BUILDING FOR A CHANGING CLIMATE

The Challenge For Construction, Planning And Energy

Peter F. Smith

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Introduction

This book is about a scenario for the future that we hope will not happen, namely a rise in average global temperature of 4°C, within the century, with all which that implies. However, the book is not based on the premise that such a temperature rise is inevitable, although there is increasing concern among climate scientists that it is more than possible. Here the argument is that while we should hope for the best, we should prepare for the worst.

There is growing scientific agreement that the impacts of climate change predicted in the Intergovernmental Panel on Climate Change (IPCC) report of 2007 were seriously underestimated. In February 2009 Dr Chris Field, co-chair of the IPCC made this assertion: 'We now have data showing that, from 2000 to 2007, greenhouse gases increased far more rapidly that we expected, primarily because developing countries, like China and India, saw a huge upsurge in electricity power generation, almost all of it based on coal' (quoted by Ian Sample in the *Guardian* 16 February 2009 'The tropics on fire: scientists' grim vision of global warming').

The purpose of the book is to explore the implications for buildings and cities based on the assumption that the world will continue on the path of the 'high emissions scenario (HES)', what used to be called 'Business as Usual (BaU)'. Coupled with climate change is the fact that the ratio between the production of oil and the rate of demand has reached its peak, soon to be followed by gas. So security of energy is also a matter of great importance, not least because the built environment is the sector responsible for the highest emissions of carbon dioxide.

The UK government in particular is constantly asserting that changes in personal behaviour will be necessary if national CO_2 emissions targets are going to be achieved. An assumption behind the book is that voluntary actions will not be nearly enough to halt the advance of climate change. Societal changes are desirable but unenforceable. Governments may rely on market forces to bring about change, but these are unpredictable and driven by the profit motive. It is the unrestrained appetite for profit that has largely created the current economic predicament; it is unwise to assume it will get us out of it.

Only governments can bring about the fundamental changes that the times require, through a combination of incentives and regulations. Planning laws (not guidance notes), stiff and enforceable building regulations and direct taxes on carbon, independent of market forces, are the only way to make radical change happen. Governments may eventually come round to this view, but it will probably be too late to prevent catastrophic climate impacts.

The underlying theme of the book is that, given the cluster of uncertainties that darken the future, the precautionary principle dictates that we should be preparing now for a more hostile environment and change building practices accordingly. Also, ultimately carbon-free energy will not just be an option but a necessity. As Nicholas Stern stated in his forceful review, *The Economics of Climate Change* (2006) investing now in adapting to future climate impacts will be considerably more cost-effective than taking emergency measures after the event. Buildings are a long-term investment, especially housing, and so his warning is especially relevant to this sector.

The book is aimed at an international readership. Where UK examples are cited, it is because they have implications for many developed and developing nations. The text falls into three sections. The first three chapters consider the reasons why there should be concern about the future effects of climate change since the world shows little inclination to deviate from the path of BaU. In the 2007 report of the IPCC BaU has been superseded by the less blame-loaded HES. First there is a brief survey of the scientific evidence of global warming across a spectrum of indicators. From this evidence it follows that there will be impacts, the severity of which will depend on the level and pace at which CO_2 emissions are stabilized in the atmosphere.

The second part, which constitutes the main body of the book, considers the implications of the HES scenario for buildings ranging from existing and new-build housing to non-domestic buildings. Since the top rating under the UK Code for Sustainable Homes assumes the inclusion of integrated or onsite renewable energy, this also receives consideration. The outlook for non-domestic buildings rounds off this section.

In the third section the focus is on energy, starting with the outlook for conventional fuels and the speculations about the levels of reserves of oil and gas. Whilst small-scale renewable technologies are featured earlier, this part considers the potential for utility or grid-scale renewable energy within the energy mix.

To finish, there is a discussion about the prospects for stemming the progress of global warming by means of geo-engineering: mirrors or 'pies' in the sky?

