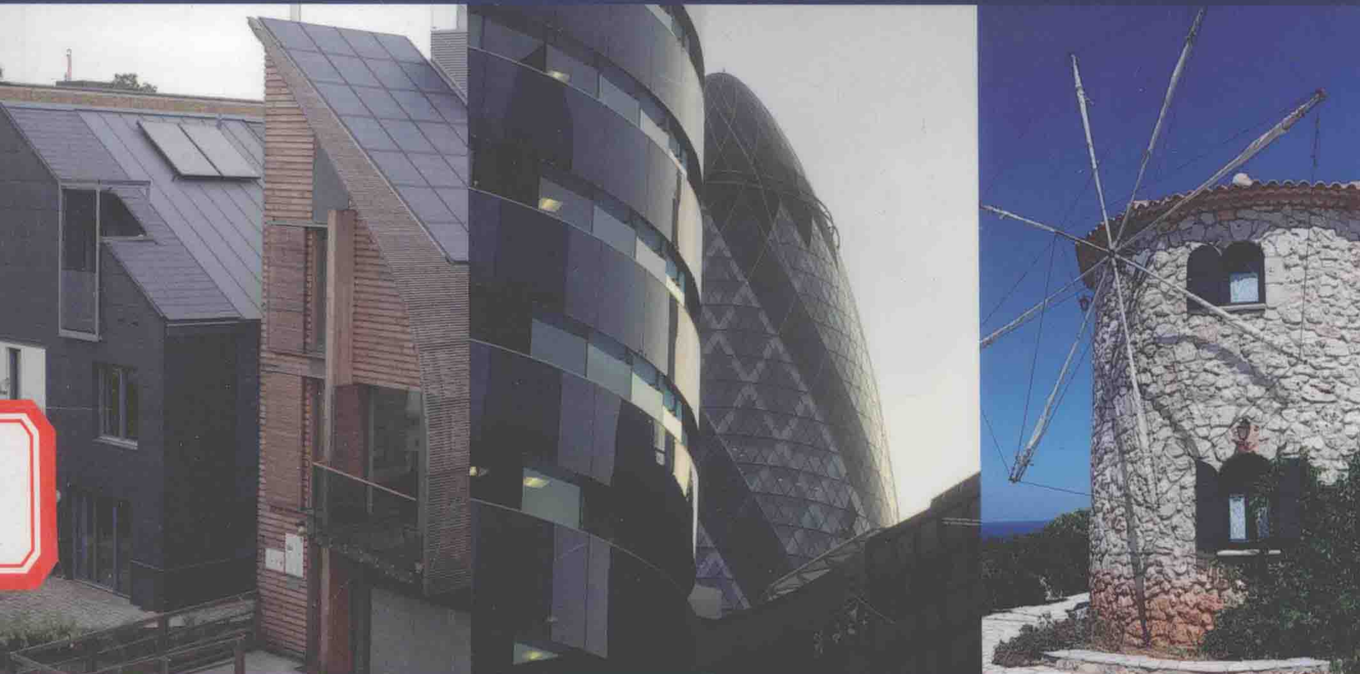
STEVE GOODHEW

Sustainable Construction Processes

A Resource Text



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Preface

This text follows the process of sustainable construction from an idea to the creation of a sustainable building.

When a client or architect imagines a sustainable building, there are a myriad of systems, processes, guidelines, and standards that are negotiated in the journey from blueprint to completed building.

Sustainable Construction Processes: A Resource Text provides a source guide along this journey, whilst also discussing the challenges and uncertainties that arise when constructing a building worthy of its sustainable credentials.

The idea for this book came from the need for a text, suited to Plymouth University's students, that would cover sustainable construction as a process rather than simply focusing on the needs of a designer. It complements but does not duplicate the many other texts on sustainable construction that focus on the design of buildings, procedures, links to sustainable development, climate change, or sustainable cities. Rather, it is concerned with how the best-laid plans of designers, planners, engineers, consultants, and project managers come to fruition, and the process though which buildings are (or are not) constructed in a fashion that makes these plans work in practice. This is a fast-moving field of study, and inevitably different policies, facts, figures, and assessment systems change with a remarkable rapidity. However, the underlying principles of how we build sustainably and the basic tools that are required for this task remain relatively static.

