exports and ever wider sourcing of food within the UK and overseas.
- Concentration of the food supply base into fewer, larger suppliers, partly to meet demand for bulk year-round supplies of uniform produce.
- Major changes in delivery patterns with most goods now routed through supermarket regional distribution centres using large heavy goods vehicles.
- Centralised sales in supermarkets, where a weekly shop by car has replaced frequent food shopping on foot at small local shops.

However, the report concluded that the transport of food was a complex issue and 'food miles' was an inadequate indicator of sustainability. There are so many variables, such as the energy used in growing the crop and the type of transport used getting it to the consumer.

Why does food travel so far?

One reason why food travels further now is because the centralised system in the UK has taken over from local markets. A litre of milk can be transported many miles to be processed and packaged at a central depot and then sent many miles back to be sold near where it was produced.

How far has my food travelled?

It's difficult to be sure. The food's origin might be on the label, but that will not tell you the means of transport. Importing joints of lamb by boat from New Zealand may have a lower environmental impact than a shorter journey by road.

Animal welfare

The transport of live animals by road to slaughter is an important animal welfare issue. Whereas animals slaughtered in Guernsey have a short journey to the local abattoir, animals slaughtered in other countries may be subjected to a long road journey to a large centralised slaughterhouse.

Fresh local produce

We have the opportunity to purchase freshly gathered vegetables and we often know the farm where they were produced. Milk comes from the local breed of Guernsey dairy cows, renowned for high quality milk. Our Guernsey cows are tested free of many cattle diseases that have become commonplace in the UK and Europe, and precautions are taken to ensure that livestock diseases do not spread to this island. Guernsey potatoes and vegetables are available in local shops and Guernsey beef, pork and lamb are available from local butchers (see Figure 47.2).

"Eat the view"

Our decisions as consumers can have a big influence on the way farmland is managed. The character of the landscape, local wildlife habitats and the quality of the environment are all linked to the farming of the land. Our sustainable farming systems provide quality products whilst maintaining environmental quality and the diversity of the countryside.

Community supported agriculture!

Community supported agriculture is about reconnecting people with the farm on which their food is grown.

Some useful addresses:

http://www.soilassociation.org
http://www.freedomfoods.org.uk
http://www.foodroutes.org

References
1. AEA Technology Environment (2005). The Validity of Food Miles as an Indicator of Sustainable Development, DEFRA.


a


b


c


d

Figure 47.2
(a) Potato packing at Guernsey Farm Produce, St Saviours.

(b) Fresh Guernsey beef at Meadowcourt Farm, St Andrews.

(c) Tostevin's Vegetable stall, Forest.

(d) Guernsey Farmhouse Ice Cream, Le Hechet Farm, St Saviours.

48. OPPORTUNITIES FOR ENERGY SAVING IN THE HOME AND OFFICE

Muir Ashworth[1]

One of the most significant ways that we can reduce emissions of carbon dioxide is by minimising energy consumption. The Building Research Establishment has estimated that 30% of all CO_2 released to the atmosphere is due to energy use in dwellings; for the average household this can be illustrated as follows:

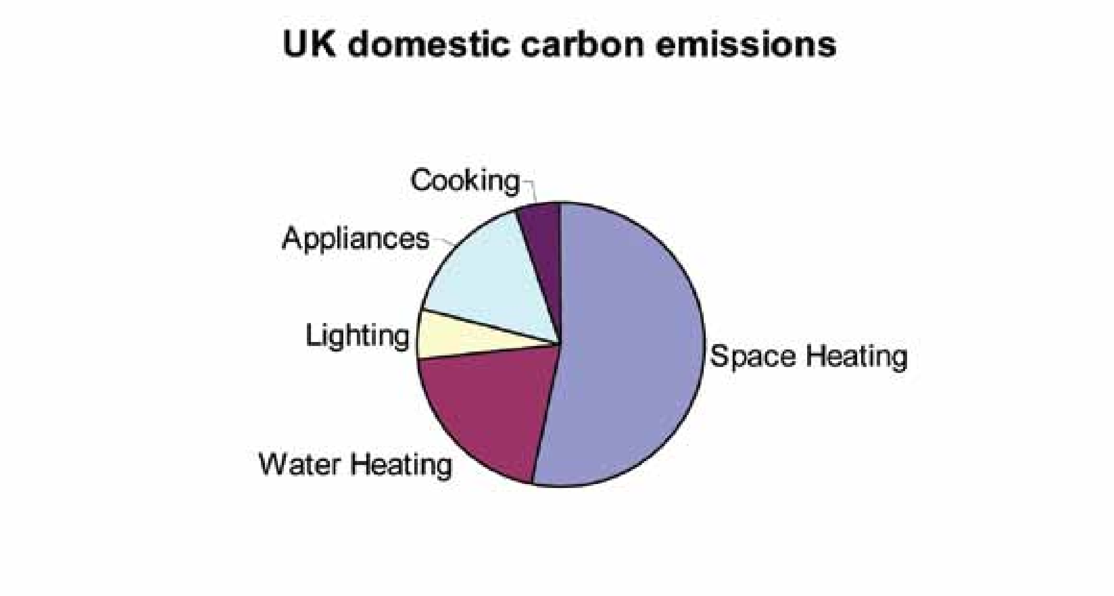


Figure 48.1 *UK domestic carbon emissions. Source HM Government (2006) Climate Change, the UK Programme.*

It is relatively easy to improve efficiency of energy use in all these areas (and so reduce the 'carbon footprint') by:

Improving thermal insulation:

- Insulating wall and loft spaces (as a financial spin off, cavity wall insulation on average pays for itself within 3 years).
- Fitting low emissivity [2] double glazing.
- Insulating hot water cylinders.
- In winter, turning heating down and wearing more clothing.

More efficient heating:

DEFRA have identified that a 'normal' heating boiler can achieve a seasonal efficiency of about 78%, whilst a condensing boiler can reach 88%. Further enhancements to overall efficiency can be gained by fitting state of the art programmable heating controls (including thermostatically controlled radiator valves).

- Sealing draughts, without compromising controlled ventilation.
- Careful use of heating and electrical appliances:
- Turning off lights when not needed, changing to energy efficient bulbs, not leaving TVs, computers, chargers etc. on standby (this wastes on average £25 per year per household).
- In the office, ensuring that heating and air conditioning are set to minimum comfort levels and keeping windows shut if either is in use.
- Using hot water efficiently, whether for washing or cooking, for example by not overfilling kettles or over boiling saucepans and ensuring that washing machines and dishwashers are filled to optimum capacity before use. Showers are more energy efficient than baths.

An efficiency plan such as this can be monitored by checking electric/gas/oil bills, which will not only highlight reduced energy use, but will also show the added benefit of reduced costs.

Indirect energy consumption also adds to CO_2 creation; nearly every aspect of home and office use encompasses the use of energy (including transport of essentials such as food and fuel) and so there is opportunity to reduce CO_2 release by purchasing such items from sources as close to the island as possible.

When building new dwellings or offices, the use of timber frame construction with rigid foam insulation is the best construction method available locally for high thermal efficiency (with the benefit of low embodied carbon).

Figure 48.2 *There are many good reasons why timber frame is the fastest growing method of construction in the UK. Its environmental, delivers high build quality, and is a faster and more efficient construction process.*

Figure 48.3 *Rigid foam insulation contains hundreds of millions of densely packed air cells. It gives very effective insulation and is practically impossible to be penetrated by moisture.*

References

1. Muir Ashworth, BSc (Hons), ICIOB, graduated from the University of Bath with a degree in engineering, and from the London Southbank University with a degree in Construction Management. He spent 23 years with a local manufacturing company and now works for Norman Piette specialising in construction materials.

2. 'emissivity' is a measure of the efficiency by which a surface emits thermal energy.

49. THE POTENTIAL FOR ECO-HOUSING

Andrew Ozanne[1]

Figure 49.1 *Completed in 2002, the Beddington Zero Energy Development (BedZED) is the UK's largest carbon-neutral eco-community - the first of its kind in this country.* Image © Bill Dunster.