Peter F. Smith
October, 2009

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List of Acronyms and Abbreviations

ABC	Algae Biofuels Challenge (Carbon Trust)
ABI	Association of British Insurers
AC	alternating current
ACH	air changes per house
AHU	air handling unit
ASHP	air source heat pump
ASPO	Association for the Study of Peak Oil
BAS	British Antarctic Survey
BaU	Business as Usual
BIPV	building integrated photovoltaics
BMS	building management system
BRE	(trading name of the) Building Research Establishment
BREEAM	BRE Environmental Assessment Method
BSF	Building Schools for the Future
CABE	Commission for Architecture and the Built Environment
CBI	Commercial Buildings Initiative
CCS	carbon capture and storage
CDM	Clean Development Mechanism
CdTe	cadmium telluride (solar cell technology)
CEO	chief executive officer
CER	certified emissions reduction
CERT	Carbon Emissions Reduction Target
CHP	combined heat and power
CIBSE	Chartered Institution of Building Services Engineers
CIGS	copper, indium, gallium and selenium (solar cell technology)
CO_2e	CO_2 equivalent
Comare	Committee on Medical Aspects of Radiation in the Environment
COP	co-efficient of performance
CSH	Code for Sustainable Homes
CSHPSS	central solar heating plants for seasonal storage
cSi	crystalline silicon
CSP	concentrated solar power
CTL	coal to liquids
DC	direct current
DCLG	Department for Communities and Local Government
DCSF	Department for Children Schools and Families
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DoE	Department of Energy (US)
DSY	Design Summer Year

DfT	Department for Transport
EESoP	Energy Efficiency Standards of Performance
ENSO	El Niño Southern Oscillation
EPC	Energy Performance Certificate
EPR	Evolutionary Power Reactor
EPSRC	Engineering and Physical Sciences Research Council
E-REV	extended range electric vehicle
ESCO	energy service company
EST	Energy Saving Trust
ETS	Emissions Trading Scheme (Europe)
EU	European Union
FIT	feed-in tariff
GDP	gross domestic product
GIS	Greenland ice sheet
GM	General Motors
GNEP	Global Nuclear Energy Partnership
GSHP	ground source heat pump
Gtoe	gigatonne of oil equivalent
HES	high emissions scenario
HHP	Hockerton Housing Project (Nottinghamshire)
HiPER	High Power Laser Energy Research
HTT	hard to treat
HVDC	high voltage direct current
ICE	internal combustion engine
IEA	International Energy Agency
IGCC	integrated gasification combined cycle
IHT	interseasonal heat transfer
IIIG+	third generation
IPCC	Intergovernmental Panel on Climate Change
ISE	Institute for Solar Energy Systems (Fraunhofer, Germany)
IT	information technology
LA	local authority
LZC	low or zero carbon
MOD	Ministry of Defence
mpg	miles per gallon
Mtoe	million tonnes of oil equivalent
NAS	National Academy of Science (US)
NGO	non-governmental organization
NHS	National Health Service
NIA	Nuclear Industry Association
NREL	National Renewable Energy Laboratory (US)
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of Oil Exporting Countries
OTEC	ocean thermal energy conversion
PCMs	phase change materials
PEM	Proton Exchange Membrane (or Polymer Electrolyte Membrane)
PG&EC	Pacific Gas and Electric Company (US)
PIV	Pujiang Intelligence Valley
POE	post occupancy evaluation

ppm	parts per million
ppmv	parts per million by volume
PPS	Planning Policy Statement
PRT	personal rapid transit
PV	photovoltaic (cell)
PVT	PV/thermal
PWR	pressurized water reactor
RIBA	Royal Institute of British Architects
RSPB	Royal Society for the Protection of Birds (UK)
SAP	Standard Assessment Procedure
SIPS	structural insulated panels
SME	small to medium-sized enterprises
SMR	small to medium sized reactor
SOFC	solid oxide fuel cell
SRES	Special Report on Emissions Scenarios (IPCC)
SSTAR	small, sealed transportable, autonomous reactor
TCPA	Town and Country Planning Association
TIM	transparent insulation material
TREC	Trans-Mediterranean Renewable Energy Cooperation
UEA	University of East Anglia
UGC	underground gasification of coal
UHI	urban heat island
UKCIP	UK Climate Impacts Programme
UK-GBC	United Kingdom Green Building Council
VHC	volumetric heat capacity
VIVACE	vortex induced vibrations for aquatic clean energy
VLS-PV	very large-scale photovoltaic systems
VOC	volatile organic compound
WAM	West African monsoon
WEC	World Energy Council
WWF	World Wide Fund for Nature
ZEH	'zero-energy' homes

