earthscan
from Routledge

A CARBON PRIMER FOR THE BUILT ENVIRONMENT

SIMON FOXELL

A Carbon Primer for the Built Environment

Simon Foxell

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

earthscan
from Routledge

First published 2014
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN

and by Routledge
711 Third Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

© 2014 Simon Foxell

The right of Simon Foxell to be identified as author of this work
has been asserted by him in accordance with sections 77 and 78
of the Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this book may be reprinted or
reproduced or utilised in any form or by any electronic, mechanical,
or other means, now known or hereafter invented, including photocopying
and recording, or in any information storage or retrieval system,
without permission in writing from the publishers.

Trademark notice: Product or corporate names may be trademarks
or registered trademarks, and are used only for identification
and explanation without intent to infringe.

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Foxell, Simon.
A carbon primer for the built environment / Simon Foxell.
pages cm
Includes bibliographical references and index.
1. Sustainable construction. 2. Greenhouse gas mitigation.
3. Energy policy. I. Title.
TH880.F69 2014
696 – dc23
2013023809

ISBN13: 978-0-415-70557-8 (hbk)
ISBN13: 978-0-415-70558-5 (pbk)
ISBN13: 978-1-315-85751-0 (ebk)

Typeset in Bembo and Gill Sans
by Florence Production Ltd, Stoodleigh, Devon, UK
Printed in Great Britain by Ashford Colour Press Ltd

FSC
www.fsc.org
MIX
Paper from
responsible sources
FSC® C011748

A Carbon Primer for the Built Environment

In a world increasingly concerned about the impact of carbon dioxide and other greenhouse gases in the atmosphere on global climate, the *Carbon Primer* provides an understanding of the science, public policy and regulation intended to tackle climate change. It spells out the essential information needed for navigating the growing regulatory maze with confidence. The book:

- provides an explanation of climate change, why carbon has been targeted as the main culprit and how this will impact the working lives of architects;
- explains key concepts such as: carbon footprinting, contraction and convergence, concentration-based targets, the Energy Performance of Buildings Directive, decarbonising supply and reducing energy demand, as well as the relevance of government targets and international agreements;
- suggests an overall framework for achieving the carbon reduction targets and the requirements that will be placed on building designers;
- outlines requirements and common standards and codes – providing guidance on compliance mechanisms;
- suggests and examines likely models for future practice.

The book is essential reading for anyone wanting to familiarise themselves with the new landscape of carbon reduction in the built environment, with a particular focus on building design. It provides an accessible reference volume for information on particular policies, terms and initiatives, as well as key data and numbers that will assist initial carbon calculations.

Simon Foxell is the principal of The Architects Practice, author of a number of books, including *Mapping London* and the *RIBA Best Practice Guide to Starting a Practice* and the editor of 'The professionals' choice', a study of the future of practice. He is a member of the government's Green Construction Board Route-map group and was a member of the RIBA's Combating Climate Change advisory group. He is a senior member of the cross-industry think tank the Edge, which has made much of the running in developing thinking and policy on carbon reduction in the built environment.

To the members of the Edge for their essential input and counsel

此为试读，需要完整PDF请访问：www.ertongbook.com

Contents

Chapter 1

Background

Almost all international bodies, governments, public agencies, companies and expert bodies now approach climate change seriously, despite the background clamour from sceptics and others who view it as an obstacle to their immediate business objectives or lifestyle choice. They understand that business as usual is no longer possible in planning for the years and decades ahead; the increasingly challenging issue is how to prepare for the future.

As Margaret Thatcher said, in a speech to the United Nations in 1989, in the still early days of general climate change awareness: 'The evidence is there. The damage is being done. What do we, the International Community, do about it?'[1]

The urgency of dealing with climate change is now increasingly evident from the opening phrases of any relevant policy document:

> The Parties included in Annex I shall strive to implement policies and measures under this Article in such a way as to minimize adverse effects, including the adverse effects of climate change, effects on international trade, and social, environmental and economic impacts on other Parties, especially developing country Parties.
>
> (Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1998)

> Climate change is one of the most serious threats facing the world's environment, economy and society. But if we all act, the world can avoid its worst effects. The devastating floods, droughts and storms we have seen in the UK and across the world in recent years show all too clearly how vulnerable we are to climate extremes and how devastating they can be. And we have been warned that things will get worse. We have to take practical action to deal with flooding and severe weather. But we also need to tackle climate change by cutting the greenhouse gas emissions that cause it.
>
> (Climate Change: the UK Programme, Department of Environment, Transport and the Regions, 2000)

> The UK Government believes that climate change is one of the gravest threats we face, and that urgent action at home and abroad is required.
>
> (National Renewable Energy Strategy for the United Kingdom, Department for Energy and Climate Change, 2011)

As a result, we are awash with initiatives to deal with and cope with the issue at international, European, national and local levels. There is a sense of a gathering storm, but so far it has had relatively little impact on lifestyles or practices in the developed world, although the same cannot be said of the many poorer areas of the world affected by droughts or rising sea levels. The inhabitants of such places have had relatively little to do with the causes of the problems facing them and are generally powerless to make any changes to their way of life that will make a difference to the solution.