We all understand how to measure architectural design, construction and maintenance in terms of financial cost. However, to apply the objective of living more 'sustainably' we need to measure the construction and building use in terms of 'environmental impact'.

In Guernsey houses are typically constructed with a dense concrete block cavity wall. This form of construction is considered thermally heavy. The internal space is slow to warm due to the time taken for the structural mass to warm up. However when the heat source is removed the mass cools down slowly releasing heat, which maintains the temperature of the space enclosed. In Scandinavia buildings are traditionally constructed of timber frame with high levels of thermal insulation. These are considered thermally lightweight. The internal space heats up quickly as the heat is contained within the space but the space cools down quickly as there is no thermal storage in the external fabric. Thermally heavy spaces make use of solar gain whereas thermally light spaces do not. Thermally heavy spaces if designed correctly can be better when the heat source is intermittent.

Thermally heavy spaces are used when there is an intention to use passive solar techniques, i.e., through large south facing conservatories or windows. A study in New Zealand showed that an insulated ground floor slab provided a heat reservoir.

Externally

The main façade of the dwelling should face as close to south as possible and endeavour to avoid over-shading. Site contours can often be exploited to maximise solar gain or minimise adverse affects of cold winds. Overheating of conservatories can be overcome by the planting of deciduous trees or shrubs, which can offer summer shade whilst allowing winter sun penetration.

Internally

Isolate heated areas within the house from unheated spaces. This can be done by insulated dividing partitions. Install low e-glass or triple glazing where possible. Select your window frames on the basis of energy efficiency and ensure that any joints in the building fabric are sealed or protected from cold bridges. Think carefully about the use of a conservatory, as they are extremely inefficient in retaining heat. The advantages gained through passive solar heat gain are quickly lost, creating an energy deficit if you centrally heat the space.

Plan layout

Rooms should be placed on the appropriate side of the building, either to benefit from solar heat gain or to avoid it where necessary. Window shades or blinds can reduce overheating yet enable winter solar gain. Maximise south facing windows and minimise north-facing windows. Traditional granite masonry walls level out the peaks and troughs of temperature due to the thermal mass of the construction. Conservatories, in addition to being a buffer space can be used to preheat incoming ventilation air.

Heating

It is important to ensure that heating boilers are appropriately sized and efficient. In traditional central heating systems thermostatic radiator valves are essential. Heating controls such as thermostats should be carefully positioned and their operating system understood. The heating system should be controlled to take account of the actual occupation requirements. Hot water storage should be located as near as possible to the points of use with storage cisterns being designed specifically to meet user needs. If your building can achieve a high standard of air tightness then a heat recovery ventilation system is beneficial if not essential, but you need to manage the risk of condensation.

Material durability

This should be considered due to the energy used in the preparation of materials, and during the construction and use. Similarly, the servicing cost of operating a grey water system must be measured against other forms of energy efficient use.

The 'Beddington Zero Energy Development'

This housing development was built in London by the Peabody Trust (a housing association). The project had to be financially viable and, in order to cover the cost of achieving the excellent energy efficiency, housing densities were high. Locally recycled materials, such as steel and wood were sourced and the fabric of the houses included 300mm of insulation and triple glazed windows. The space-heating requirement was 90% less than a normal house. A central combined heat and power unit fuelled by both gas and wood was installed to generate heat and electricity, with the excess sold to the National Grid. Solar energy units were used to power 40 electric cars in a car pool. Water conservation was achieved by using water saving toilets, dishwashers and washing machines. Rainwater and grey water is collected and recycled and a recycling programme (including organic composting) is operating.

Figure 49.2 *Schematic drawing of the BedZED development shown in the main image Figure 49.1.* Image © Bill Dunster.

This development is likely to be a signpost to the 'house of the future'.

Further reading: http://www.peabody.org.uk.

References
1. Andrew Ozanne is a Partner in Lovell Ozanne & Partners, Chartered Architects and Surveyors.

50. WHAT ARE PERSONAL CARBON EMISSIONS?

Tina Fawcett[1]

Figure 50.1 *Air travel is already responsible for twice the emissions of land-based travel.*

All of us are responsible for emissions of carbon dioxide ('carbon' for short) in our daily lives. Every time we fill up the car, switch on the lights or take a flight, carbon is emitted into the atmosphere as a consequence of fossil fuel energy usage. In the UK, household energy and personal transport are together responsible for around half of all carbon emissions. The other emissions in the economy are from organisations that provide us with goods and services.

Personal emissions from direct use of energy vary hugely between people. Emissions are affected by many factors from the efficiency of your house or the heating fuel you use to where you take your holidays and how you get there. A study of a small number of people in the UK showed the highest person emitted thirteen times as much as the lowest (some examples of emissions are shown in Figure 50.2). Even higher emitters with annual footprints above 50 tCO_2e - ten times the national average - have been found in other studies.

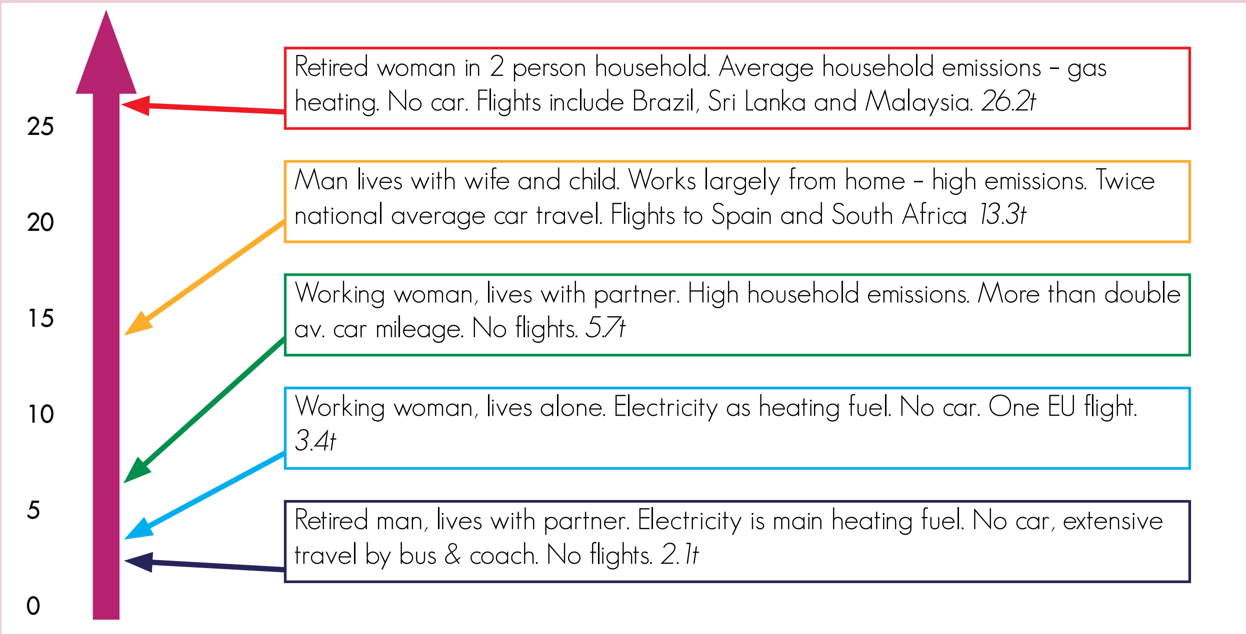


Figure 50.2 *Examples of Personal Annual Carbon Emissions in the UK in 2004 (where air travel is calculated as carbon dioxide equivalent (CO_2e)).*

For UK residents, the biggest contribution to personal emissions comes from household energy use (43% of the total), followed by air travel (34%) and then travel on land (23%). As air travel is rising very quickly, its proportion of the total will increase – indeed some estimates suggest it may be already responsible for twice the emissions of land-based travel.