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Prepare for Four Degrees

The UK government issued a report in summer 2008 entitled: *Adapting to Climate Change in England: A Framework for Action* (Defra). This is a clear statement of the perceived scope of government responsibility in this matter. In his Introduction the Secretary of State for the Environment, Hilary Benn, conceded that:

> *Even with concerted international action now, we are committed to continued global warming for decades to come. To avoid dangerous climate change we must work, internationally and at home, to reduce greenhouse gas emissions. Even so, we will have to adapt to a warmer climate in the UK with more extreme events including heat waves, storms and floods and more gradual changes, such as the pattern of the seasons.*
>
> (Defra, 2008a, pp4–5)

The report later explains the role of government which is:

> *Raising awareness of changing climate … will encourage people to adapt their behaviour to reduce the potential costs as well take advantage of the opportunities.*
>
> (Defra, 2008a, p20)

Finally the report concedes that 'Governments have a role to play in making adaptation happen, starting now and providing both policy guidance and economic and institutional support to the private sector and civil society' (Defra, 2008a, p8). In other words, 'over to you'.

Getting down to the detail, the report's action plan is divided into two phases. The objectives of phase 1 are:

- develop a more robust and comprehensive evidence base about the impacts and consequences of climate change in the UK;
- raise awareness of the need to take action now and help others to take action;
- measure success and take steps to ensure effective delivery;
- work across government at a national, regional and local level to embed adaptation into Government policies, programmes and systems.

In terms of the first objective, there is already enough evidence to gauge the impacts that will affect society, in particular urban society. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) published between February and April 2007 contains data that should provide incentives to all concerned with the built environment to raise their sights to meet the extraordinary challenges that lie in wait as climate changes. However, since its publication, the IPCC report has come under some criticism.

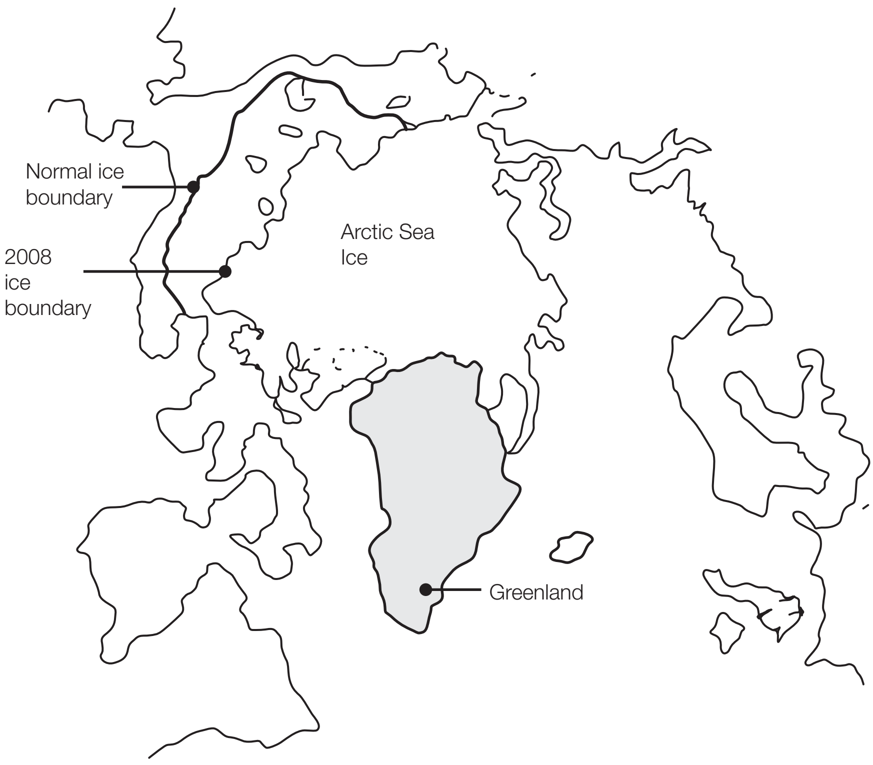
The Defra document used the IPCC report as the framework for its adaptive strategies. The problem with the IPCC report is that the cut-off date for its evidence base was the end of 2004. Since then, there has been a considerable accumulation of scientific evidence that global warming and climate change have entered a new and more vigorous phase since 2004. This has caused scientists to dispute some of the key findings of the report. To understand why this is important to all concerned with adaptation strategies for buildings, it is worth summarizing the various divergences from the IPCC.