This book focuses on the nature of the problem, the responses at different levels and some of the potential solutions. The responses described are mainly at a European or UK level and sometimes relate only to England. This is not to ignore the global nature of the issue, but to recognise that most of the solutions are close to home, and, if we are going to tackle anything on the wider scale, we must first clean up our own act.

The following chapters will deal with the reasons behind the threat of climate change and the possible actions to be taken in greater depth, and it is possible to skip directly to them if you wish. What follows here is a brief overview, in very approximate terms, of current issues and responses.

Principles of climate change

The temperature of a body floating in a perfect vacuum, such as the Earth, relates directly to the amount of energy it absorbs. As its heat loss rises with its temperature, it will reach a stable temperature when it warms to the point when it is radiating energy at exactly the same rate as it receives it.

The only external source of energy that the Earth has is the sun, radiating energy at us at a reasonably constant rate, with only minor fluctuations on an 11-year periodic cycle. However, only about half the sun's energy is absorbed, and the other half is reflected back into space and lost again. The heat loss from the Earth itself is in addition to this reflected loss and, importantly, it is relative only to its temperature at its outer face, effectively that of the upper reaches of the atmosphere.

That the atmosphere gets colder as the distance from the surface of the planet increases now feels part of the natural order of things. However, it is neither intuitive (just ask Icarus) nor fully true – at a certain point, the tropopause, it starts to get warmer again, before eventually reverting to a downward gradient towards the effectively bitter cold of outer space. Vitally, for the warmth of the planet, the tropopause prevents the convective heat of rising warm air simply

此为试读，需要完整PDF请访问：www.ertongbook.com

dissipating into space, and the only-partial transparency of the atmosphere prevents it all being lost by radiation.

Looking at the sky on a clear night, with a crystal-clear view of stars billions of light years away, the atmosphere appears transparent enough; but this is only true for parts of the electromagnetic spectrum. In other parts of the spectrum, including the infrared section, the atmosphere is semi-opaque, and it is because the atmosphere is transparent to radiation from very hot bodies such as the sun and stars, and not to that from warm bodies such as the surface of the Earth and ourselves, that the planet has reached an equilibrium at a habitable, Goldilocks level – not too hot and not too cold. This is what is known as the greenhouse effect, the continued working of which is essential for our planetary comfort and survival.

The constituent parts of the atmosphere that absorb the infrared radiation and reduce its transparency are the larger and heavier molecules in the air, collectively known as the greenhouse gases (GHGs). They include water vapour (clouds) and particles of carbon (smoke and soot), but the most prevalent and long lasting of these GHGs is carbon dioxide (CO_2). CO_2 is the gas that we, and our cars, breathe out as we convert fuel into exhaust fumes, and that plants reabsorb as they use the energy of sunlight to convert it back into carbon-based molecules. In simplistic terms, the more CO_2 (together with the other GHGs) there is in the atmosphere, the more re-radiated heat is absorbed, and the higher the temperature of the Earth at equilibrium becomes.

Since the industrial revolution, mankind has been extracting greater and greater amounts of carbon-based fuel from the Earth and burning it to create energy. The CO_2 produced as a side-product has been finding its way into the atmosphere, and, as a result, the planet has begun to warm. It is now averaging approximately 0.6°C above pre-industrial (before 1750) temperatures, and current predictions for the increase in temperature at the end of the century range from 2.0°C to 6.4°C.[2] Such temperature changes would be disastrous for the ecology and liveability of the planet, and this is why scientists, politicians and campaigning groups are so concerned. (See Chapter 2 for greater detail.)