So, are emissions on Guernsey likely to be very different from those in the UK? Guernsey differs in a number of significant ways from the UK. From Figure 50.2 we can see a number of factors potentially pushing emissions higher than the UK and a number pushing them lower. The combination of Guernsey's location and the affluence of the population probably means people travel significantly more by air, which could overwhelm all other factors and lead to higher personal emissions. It seems unlikely that personal emissions would be much lower than in the UK. With that average figure of 5.4 tCO_2e in mind, how about calculating your emissions to see how you compare?

Factors leading to higher emissions

- Long distance travel inevitably involves either ferries or aircraft which have high climate impact.
- Affluent population – emissions tend to rise with income.
- Main heating fuel – oil is higher carbon than natural gas, the UK majority fuel.

Factors leading to lower emissions

- Less opportunity for day-to-day long distance driving.
- Warmer climate – less need for home heating energy.
- Electricity has lower carbon emissions per unit.

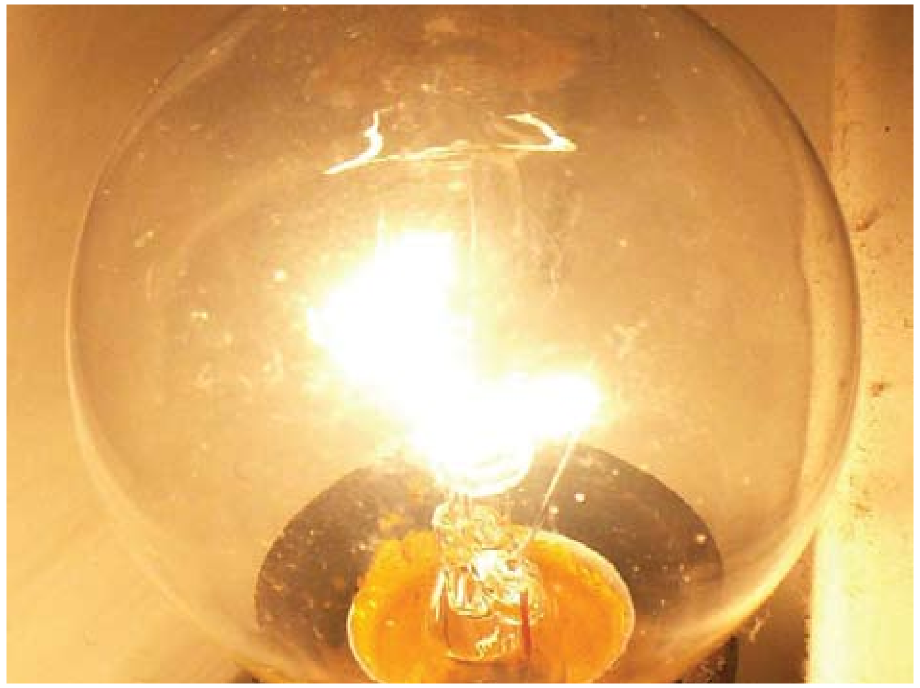


Figure 50.3 *In the UK, 43% of personal CO_2 emissions comes from household energy use. Turning off lights and appliances will help to reduce this.*

References
1. Dr Tina Fawcett works at the Environmental Change Institute, University of Oxford and for the UK Energy Research Centre. She is co-author of the Penguin book 'How we can save the planet' (Hillman and Fawcett 2004).

51. CALCULATING YOUR PERSONAL CARBON EMISSIONS [1]

Tina Fawcett

So where do you fit on the scale of carbon emissions? Are you deep green (less than half the average) or bright red (more than four times the average)?

decreasing personal carbon emissions - what colour are you?

To calculate your carbon footprint, first of all you need to collect information about your household energy use and distance travelled by different methods. You could either start collecting information now for the coming year, or use existing records and estimates of last year's energy use and travel. Then you can use the conversion factors provided in Table 51.1 to translate these into an annual carbon emissions figure.

Step 1: Collecting information about household energy use

- Electricity – from your electricity bills find out how much electricity in kilowatt hours (kWh) you use per year. It doesn't matter whether the electricity is on-peak or off-peak – it's the overall annual total you need.
- LPG Gas – you need your consumption in kWh.
- Oil – you need your annual consumption in litres of oil.
- Solid fuel – if you use wood for heating, assume zero carbon emissions. If you use coal, one kilogramme of coal produces 2.4 kgCO_2.

For all types of household energy divide each total by the number of people in your household, to get your personal energy consumption.

Step 2: Collecting information about personal travel

- Car – only count the distance you travelled as a driver. Car passenger miles are not counted.
- Air travel– work out the distance you flew by using www.webflyer.com – or estimate based on your geographical knowledge.

All distances travelled in miles can be converted to kilometres by multiplying by 1.6.

Step 3: Calculating your emissions

- Put these figures for your annual consumption in the table to the right.
- Then use the multiplier in the next column to get the figure for your carbon dioxide emissions in kilograms (kgCO_2).
- Add up your emissions from all your different activities to get an annual figure in kilograms of CO_2, divide by 1000 to get the answer in tonnes.

What next

Having obtained your total, now compare yourself with the average UK resident. If you can, compare yourself with some friends and colleagues as well. How did you do? Work out where most of your emissions come from and where you could cut down.

In addition, think about how your emissions relate to future reductions targets. As the scientific evidence about climate change becomes ever more alarming, deeper emissions cuts are demanded. We may be required as a country and individuals to cut emissions by between 60% and 90% within the next thirty years.

Taking action on your own to reduce emissions can be difficult, so consider getting together with other people. You could create a carbon 'Weightwatchers' club. Already people are starting to take action like this – for examples of UK groups see:

www.carbonrationing.org.uk.

Larger communities are also working together to reduce their emissions see:

www.goingcarbonneutral.co.uk.

Good luck!

Energy Use		YOUR annual consumption	Multiplier	YOUR emissions	Average UK individual
In the household					
Electricity (Guernsey specific figure)		kWh	x 0.205		} 2,350
Gas (LPG)		kWh	x 0.23		
Oil*		Litres	x 3.0		
Personal Travel					
Car**	petrol (as driver)	km	x 2.0		} 1,060
	diesel (as driver)	km	x 0.14		
Rail	Intercity	km	x 0.11		} 100
	Other services	km	x 0.16		
Bus	Local	km	x 0.17		} 90
	express coach	km	x 0.08		
Air***	within Europe	km	x 0.51		} 1,800
	outside Europe	km	x 0.32		
Ferry****		km	x 0.35		
Annual total					5,400

Table 51.1 *Annual carbon dioxide emissions (kgCO_2e) for personal energy use.*

* Each tonne of fuel oil generates approx. 780 - 875 kilos of carbon depending on grade of fuel. Multiply by 3.2 to get tonnes of carbon dioxide produced. Therefore, one tonne of fuel oil produces about 2.5 - 2.8 tonnes of carbon dioxide!

**This is an average figure for all cars. However, large 4X4s can have emissions three times those of small fuel-efficient cars. So if you have a large car this calculation will underestimate your true emissions. For more details on emissions from your particular car see www.vcacarfueldata.org.uk.

*** Calculating emissions from air travel is still hotly debated. These figures include a multiplier of three to account for the full global warming effect of emissions from aircraft.

**** Emissions factors for ferries are not well known, this is the best current estimate.

Figure 51.2 *Once you have calculated (and reduced) your own carbon emissions, why not turn your attention to reducing emissions from your place of work.*

Further information

Hillman and Fawcett 2004 '*How we can save the planet*'. Penguin. London. (The source for most numbers and calculations used in this article).

icount 2006 '*Your step-by-step guide to climate bliss*'. Penguin. London. (Very lively practical guide from 'Stop Climate Chaos' a coalition of environment and development organisations).

www.est.co.uk/myhome - comprehensive advice about saving energy at home.

References

1. This calculation is of your personal emissions and does not include other 'national' emissions.

52. COMMERCIAL BUILDINGS – REDUCING BUSINESS CARBON FOOTPRINT

Chris Leach [1]

Figure 52.1 *Commercial light pollution in St Peter Port, Guernsey.* *Pictures reproduced courtesy The Guernsey Press Co Ltd.*

Commercial buildings in Guernsey mainly use gas or oil as fuel for heating, but with the introduction of air-conditioning systems over the past 15-20 years they are also a big consumer of electricity.