First, the IPCC Report has been criticized for understating projections of climate impacts, not least by Dr Chris Field co-chair of the IPCC and director of global ecology at the US Carnegie Institute. In an address to the American Association for the Advancement of Science he asserted that the IPCC report of 2007 substantially underestimated the severity of global warming over the rest of the century. 'We now have data showing that, from 2000 to 2007, greenhouse gases increased far more rapidly than we expected, primarily because developing countries, like China and India, saw a huge upsurge in electric power generation, almost all of it based on coal' (reported in the *Guardian*, 16 February 2009).

This has been endorsed by James Hansen (Hansen et al, 2007), director of the NASA Goddard Space Institute, who believes that the IPCC prediction of a maximum sea level rise by 2100 of 0.59m to 'be dangerously conservative'. Reasons include the fact that ice loss from Greenland has tripled since 2004, making the prospect of catastrophic collapse of the ice sheet within the century a real possibility. The IPCC assumed only melting by direct solar radiation, whereas melt water is almost certainly plunging to the base of the ice through massive holes or moulins which have opened up across the ice sheet. This would help lubricate and speed up the passage of the ice sheet to the sea.

According to Dr Timothy Lenton (2007) the tipping point element with the least uncertainty regarding its irreversible melting is the Greenland ice sheet (GIS). Above a local temperature increase of 3°C, the GIS goes into mass melt and possible disappearance. As the Arctic is warming at about three times the global average, the corresponding global average is 1–2°C.

This rate of warming has resulted in the Arctic sea ice contracting more extensively in 2008 than in any previous year. A satellite image recorded on 26 August 2008 shows the extent of



Source: Image: Derived from the US National Snow and Ice Data Center

Figure 1.1 Extent of Arctic sea ice on 26 August 2008 compared with the average extent 1979–2000 summer melt compared with the average melt between 1979 and 2000 (Figure 1.1).

As further evidence of impacts, 2007 has revealed the largest reduction in the thickness of winter ice since records began in the early 1990s.

Whilst the 2007 IPCC report considered that late summer Arctic ice would not completely disappear until the end of the century, the latest scientific opinion is that it could disappear in late summer as soon as three to five years hence (*Guardian*, 25 November 2008, p27). One consequence of this melt rate is that an increasing area of water is becoming exposed and absorbing solar radiation. According to recent research, the extra warming due to sea ice melt could extend for 1000 miles inland. This would account for most of the area subject to permafrost. The Arctic permafrost contains twice as much carbon as the entire global atmosphere (ref *Geophysical Research Letters*, *Guardian*, 25 November 2008, p27). The most alarming aspect of this finding is that the effect of melting permafrost is not considered within global climate models, so is likely to be the elephant in the room.

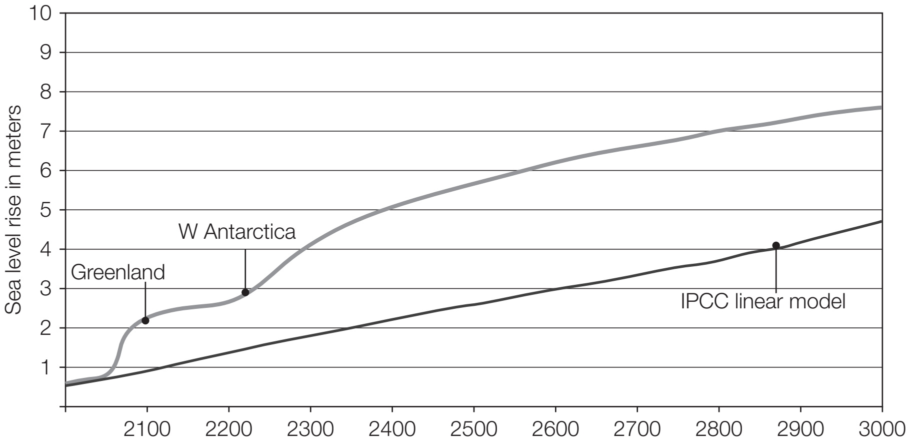
The latest evidence of climate change from Antarctica has come from the British Antarctic Survey (BAS). It reported in 2008 that the massive Wilkins ice shelf is breaking off from the Antarctic Peninsular. The 6180 square miles of the shelf is 'hanging by a thread' according to Jim Elliott of the BAS. The importance of ice shelves is that they act as buttresses supporting