Recordings and commitments

Concern first surfaced in the scientific community in the 1960s, as it saw evidence of both CO_2 levels and temperatures rising when compared with the historic record being extrapolated from evidence in tree rings, ice cores and geological samples. The basic science of global temperatures had long been understood, following the work of Fourier and Arrhenius in the nineteenth century, and the rising temperature of the Earth had first been noted by Guy Callendar in the 1930s, but other parts of the jigsaw were only assembled when CO_2 measurements from high-altitude observatories, such as Mauna Loa in Hawaii, replaced the more traditional monitoring at sea level. Charles Keeling started measuring the CO_2 at Mauna Loa for the Scripps Institution of

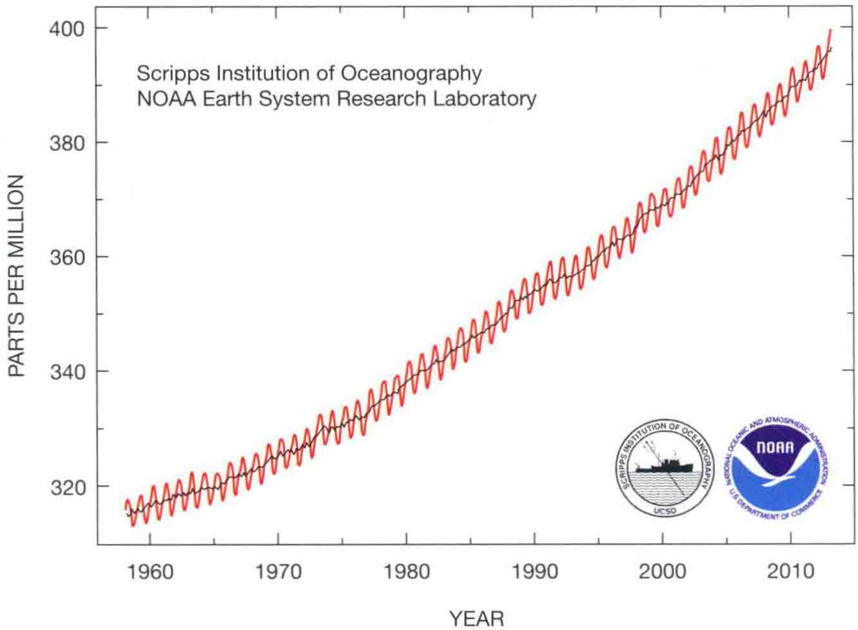

Figure 1.1 Atmospheric CO_2 recorded at the Mauna Loa Observatory in Hawaii from 1958 to 2013

Source: Data/image provided by National Oceanic and Atmospheric Administration, Earth System Research Laboratory, Global Monitoring Division, Boulder, CO, USA, http://esrl.noaa.gov/gmd/.

Oceanography in 1958 and each year saw a steady average rise in its concentration in the atmosphere; a rise that continues to this day (see Figure 1.1).

The issue attracted political attention in 1988, at just the point when international politicians were flushed with the success of the Montreal Protocol in banning gases identified as creating a hole in the ozone layer over Antarctica, and through the UN they rapidly put in place a series of bodies charged with assessing and controlling climate change, including the Intergovernmental Panel on Climate Change (IPCC) in 1988 and the United Nations Framework Convention on Climate Change (UNFCCC) established at the Rio Earth Summit in 1992. An international protocol to tackle the issue of climate change and with specific and binding CO_2 reduction targets was agreed in Kyoto in 1997, albeit a protocol that the United States never signed, and that Russia only ratified in 2003, Australia in 2007 and Turkey and Zimbabwe in 2009. A grand and internationally binding agreement was planned for the UNFCCC meeting in Copenhagen in December 2009, but it was a meeting that failed to agree anything of significance, leaving the world with a mixed set of targets and agreements and no clear way forward on overall reductions in GHG emissions.

Regionally, from Kyoto on, and even in the United States, emission reductions were tackled through local regulations and target setting, in part to meet national obligations under the Kyoto Protocol, and in part because of a genuine recognition of the problem and a determination to get ahead of the carbon reduction game. No country or regional grouping wanted to be burdened with heavy carbon polluting industry and power generation if they could help it, although some countries, such as China, saw no other way of achieving the growth that they desired even more. The European Union has set stringent carbon targets on its member states, as have individual countries within the EU.

The UK's requirement for an 80% cut in CO_2 emissions from 1990 levels, by 2050, as required by the Climate Change Act of 2008, is possibly the toughest of these commitments and is supported by a series of carbon budgets leading to 2050 that need to be met in turn. What is less clear is that the UK has put into place the mechanisms for adequately tackling the country's emissions and its physical and psychological reliance on burning fossil fuels to maintain its industry and the country's living standards.