Guernsey's commercial sector accounts for 46% of the electricity consumed, and electricity consumption in this sector has risen over 30% in the past 10 years. Some may argue that the majority of Guernsey's electricity is generated from a 'clean' source (i.e. nuclear), but there is no guarantee that this will remain the source of our electricity supply in the long term. It therefore makes sense to look closely at the energy use of commercial buildings.

Energy is one of the largest controllable costs in most organisations and there is usually considerable scope for reducing consumption in buildings.

As an offshore finance centre Guernsey is home to a large number of prestigious offices and commercial buildings. These buildings vary in age and construction and the services within them vary enormously. This provides an opportunity for the occupiers to understand their building and introduce changes that reduce their fuel consumption, thus reducing their annual spending on electricity, oil and gas and, in the process, reducing their carbon footprint.

The majority of commercial building occupiers are not trained in energy management and may struggle to understand how best to reduce fuel consumption, but help is available. A register of qualified Low Carbon Consultants [4] is available on line and these people will provide professional advice. There are also some straight-forward guidelines to follow:

Look at the building fabric:

- Older buildings may require wall or roof space insulation.
- Check the glazing, clear glass generates high solar gains in a building and puts a high demand on air-conditioning systems; external shading or coating the glazing can reduce solar heat gains.

Look at the building services:

- Use heat recovery ventilation, heat pumps and free cooling systems.
- Use condensing boilers, these have a higher efficiency than conventional boilers.
- Use low energy lighting systems (avoid tungsten lamps).
- Use lighting control systems to switch off lights when natural lighting is adequate or to ensure unoccupied areas are not lit; particularly relevant in underground car parks.
- Make use of building control systems to operate plant and equipment; these systems carry out a wide range of automatic operations from basic time-clock control to full energy monitoring.

Monitor Energy Consumption:

- Electricity, oil and gas consumption can be easily monitored either by manual reading of meters or automatically by using data logging equipment.
- Maintain a log book of energy usage. You cannot attempt to save energy until you start to monitor current consumption trends.
- Consumption can be compared against industry benchmarks for particular building types.
- Set targets to reduce consumption and introduce initiatives to help meet these targets.

Benchmarking

Benchmarking is a useful way of seeing how your building's energy consumption compares against other similar buildings. Organisations such as the Building Services Research and Information Association [2] and The Carbon Trust [3] provide typical and good practice energy consumption targets in KWh/m2 per year for different types of commercial building. The energy use of many Guernsey buildings is as much as 50% above the amount considered 'good practice'. There are considerable opportunities for improvement and cost savings.

Energy Saving Initiatives

Contrary to popular belief, energy saving initiatives do not always require a large capital spend. Companies and organisations can follow some simple steps:

- Start with a simple energy policy that involves the staff and encourages their ideas.
- Adopt an organisational structure that recognises employees responsibilities for energy management.
- Adopt a staff suggestion scheme to generate ideas.
- Monitor energy consumption and set targets. This costs little but can save 5% energy consumption.
- Ensure that existing plant and equipment is appropriately maintained, which must include the building services control systems.
- Procure energy efficient equipment when repurchasing (i.e. replacing CRT monitors (40w) with flat screens (20w)).

Legislation

It makes economic sense for organisations to take the initiative and reduce their energy consumption but when Guernsey adopts the latest changes in the UK building regulations many of the suggested initiatives are likely to become mandatory for building operators:

- In the UK, changes in the Building Regulations were introduced in 2006 to achieve a reduction in carbon emissions by up to 27% in non-dwellings, 22% in houses and 18% in flats when compared against 2002 levels.
- The regulation includes the installation of utility meters and regular and detailed monitoring in a building log-book so that 'at least 90% of the estimated annual energy consumption of each fuel can be accounted for', and any changes to a building that would effect the energy consumption are recorded.

Figure 52.2 *Infra-red imaging shows areas of heat loss.*

Useful information booklets available from The Carbon Trust:

Include:

GPG231 – Introducing Information Systems of Energy Management.

ECG019 – Energy use in offices.

GIR012 – Organisational Aspects of Energy Management.

References

1. Chris Leach has a degree in mechanical engineering and is a member of the British Institute of Facilities Management. He is managing director of Amalgamated Facilities Management.

2. BSRA – http://www.bsra.ac.uk.

3. The carbon trust: http://www.carbontrust.co.uk/.

4. Low Carbon Consultants register: http://www.cibse.org.

53. OFFSETTING CARBON DIOXIDE EMISSIONS

Nicholas Day[1]

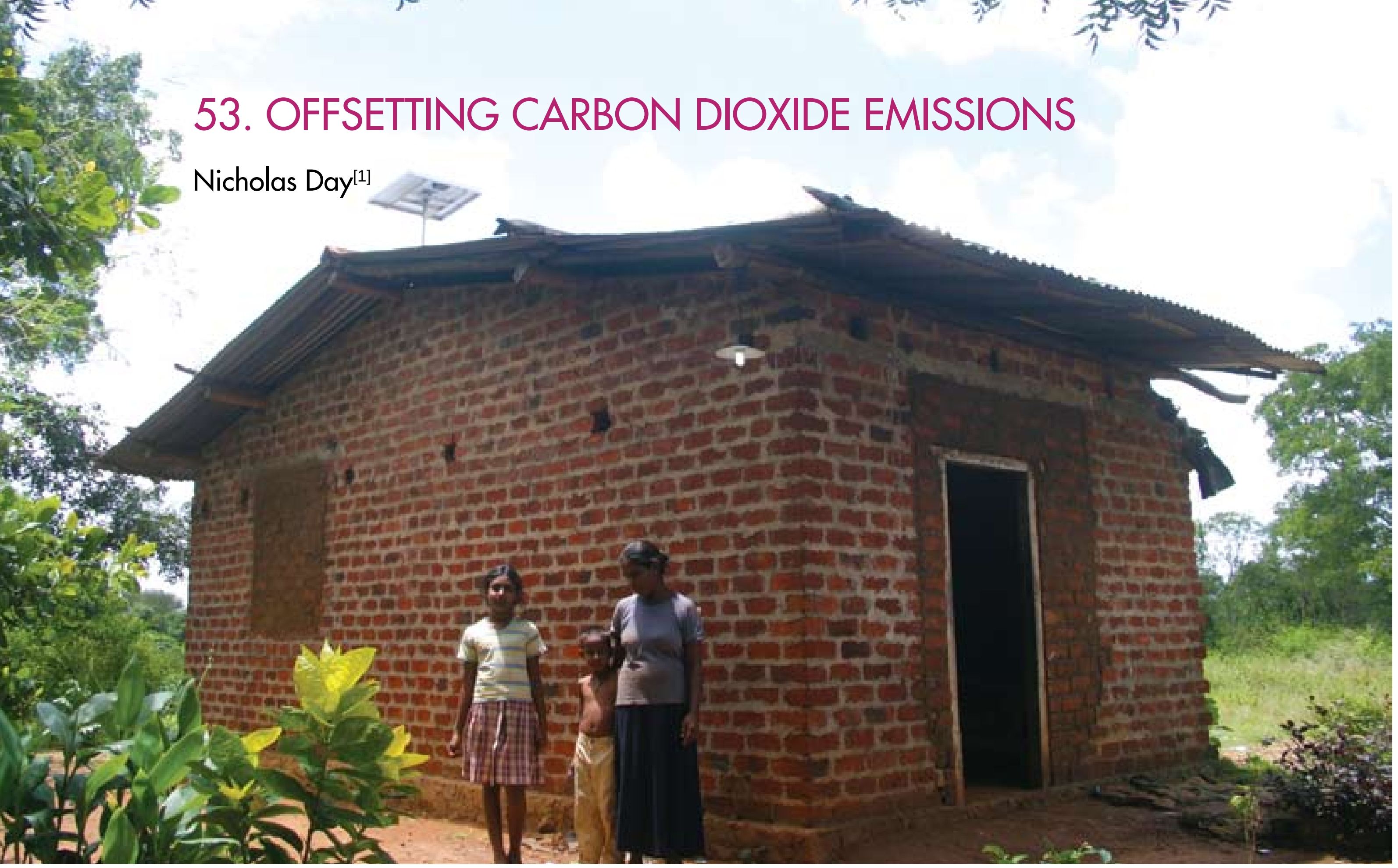


Figure 53.1 *Global Warming is a global problem. Third world countries such as Sri Lanka are benefiting from carbon offsetting. Note the photovoltaic cell panel on roof.*

Carbon 'offsetting' has emerged as an additional way that individuals and organizations can indirectly cut their carbon emissions. Carbon offsets are generated from projects that reduce the amount of greenhouse gases entering the atmosphere.