Source: Photo Jim Elliott, BAS

Figure 1.2 Wilkins ice shelf undergoing calving

the land-based ice. This part of the Antarctic ice sheet has the least support from ice shelves. When it breaks away completely, this will be the seventh major ice shelf in this region to collapse. In January 2009 Dr David Vaughan of the BAS visited the ice shelf 'to see its final death throes'. He reported that 'the ice sheet holding the shelf in place is now at its thinnest point 500m wide. This could snap off at any moment' (Figure 1.2).

These are amongst the reasons why the Tyndall Centre for Climate Change Research has taken issue with the IPCC over its prediction that global warming will produce change on an incremental basis or straight line graph. Tyndall has produced an alternative graph linking temperature change to sharp and severe impacts as ice sheets melt; Figure 1.3 illustrates both



Source: Lenton et al, 2006

Figure 1.3 Potential for abrupt changes compared with linear IPCC forecast scenarioa. The IPCC has since come to accept the validity of Tyndall's scenario.

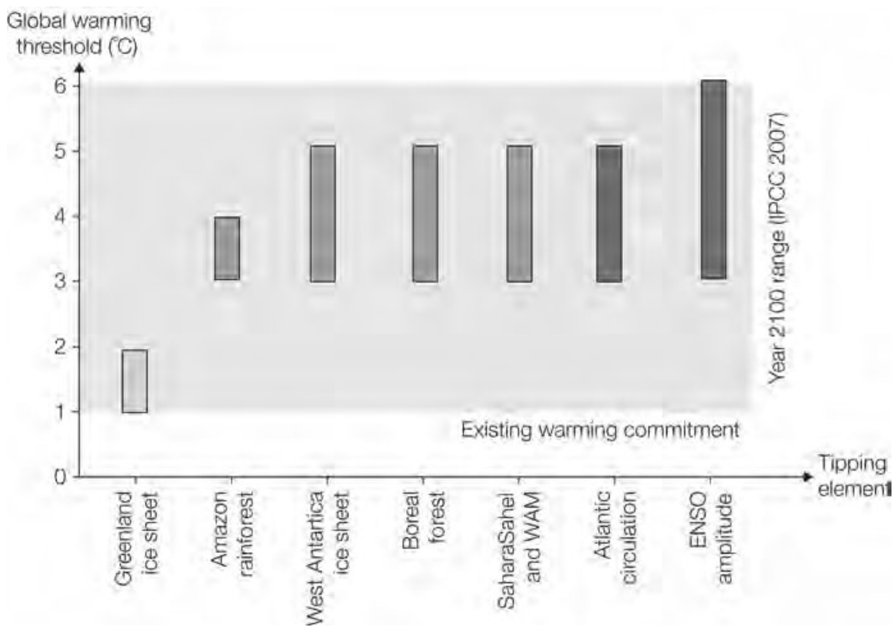
The Tyndall Centre has produced a timetable of suggested tipping points for various climate change impacts such as the melting of Greenland ice sheet which, it indicates, is underway already (Figure 1.4).

The idea that climate changes could be abrupt has also received endorsement from proxy evidence from the Arctic. This relates to the Younger Dryas cold period, which lasted ~1300 years and ended abruptly about 11,500 years ago. Samples from insects and plants of the period indicate that the end of this cold episode was dramatic. This has been reinforced by ice cores that show that there was an abrupt change when the temperature rose around 5°C in ~3 years. This is just one example of many sharp changes revealed in the ice core evidence and offers little room for confidence that such a change will not happen in the near future for the reasons outlined by James Hansen above.