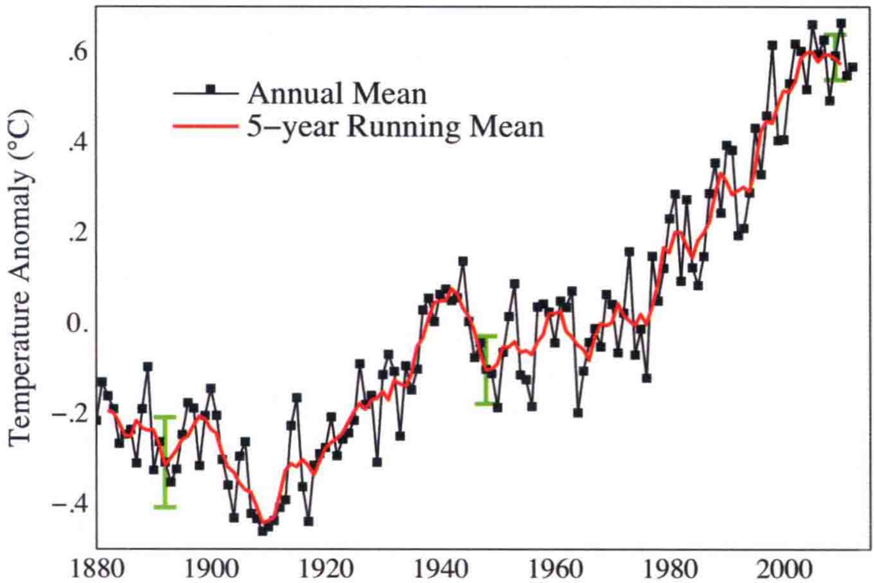

Figure 1.2 Global land–ocean temperature index

Source: NASA Goddard Institute for Space Studies. An updated version of the graph in James Hansen et al.'s paper, 'Global temperature change' (*Proceedings of the National Academy of Sciences*, 2006).

Official measures have included encouragement for renewable generating capacity, support for nuclear power in the UK at a level last seen in the 1970s, early stage investment in carbon capture and storage (CCS) technologies, a progressive tightening up of Building Regulation standards on heat and energy conservation and programmes of building energy efficiency measures. However, any real push for carbon reduction has yet to come. (See Chapters 5 and 6.)

Overall sustainability

Towards the end of the twentieth century, while the world was gradually becoming aware of the threat of climate change, a range of other environmental issues were also clamouring for attention, including; resource and energy supply shortages, decreasing availability of clean water, diminishing biodiversity and rising levels of pollution. The Earth Summit held in Rio de Janeiro in 1992 was convened to discuss the full range of issues that threatened the planet, with climate change and global carbon emissions as just one subject out of many. It is only since then that this has emerged as the most pressing, although there is a strong argument that it has had the effect of dangerously overshadowing the equally urgent issue of biodiversity loss.

The wide range of environmental issues led initially to a concern for overall sustainability responses and to a focus on the bigger picture. Rio produced a range of initiatives, including Agenda 21, that tackled the broad challenge of sustainable development. Around the same time several overall sustainability rating systems such as the Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED) were developed, which synthesise many issues to achieve a total weighted score, as well as government programmes such as Sustainable Communities, with a multiplicity of policy aims and outcomes. Unfortunately, such broad aims, without hard targets and effective monitoring, resulted in a lack of focus, with a tendency to trade one aspect of sustainability off against another, and to wilful claims of 'greenness' on the basis of a single item of sustainable design or equipment. The hard numbers of energy calculation, monitoring and managing were rarely attended to.

Within the overall sustainability agenda, there were a number of projects and programmes – largely sponsored outside mainstream government initiatives – that did try to answer hard questions of energy use and how to achieve very low or even net-zero carbon emissions. These included:

- The Probe studies: a series of post-occupancy studies running from 1995 to 2002 that looked in detail at the energy use of individual buildings. Accessible data on real buildings in use are still very hard to come by, and the Probe studies are a rare example of good, methodically researched information that has been fed back into the general knowledge bank on how buildings really perform and how that performance can be improved. See www.usablebuildings.co.uk