The most cost effective and environmentally sound way to address an individual's (or organization's) carbon footprint is to first focus on direct emissions. Reduce your carbon footprint and make cost savings by implementing cost-effective energy efficiency measures. Then, if appropriate, consider developing an offset strategy, purchasing only high quality offsets from verified projects that genuinely create reductions in emissions.

The basic concept of offsetting is appealing. Carbon dioxide emissions are a global problem, and the atmosphere mixes fairly efficiently. It makes little difference to future global atmospheric concentrations where emissions, or reductions in emissions, take place, so there is much to be said for reducing emissions where it is easiest and cheapest to do so.

In much of the developing world, major improvements to a rural community's local economy and way of life can be made by the provision of a non-polluting electricity supply. One example is the supply of photovoltaic solar panels to a rural village in Bangladesh, where previously light had come from kerosene lamps, and electric power from diesel generators. As the number of panels increases, providing an almost cost-free electricity supply, many aspects of local life improve. There are many such examples where the benefits of an offsetting programme can be disproportionately large, given the level of investment made.

Offsetting, however, has received a mixed press. Several environmental groups object to it, suggesting that offsetting is a soft option, giving people an excuse from making the effort to reduce their own emissions, which in the future they will have to do. This counsel of perfection is not easily applied in small island communities such as Guernsey. Transport to and from the island is an essential lifeline, and offsetting the ensuing emissions is the only option until transport technology changes. Additionally, a close relationship with the marine environment is an essential component of many small islands' culture. Much of this 'pleasure boating' is dependent on fossil fuels, which can be made carbon neutral by 'offsetting'.

More substantial reservations have been expressed that some of the offsetting schemes lacked transparency, or any guarantee that the claimed reductions would actually occur. For schemes based on tree planting, additional arguments were raised, that many years would elapse before the full impact would be achieved, and that in the interim the trees could die, be consumed by fire with the carbon returning to the atmosphere, or otherwise not achieve the carbon sequestration claimed.

Clearly purchasers of offsets need to be confident that the emission reduction apparently purchased will actually occur. In order to provide assurance to purchasers of offsets that the requisite reductions will occur, the Department of the Environment in the UK is establishing a system of certification.

There are ten or more schemes in the UK which offer offsetting. Details of most of them can be found at the website www.all-energy.co.uk. They encompass a wide variety of projects. The merits of the different types of project are discussed in some detail in the publication 'The Carbon Trust three-stage approach for a more robust offsetting strategy' that is available free of charge from the Carbon Trust [2].

Many projects, particularly in developing countries, offer wider social and environmental benefits than just the emission reduction. Offsetting, despite the doubts sometimes expressed, is still the only feasible way to eliminate one's carbon footprint. In an island community such as Guernsey, where air and sea travel are indispensable, and many people have a close relationship with the sea, offsetting could have an especially important role to play.

Figure 53.2 *Treadle pumps, supplied by Climate Care [3], used for irrigation in India to replace diesel powered pumps. Each treadle pump saves approximately 0.5 tons CO_2 per year.* Image courtesy of Climate Care.

Figure 53.3 *Smoke-free Patsari stoves in a tortilla restaurant in Mexico. Each stove saves over 5 tonnes of CO_2 per year (compared with an open fire) and Climate Care is funding GIRA to provide 500 more stoves over the next 3 years.* Image courtesy of Ashden Awards.

References

1. Professor Nicholas Day is Emeritus Professor of epidemiology at the University of Cambridge, where he was director of the Institute of Public Health, and co-director of the Strangeways genetic epidemiology research laboratory. He has been associated with Guernsey for almost 50 years.

2. The Carbon Trust three stage approach to developing a robust offsetting strategy. Booklet CTC 621, November 2006. Available as a PDF or as a free printed publication. www.carbontrust.co.uk.

3. www.climatecare.org.

54. GUERNSEY CASE STUDIES: COMBATING RELIANCE ON FOSSIL FUELS

Paul Fletcher [1]

Renewable energy can be provided by new innovative, yet off-the-shelf, technologies and techniques. A combination of energy conservation by improved insulation and efficient technologies, means that energy use and carbon dioxide emissions can be substantially reduced, in some cases by as much as 60 - 70% by these well proven techniques. The technology is available to implement Carbon Zero housing, it just takes planning and investment. Technologically it's not hard to save the planet!

The following local people have made a start:

Nigel Gale

On building a new house, Nigel (a local builder) wished to build in as much energy efficiency as possible. He combined Rockwool filled 100mm cavity walls, 60mm thick Celotex roof insulation, and floor insulation with underfloor heating pipes. An NHER [2] energy assessment worked out the heat loss of the home to size the condensing boiler back up. A bespoke heating and control system was designed to heat the house and pool, utilising some of the heat otherwise lost in winter to the home from the solar pool heating system. Compared to a normal domestic home and pool heated by a conventional oil boiler, Mr Gale has reduced comparative oil use by an estimated 60%.

Figure 54.1 *Solar pool heating collectors. Image courtesy of Paul Fletcher.*

Figure 54.2 *Ground loop heating pipes buried in the garden. Image courtesy of Paul Fletcher.*

Emma Allen and Tim le Tissier

The first thing to find out for this young couple was the projected energy use of their small granite cottage. An NHER energy assessment was calculated, and the different heating systems based on gas, oil, heat pump, or solar energy were discussed. Their preferred choice was a Ground Source Heat Pump – if the ground loop would fit in their long but narrow garden! It did, and it's all up and running. The system uses 4 times less energy than an oil, gas or electric boiler system, and the running costs are half what one would expect from an orthodox oil boiler. It uses electricity to power the compressor, which can be locally generated by renewable energy from photovoltaic cells (or a wind turbine), and, one-day, off-shore wind or tidal turbines.

Jacqui Golden and Tony Thomas

This system was designed and built with environmental concerns as a first principle. The contemporary house makes best use of natural light, and utilises insulated cavity walls, roof and floor insulation and underfloor heating throughout. Jacqui and Tony wanted an eco-heating system from the start so no gas or oil for them. Ground loop panels were too large for the back garden and a borehole ground loop was difficult. Internal space was at a premium so careful design has integrated latent heat thermal stores, large solar heating collectors on the flat roof, horizontal hot water tank and a 4kW in-line electric boiler. Designed for low power consumption over longer periods the planned 2kW photovoltaic system will be able to displace as much direct electricity as possible to power the heating.

Figure 54.3 *Solar collectors heat water and central heating utilising thermal stoves. Image courtesy of Paul Fletcher.*

John and Sally le Couteur

John and Sally wanted to make their life more efficient, easier and less polluting by getting rid of their coal back boilers. With a condensing oil boiler, hot water solar heating system, intelligent heating controls, and a house that could be zoned into two areas, carbon emissions were reduced very considerably. A later addition was to install a grid-connected photovoltaic electrical generation plant. Energy from the sun generates electricity in the special silicon panels. The electricity generated is converted from DC (direct current) by an 'inverter', into the normal AC (alternating current) used in the house. If no electricity is being used it can be exported to Guernsey Electricity.

Figure 54.4 *Photovoltaic cells mounted on conservatory roof with solar water heating. Image courtesy of Paul Fletcher.*

References

1. Paul Fletcher is Director of a local company specialising in designing, installing and maintaining advanced technology installations.

2. http://nher.co.uk/.