Inevitable warming

Hansen and colleagues (Hansen et al, 2007) suggested that the Earth climate system is about twice as sensitive to CO_2 pollution than suggested in the IPCC century-long projection. A conclusion that followed is that there are already enough greenhouse gases in the atmosphere to cause 2°C of warming. If true, this means the world is committed to a level of warming that would produce 'dangerous climate impacts'. The team has concluded that 'if humanity wishes to preserve a planet similar to the one in which civilisation developed and to which life on Earth is adapted … CO_2 will need to be reduced from its current 385ppm to, at most, 350ppm'. They suggest that this can only be achieved by terminating the burning of coal by 2030 and 'aggressively' cutting atmospheric CO_2 by the planting of tropical forests and via agricultural soils.

John Holdren, president of the American Association for the Advancement of Science



Source: Lenton, 2007

Figure 1.4 Tyndall tipping points

and appointed to a key post in the Obama Administration, has added weight to the argument: 'if the current pace of change continued, a catastrophic sea level rise of 4m (13ft) this century was within the realm of possibility' (BBC interview, August 2006).

Optimism over gains in energy efficiency

A further problem with the IPCC report has been explained by the UK Climate Impacts Programme (UKCIP) in a 2008 paper in *Nature* by Pielke, Wigley and Green. This paper claims that the technological challenge required to stabilize atmospheric CO_2 concentrations has been underestimated by the IPCC. In particular the IPCC Special Report on Emissions Scenarios (SRES) makes its calculations on the assumption that there will be much greater energy efficiency gains than is realistic, thereby understating the necessary emissions reduction target.

Pielke et al argue that the IPCC SRES scenarios are already inconsistent in the short-term (2000–2010) with the recent evolution of global energy intensity and carbon intensity. Dramatic changes in the global economy (China and India) are in stark contrast to the near-future IPCC SRES. This leads Pielke et al (2008) 'to conclude that enormous advances in energy technology will be needed to stabilise atmospheric CO_2 concentrations'.

The amended Stern Report

A further blow to the IPCC was administered by Nicholas Stern. His UK government sponsored report, known as the *Stern Review on the Economics of Climate Change* was based on IPCC data. Since its publication in 2006, Stern has admitted that he underestimated the threat posed by climate change as posited by the IPCC. He said:

> *emissions are growing much faster than we thought; the absorptive capacity of the Earth is less than we'd thought; the risks of greenhouse gases are potentially much bigger than more cautious estimates; the speed of climate change seems to be faster.*
>
> (Stern, 2009, p26)

Stern concludes: 'Last October [2007] scientists warned that global warming will be "stronger than expected and sooner than expected" after new analysis showed carbon dioxide is accumulating in the atmosphere much more quickly than expected' (2006, p26). The Stern Review recommended that greenhouse gases should be stabilized at between 450 and 550ppm of CO_2e (equivalent). In January 2009 Stern amended the limit to 500ppm.

Scientists tend to refer solely to carbon dioxide since it is the gas that is the dominant driver of global warming and is the one that is most readily associated with human activity. It comprises around two-thirds of all greenhouse gases. On the other hand, politicians and economists often lump together all greenhouse gases and then refer to their CO_2 equivalent (CO_2e).

This means that the call to stabilize at 500ppm CO_2e equates to 333ppm CO_2, which, coincidentally, is close to the limit set by James Hansen (above) if the world is to achieve climate stability at a tolerable level. The latest concentration is 387ppm!

This view was reinforced by the Royal Society. On the 1 September 2008 it published a series of scientific papers in *Philosophical Transactions A* on the topic of geo-engineering as a way of countering global warming. This will feature in the closing chapter. At this point it is worth citing its authors on the reasons for embarking on this study, which are: 'There is increasingly the sense that governments are failing to come to grips with the urgency of setting in place measures that will assuredly lead to our planet reaching a safe equilibrium.' In a paper by Alice Bows and Kevin Anderson (Anderson and Bows, 2008), they state: 'politicians have significantly underestimated the scale of the climate challenge'. For example, 'this year's G8 pledge to cut global emissions by 50% by 2050 in an effort to limit global warming to 2°C, has no scientific basis and could lead to "dangerously misguided" policies'.

Furthermore, the authors cast doubt on the realistic chances of stabilizing carbon emissions