- Passivhaus: the Passivhaus approach, originated by Bo Adamson of Sweden and Wolfgang Feist of Germany in 1988, has grown from a terrace of four houses built in 1990 to upwards of 15,000 buildings, all designed to comply with a specific low energy standard of no more than 120kWh/m^2 per year. The approach includes rigorous testing of fabric performance. See www.passivhaustrust.org.uk
- BedZED: a housing development in the London Borough of Sutton (the Beddington Zero Energy Development), with ninety-nine homes and 1,400m^2 of workspace. Built in 2000–2002, the development had the ambitious aim to be zero carbon and generate all the reduced energy levels it required on site with renewable technologies. BedZED has succeeded in reducing electricity use from a local average of 5.5kWh/person/day to an average of 3.4kWh/person/day, but carbon footprints remain higher than hoped at 9.9T per year, in comparison with the UK average of 11T. See www.bioregional.com and www.zedfactory.com
- The Elizabeth Fry building: an academic building at the University of East Anglia containing a mix of lecture rooms and offices and the subject of one of the Probe studies. The highly insulated and sealed building uses a system of ventilated hollowcore slabs floors/ceilings for cooling. Completed in 1995, the Elizabeth Fry building remains one of the best energy-performing buildings in the UK in the 15 years since its occupation. The Probe study recorded CO_2 emissions of 44kg/m^2yr, in comparison with the ECON 19 good-practice benchmark for a type-3 office building of 96kg/m^2yr, or the typical benchmark in CIBSE TM46 of 89.6kg/m^2yr for a University campus. See *Building Services Journal*, April 1998, or Usable Buildings Trust.
- Numerous individual houses: a series of low-carbon innovators have used the individual house to explore, test and prove the viability of low-carbon living, and many zero-carbon houses have been built, or in some cases converted from existing buildings. See *Ecohouse*, by Roaf, Fuentes and Thomas (2007), or the Low Energy Buildings Database, www.retrofitforthefuture.org

All these examples, along with many others as the impetus for change has grown, have led the way for a greater focus on energy performance in buildings and a downplaying of general green claims. In turn, they have led to a confidence to legislate for better performance through the Building Regulations and among clients and funders specifying higher levels of performance.

Future scenarios

The threat of climate change has made the need to plan for the medium- and long-term future compelling, and numerous organisations have elaborated scenarios describing the path to 2050 and beyond if the threat is going to be countered. A number of these are described further in Chapter 10.

With or without reduction, or mitigation, of carbon emissions, the climate is due to change. There is an approximate lag in the period between the release of GHGs into the atmosphere and a measurable change in average global temperature of almost forty years. The lag is due to a range of factors, but a major contributor is the thermal inertia of the oceans. Projections suggest that, by 2050, temperatures may be up to 2°C higher than 1990 levels – an increase frequently described as the maximum safe level for planetary systems – but, even under the most ambitious scenarios for carbon mitigation, temperature rise can only be limited to a 1.5°C rise and kept to just under 2°C by the end of the century.

The temperature rises already in train will require adaptation measures to be taken, not least to the building stock (see Chapter 12), but, currently, the greatest urgency is being given to reducing carbon emissions to a stable level – a level that needs to be no greater than the rate at which planetary systems are capable of absorption. The UK has legislated for such reductions in the

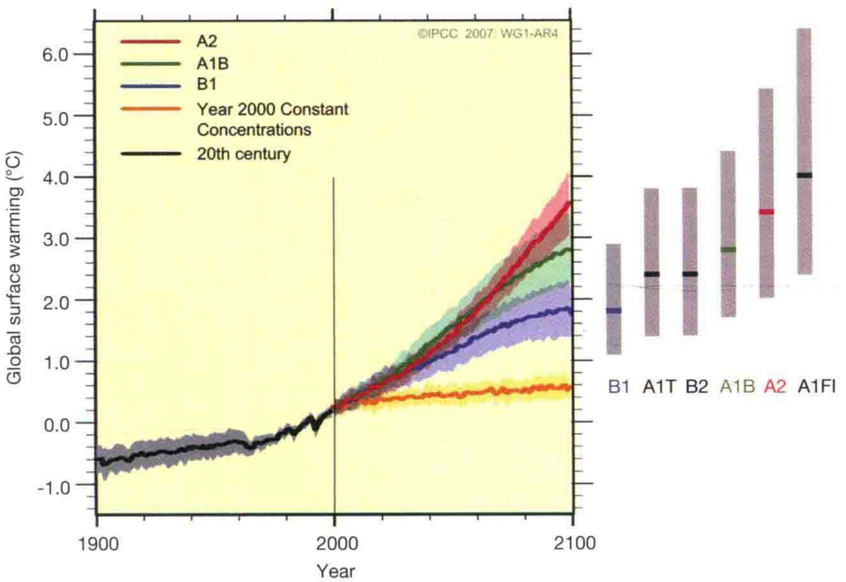

Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the* ***likely*** *range assessed for the six SRES marker scenarios. The assessment of the best estimate and* ***likely*** *ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

Figure 1.3 Graph showing global warming assessed by the IPCC for a range of scenarios

Source: IPCC, Fourth Assessment Report, Climate Change Science 2007, The Physical Science Basis, Summary for Policy Makers, p14.

此为试读，需要完整PDF请访问：www.ertongbook.com