55. REDUCING OUR PERSONAL USE OF RESOURCES: A LOW-COST GUERNSEY CASE STUDY

Andrew Casebow

Figure 55.1 *Environmentalists Amanda de la Mare and Iain Brouard cycled their way across America.*

Whilst many of us would like to take action, we don't all have the money available to invest in new boilers, heat pumps and the like. People who consume most will have to make the greatest cuts, but we can all contribute, and success will come from a combination of many different initiatives.

We have all seen the lists of possible actions that we can take. Here are a few of them:

- Reducing energy use in the home and workplace – better insulation, energy efficient light bulbs, modern efficient central heating.
- Reducing waste going to landfill – by composting, recycling, and minimal packaging.
- Reducing traffic and pollution – encouraging people to walk or cycle, or to use public transport, etc. Not so easy if you have young children!
- Reducing resource use – consider renewable electricity, efficient use of water, using renewable rather than non-renewable products.
- Using fresh local products - wherever possible instead of imported food.

Probably the most important thing we can do today is to switch off lights, heating and appliances in the home when you are not using them. You will probably save more energy doing this than by initially investing in improved technology.

How local people take action to cut their energy use.

Amanda de la Mare and Iain Brouard live in Castel, and 'Mandy' can often be seen cycling to and from work in St Martins. They are good examples of young people who are trying to do their bit!

Housing

"*We have just purchased our own home, a 400 year old Guernsey cottage in need of total renovation and will be using recycled and natural materials when ever possible. Materials, such as reclaimed timber, bricks and pan tiles, lime plaster and sheep's wool insulation. Using these materials will be sympathetic to the cottage's construction and aesthetics whilst also helping the environment and saving us some pennies. We are gathering information from the internet, books and the Centre of Alternative Technology in Wales (www.cat.org.uk), who have been very helpful. We will also be incorporating into the project solar water heating, photo-voltaic cells and perhaps a wind turbine. Hopefully, come spring, the site will be clear enough to start a small veg garden.*"

Figure 55.2 *'Bru' and Mandy's renovation of a 400 year old Guernsey cottage is both environmentally friendly and cost effective.*

Heating and lighting

"*Heating the house is a major challenge. At the moment we have a wood burning stove and they are apparently carbon neutral. We are hoping to install a geothermal system with under-floor heating which is very efficient but unfortunately, as with most new technologies, it is expensive. May be it is time for Guernsey to follow the U.K and Europe's lead and provide grants for energy saving initiatives. We use energy saving light bulbs. Hopefully these will become the norm and incandescent bulbs will be banned from sale as in Australia.*"

Shopping

"*We go shopping on our bikes and use reusable bags. We try to buy local produce and, as we are both vegetarians, buy a lot of our food from hedge stalls. We also belong to a local 'organic box' scheme. It's not always that easy but we try to avoid buying over-packaged goods, or products that have travelled a long way. I use environmentally friendly products to avoid putting chemicals down the drain, which therefore end up untreated in our local waters.*"

Transport

"*We cycle or share a car whenever possible.*"

Holidays

"*We like to cycle and camp when on holiday, and we try to avoid flying when ever possible. We also do volunteering work whilst away from home as it's a good way to meet the locals*"

We might not all wish (or be able) to cycle as much, or to lead such a 'low impact' lifestyle as Mandy and Bru, but we can all take worthwhile actions to save energy use. However, with so much of the energy that we personally use being in the home and for personal transport, that is the area where we can make the greatest savings.

Perhaps what makes us reluctant to consider the type of 'low energy' lifestyle essential to a sustainable future is that we have been indoctrinated to believe that consuming less energy inevitably means a lower quality of life. That need not be the case.

Figure 55.3 *This total renovation project will use recycled and natural materials when ever possible, such as (a and b) reclaimed timber, bricks and pan tiles, lime plaster and (c) sheep's wool insulation.*

56. RECYCLING IN GUERNSEY

Chris Regan

Figure 56.1 *Recycling Officer - Dr Keith Russell - at the Salerie Corner super site.*

On average every person in Guernsey throws away their own body weight in rubbish every 7 weeks, or to be more precise, buries their own body weight every seven weeks in the islands only landfill site, Mont Cuet. If we continue at the same rate, Mont Cuet will be full by 2015. We need to reduce the amount of commercial and household waste that is going to landfill to ensure that Mont Cuet remains open as long as possible. Rotting waste in landfill also produces large quantities of methane, one of the greenhouse gases.

Reducing

The good news is that Guernsey residents are recycling more now than ever before. However, there is always room for improvement and there are many ways that we can reduce the amount of rubbish that our families produce. For example:

- Try and buy products with less packaging such as fresh local fruit and vegetables. This not only saves on packaging but also supports local industry.
- Invest in a reusable shopping bag; these can be purchased for a few pence and they will last for months, but remember to keep them in your car so you're prepared when you go shopping. If everyone in Guernsey stopped using plastic bags for one year and switched to a reusable bag, we'd save 7.8 million plastic bags - that's enough plastic to tie around the island 100 times.
- Re-use whenever possible; repair shoes, furniture and clothing etc. Britain has become a throw away nation compared to countries such as India which tend to re-use everything. Avoid disposable 'single-use' items.

Recycling

Household rubbish such as cardboard and paper, glass bottles and jars, aluminium drink cans, food cans, plastic bottles and clothing and household linen (including duvets and pillows, etc, as long as they are clean and in good condition) can be deposited at a number of recycling sites throughout the island.

You can separate your household recycling quite easily into a storage box under the sink or if you have more space you can purchase stacking boxes specifically for this. Grass cuttings, garden waste and some food waste can be thrown on the compost heap; composting kits are available from local garden centres. Garden waste can also be taken to the green waste site at Chouet, Vale.. For information on home composting go to www.gov.gg/recycling.

Household Scrap Metal and WEEE (Waste Electrical and Electronic Equipment) can be deposited in the scrap metal skip at Mont Cuet during opening hours (7am - 4pm, Monday - Friday, 7am - 10am, Saturdays). The Public Services Department also provides regular metal recycling weekends for the recycling of these items. There is also a skip for bulk deliveries of household cardboard available at Mont Cuet.

Nearly 30,000 tonnes of commercial and industrial waste was dumped at Mont Cuet in 2006. All businesses have to pay to dispose of commercial waste, so re-using and recycling is an opportunity to save money whilst being environmentally friendly. For advice on commercial recycling contact the Recycling Officer at the Public Services Department on tel. 717000.

So now you know where to dispose of your recycling but what happens to it after that? The following items are exported or processed as follows:

States of Guernsey

- Clear glass is exported off-island for smelting and re-forming into new bottles, approximately half the cost to do this is recovered. Green and brown glass in crushed on-island and made available for use as building aggregate.
- Food tins and drink cans are collected together and put in to a 'hopper' for magnetic sorting; both aluminium and steel are sent out of the island. Recoveries from steel exportation tends to break even, or generate a small financial surplus, whereas aluminium's surplus is considerably more.
- Soil conditioner produced from composted green waste is used on the Island, and is particularly useful in regeneration schemes.

Commercially

- Paper, cardboard and plastics (HDPE [1] and PET [2]) are exported off-island by Mayside to be re-formed.
- Clothes and textiles are collected on behalf of the Salvation Army. The bags collected are sent to the UK and bulk loads are then transported to the developing world for distribution, providing job creation opportunities, and affordable clothing for the needy.
- Items such as scrap metal, electronic equipment, wooden pallets and tyres, etc, are exported for recirculation, reconditioning or recycling. Some soft products such as wood shavings and clean newspaper is kept on-island for animal bedding.
- 'Wet Recyclables' such as mineral and kitchen oil are exported to the North of England, where they can be recycled into fuel oil.

For recycling sites and quick reference details on how to dispose of further recyclables, see **'Recycling Sites'** overleaf.

For comprehensive information on recycling in Guernsey, visit:

www.gov.gg/recycling

or call the Waste Disposal & Recycling Information Line, tel. 12077.

If everyone in Guernsey stopped using plastic bags for one year and switched to a reusable bag, we'd save 7.8 million plastic bags - that's enough plastic to tie around the island 100 times.

References

1. HDPE: A high-density polyethylene plastic used in packaging such as detergent bottles, margarine tubs and rubbish containers.

2. PET: (polyethylene terephthalate) A type of plastic commonly used to package soft drinks, water, juice, salad dressings and oil, cosmetics and household cleaners.

RECYCLING SITES*

Public Services has eight 'super' bring bank sites where you can recycle household **cardboard**, **paper**, **glass** and **plastic bottles** and **jars, drinks** and **food tins** and **textiles**.

They are at:

1. Safeway, Rohais (Perry's Guide ref 16C4)
2. Checkers (Manor Stores) St Martin's (31E2)
3. Salerie Corner car park, St Peter Port (17H3)
4. Vazon Bay car park, Castel (14B1)
5. Cobo Village (pumping station), Castel (8A3)
6. L'Eree car park, St Peter's (20B1)
7. Chouet headland, Vale (6A1)
8. Longfrie Inn, St Peter's (27F1)

There are also limited facilities at a number of other sites throughout the island.

DOMESTIC RECYCLING ROUTES

- **Aerosols:** Aluminium and steel aerosols with their plastic lids removed can be put into bring banks for cans.
- **Bulk Refuse. Vehicles and bulky household items such as beds, sofas, appliances, oil tanks etc:** Public Services, Bulk Refuse Coordinator (tel: 717227) forms available online at www.gov.gg.
- **Car batteries:** Guernsey Recycling (tel. 245402); Wastenot Ltd (tel. 716580); Scrap-it (tel. 07781 126250).
- **Car, Lorry and Motorbike tyres:** Target Auto Parts (tel. 720986); Sarnia Autos, by arrangement (tel. 07781 126250).
- **Computers, Monitors and printers:** Guernsey Recycling (tel. 245402); Scrap-it (tel.07781 126250).
- **Electrical items such as irons, toasters and kettles:** Metal recycling skip at Mont Cuet during tip opening times (tel. 245106).
- **Ferrous and non-ferrous scrap metals:** Guernsey Recycling (tel. 245402); Wastenot Ltd, only ferrous (tel. 716580); Scrap-it (tel. 07781 126250).
- **Garden and horticultural waste, not diseased or sprayed with pesticide:** Chouet horticultural site (tel. 245106).
- **Granite including building stone, lintels, paving, pebbles, boulders:** Vaudin Stonemasons, La Fontaine Vinery (tel. 248316).
- **Greenhouse and house timber, not rotten:** Portinfer timber yard (tel. 254118).
- **Household batteries - bagabattery.com:** ecomundi (tel. 235580); lucas freight (tel. 724480).
- **Laser and inkjet cartridges:** Edgetech Ltd (tel. 729560); Guernsey Specials Gym (tel. 238800).
- **Mobile phones:** Wave Telecom shop (tel. 818181); Cable and Wireless (tel. 700700); St John Ambulance training hall, Rohais (tel. 727129).
- **Oil filters:** Total Waste Recycling (tel. 07781 426460)
- **Pallets (wood & plastic):** Guernsey Pallet Company (tel. 07781 100999); Waste Not (tel. 716580).
- **Plate glass:** Longue Hougue Reclamation Site (tel. 249628).
- **Recoverable inert waste. Builder's rubble, concrete blocks and bricks:** Ronez (tel. 256426) or Island Waste (tel. 235762), both by arrangement.
- **Scrap metal such as bikes and other appliances, small amounts:** Mont Cuet landfill site (tel. 245106).
- **Spectacles:** Specsavers Opticians, Market Street, St Peter Port (tel. 723530).
- **Uncontaminated inert waste. Rubble, sand, gravel, stone:** Longue Hougue reclamation site (tel. 249628).

*Information correct at time of going to print

57. LEARNING OUR WAY OUT OF THE PROBLEM

Alun Williams [1]

Any book that deals with climate change must leave readers anxious and concerned. If so, the antidote may well be to visit any Guernsey school and experience the positive response and the potential for change amongst the island's young people.

Over the past few years global warming, alternative energy and measuring carbon footprints have embedded themselves in the curriculum of our primary and secondary schools.

And so they should. There is no greater challenge for our future generation than how it will sustain the lifestyle to which Guernsey folk are accustomed.

Schools have taken it upon themselves to inform young people of the issues associated with global change. Most areas of the curriculum have embraced the subject:

- The geography curriculum has, of course, been shaped by the debate. Geography is all about natural systems, climate, countries and cultures so, at its very core, is the earth.
- Science can be brought to the very edge of current thinking about developments in animal and plant life.
- And what about citizenship? Where we teach how communities have to live in harmony with each other and the roles and responsibilities of each individual.

The good news is that the young people are well-placed to take up the challenge and respond to it. In spring 2007 the Guernsey Young People Survey was held that asked 100 questions of 2,000 10-17 year olds. The survey was intended to gauge their attitudes to life in Guernsey. The survey is overwhelmingly positive, and, of particular interest to this book, is their attitude to the future and the environment.

When answering the question 'If I were Chief Minister I would...' the priority issue that they identified was, by far, the environment. Their comments are insightful...

- "Get recycling to be compulsory"
- "Clean up Guernsey and make a limit of how many cars there are on the roads"
- "Try to sort out the sewage problem and help fight global warming"
- "Put wave turbines in to make electricity"

The message from young people was:

- Young People know about the environmental issues facing Guernsey.
- They care about their Island and the impact of climate change.
- They are ready and able to do something about it.

So let's follow the lead of the island's young people. Let's learn our way out of the problem.

Figure 57.1 *The Education Department is ensuring that all its new buildings, including the Sixth Form Centre at the Grammar School, and the Princess Royal Centre for Performing Arts, which are both pictured, are designed to modern environmental standards.*

References

1. Alun Williams is the island's lifelong learning manager.

PLANNING FOR A SUSTAINABLE FUTURE

Andrew Casebow

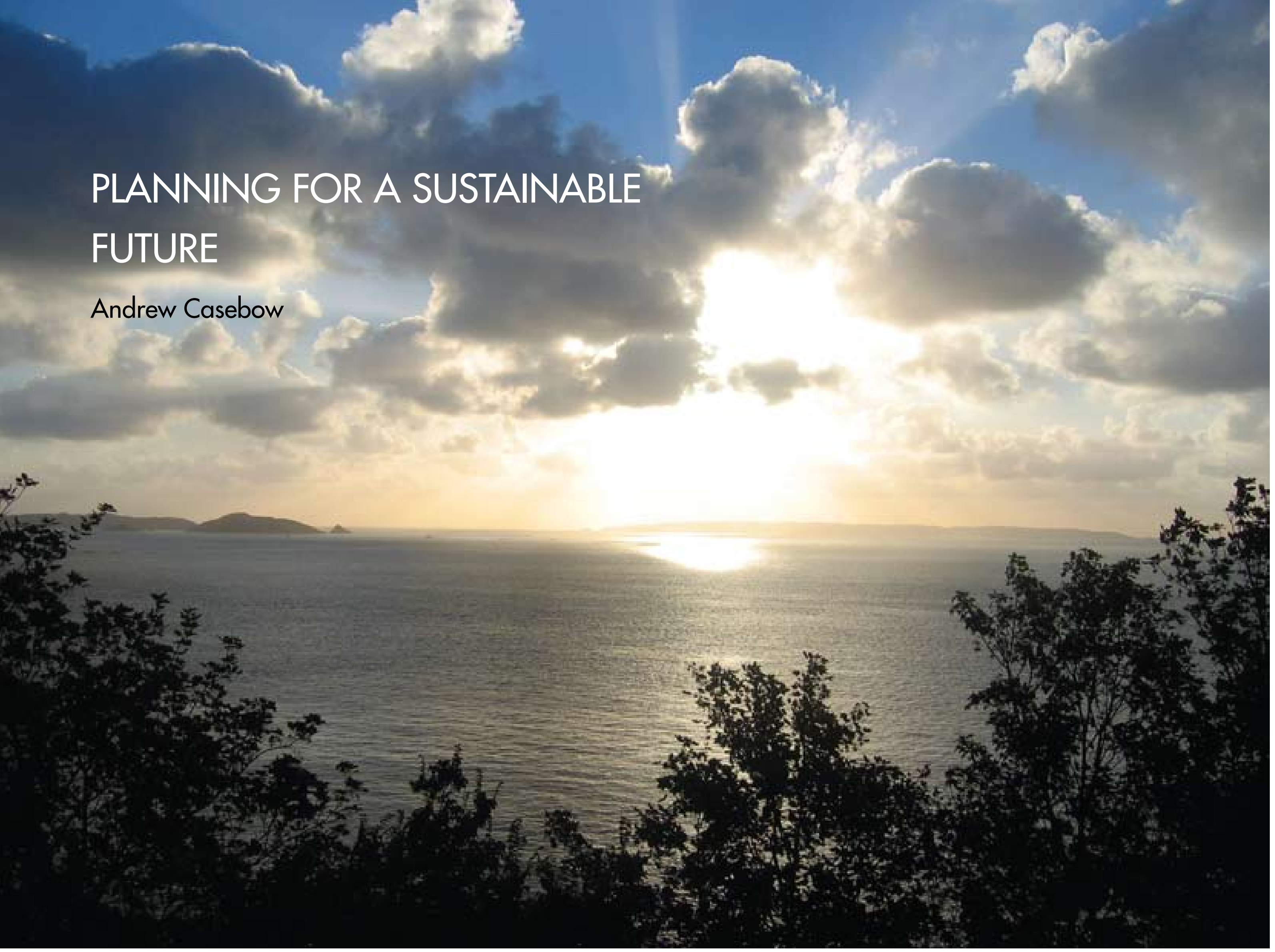


Figure 57.1 *Sunrise over the islands.*

'Planet Guernsey' has demonstrated how climate change has affected our island in the past, and provided solid evidence of the global warming that is already affecting our climate, the wildlife of our island, the production of our food and even the flowers that grow in our gardens. The future will bring much greater climate change, even if immediate and effective steps are taken throughout the world to reduce the emissions of 'greenhouse' gases. The future climate for the next 20 or 30 years has already been determined, but the future of our planet and our civilisation depends on our actions now and in the years to come.

The expanding human population of the planet has already exceeded the capacity of the Earth to sustain it and has become a major 'driver' of climate change. The world population was 4 billion as recently as 1970, is over 6 billion now and predictions are that it will be over 9 billion by 2050 (Figure 57.2). There is bound to be increased migration and conflict between those that already have, and those that want an energy hungry 'western' life-style. Also, as people become more affluent they demand a meat-based diet that uses more of the planet's resources as well as producing greenhouse gases that contribute to climate change.

Climate change has been caused by the burning of fossil fuels to provide energy for our lifestyle, and by the destruction of forests to provide additional agricultural land to feed the expanding world population. It has been caused by industrialisation, by the use of lighting, heating and air conditioning in our homes and offices; by our use of transport, our insatiable demand for new commodities, and by the whole fabric of our lives that is dependent on the profligate use of energy.

But there is a cost and until recently many of us were living in a 'fool's paradise', not realising that our planet and the future generations of human beings, and all wild creatures, would pay the price. As Brenda Boardman wrote in an earlier chapter "We are the cause, so we are the solution". We need to take responsibility for the way that we live our lives and the effect that we are having on the disadvantaged and future generations.

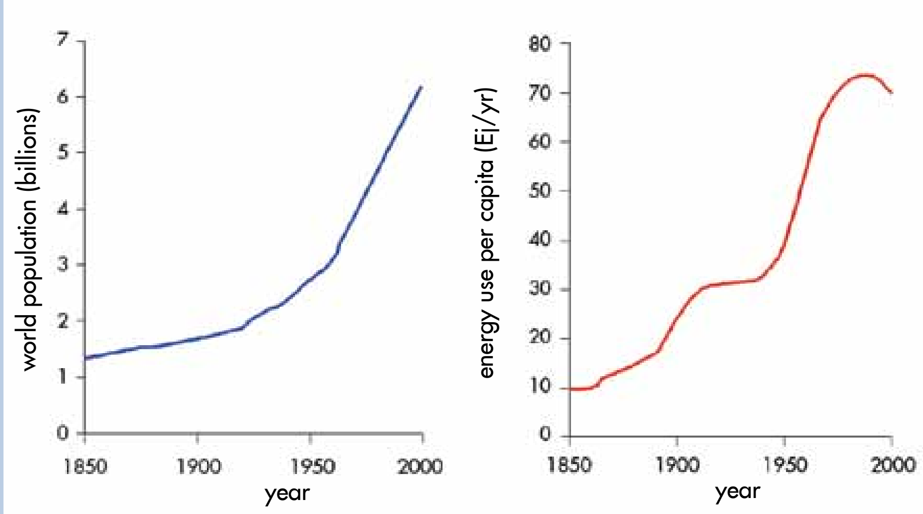


Figure 57.2 *Drivers of CO_2 emissions: population and energy use.* *Source Hadley Centre for Climate Prediction and Research, data from Open University.*

We can make savings. We can stop wasting heat in our homes and invest in better insulation. We can find ways to reduce our use of fuels for transport. We may do our bit by using 'bio-fuel' in the future, but will we be comfortable in knowing that food prices will increase to pay for that luxury, and others will be starving. We can and must be personally responsible. As Sir John Houghton has said, each and every one of us does have a moral responsibility to take action.

Figure 57.3 *Local engineers Mark and Peter Parr have developed their own electric car.*

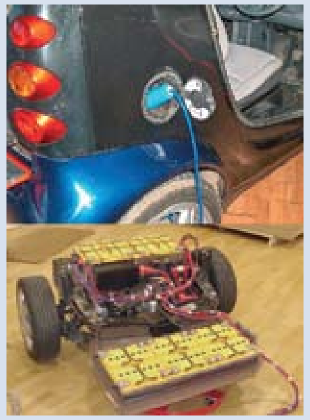


Figure 57.4 *The electric car. Quiet, cheap to run and good for the environment. Just plug it into any 13 Amp socket.*

Within our island we also have a joint responsibility to take action. Difficult decisions will need to be taken about our sea defences, and whether it will be accepted that some land is lost to the rising sea. It may be that not everywhere can be protected at a socially acceptable cost. Our future energy and transport policies must also be considered and new investment agreed to stimulate change.

Authors within our booklet have suggested a number of ways by which individuals can reduce their emissions, and lead a 'more ethical' lifestyle. But perhaps a more radical approach is needed. Guernsey has access to low CO_2 emission (nuclear fuelled) electricity from France, and great potential for electricity generation from renewable sources. The island, with its moderate speeds and short distances, is also ideally suited to electricity-powered transport. It has been suggested that the island's adoption of new policy initiatives could convert Guernsey to a community that is powered largely by low emission electricity. Such an initiative could lead the way to a carbon neutral future. We may just avert a disaster!

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Plymouth University is one of the most popular university destinations for Guernsey undergraduates. It is renowned for its pursuit of environmental knowledge ensuring the discussion of climate change is a feature throughout university life.

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We are also grateful to the following sponsors who have contributed to the launch of the booklet and the expenses incurred in bringing speakers to the island.

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THE REVENGE OF GAIA

"I speak as a planetary physician whose patient, the living earth, complains of fever; I see the Earth's declining health as our most important concern, our very lives depending on a healthy Earth. Our concern for it must come first, because the welfare of the burgeoning masses of humanity demands a healthy planet."

"We suspect the existence of a threshold, set by the temperature or the level of Carbon Dioxide in the air; once this is passed nothing the nations of the world do will alter the outcome and the earth will move irreversibly to a new hot state. We are now approaching one of those tipping points, and our future is like that of the passengers on a small pleasure boat sailing quietly over Niagara Falls, not knowing that the engines are about to fail."

James Lovelock
The Revenge of Gaia:
Why the Earth is Fighting Back – and How We Can Save Humanity.'

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Published by the Guernsey Climate Change Partnership (GCCP)
October 2007