This book introduces the rationale and history that lie behind the drivers for sustainable construction. Decisions inform even the earliest stage of a build, such as the client deciding whether they require a new or refurbished building. From this beginning, the text follows the decision-making process for each stage of a building's life cycle to illuminate the requirements and challenges of designing, constructing, and occupying sustainable buildings. It leads the reader through the areas of sustainable procurement: how we can obtain buildings that will meet the needs of our clients, as well as the broader needs of society and the environment, without costing us and our communities too much. The elements of building design related to energy, water, and materials are examined to demonstrate how construction processes can ensure that our buildings are truly sustainable. Assessment systems are introduced and their basic underlying principles discussed. The challenge of anticipating the behaviours of occupants and the practicalities of building with some of the new sustainable technologies are considered. Finally, we consider potential areas of growth and present some contrasting visions for the future of sustainability.

About the author

Steve Goodhew is Professor of Environmental Building and Discipline Leader of the School of Architecture, Design, and Environment at Plymouth University. He has carried out research and taught in the area of sustainable construction for over 20 years. His main focus has been the assessment and monitoring of existing buildings specialising in the in situ measurement of the thermal properties of building materials, particularly the use of thermal imaging.

Steve is the Associate Head of Research and a fellow of the RICS and the CIOB. He studied at Bristol Polytechnic, London University, and Cranfield Institute of Technology, gaining his PhD from Plymouth University.

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Contents

1. Introduction to sustainable construction

1.1 Why a book focused on sustainable construction?

This book explores the concepts and practicalities that lead to sustainable construction. Numerous volumes describe and advise the designer how to maximise the sustainability of buildings; this text supplements these by focusing on the construction and operational aspects of sustainable buildings, as well as some of the more fundamental design-related considerations. This is therefore not a text that will provide detailed designs of finished, green, eco-friendly, energy efficient, or net zero carbon buildings. However, this volume provides the reader with the underlying principles of how to build sustainably and then assesses many of the tools required for the task. From energy to materials and from procurement to operation, all aspects play their part in turning a theoretically sustainable building project into a reality.

Attention must be paid to the sustainability of constructing buildings at a considerably earlier stage than their construction or even design. The decisions that lead to the procurement of a building strongly influence the sustainability of the completed project. Does a client require a new building or could refurbishment of an existing building meet the salient objectives?

What a building is made of, its use of technology, the appropriateness of the building form and how the building's occupants can operate the building influence the sustainability of a project, both now and far into the future. This book guides the reader through the underpinning data and theories that have influenced the majority of building professionals, as well as their counterparts in local and national governments, to legislate and produce guidance to encourage sustainable building as the norm of construction.

Sustainable Construction Processes: A Resource Text, First Edition. Steve Goodhew.

1.2 Why construct sustainably?

'But the world cannot become a factory, nor a mine. No amount of ingenuity will ever make iron digestible by the million, nor substitute hydrogen for wine' John Ruskin (1862).

Many people view the requirements of governments, local authorities, companies, and clients to construct buildings and structures sustainably to be an optional extra, an additional burden on business, believing sustainable construction methods should only be adopted because of a need to comply with legislation or for financial reasons. For these people, sustainable construction is not felt to be an explicit part of the mainstream building industry. This to an extent is understandable; the underlying issues and the benefits of sustainable buildings and construction processes are often not clearly articulated. Often the value of constructing sustainably is accrued over time or is not easily measured (but is nevertheless tangible). Yet to the users, owners, and designers of buildings, the value of sustainable construction is high. There are analogies in other walks of life. It can be more effective to integrate healthy habits into daily routines that then become everyday, rather than artificially adding a compensatory regime to an otherwise unhealthy lifestyle. In this sense sustainable construction integrated as the norm is more desirable than seeing it as a set of added requirements. Good, reliable information that offers a believable basis for the promise of living X years longer, feeling better, and being able to do more might make enforcement/legislation less necessary. As with buildings, a construction industry that relies less on imported non-renewable energy and provides living, working, and other spaces that are comfortable, long-lasting, socially fit for purpose, and economical to run can have many immediate and longer-term benefits for us all. Through a clearer articulation of the benefits, identification of relevant tools, and analysis of possible solutions, this book will aid the reader in the search for what sustainable construction means to them and how, in their own way, they can help construct sustainably.

1.3 How can we define sustainability?

Oxford Dictionaries defines *sustainability* as being 'able to be maintained at a certain rate or level' and sustainable development as 'economic development that is conducted without depletion of natural resources' (Oxford Dictionaries 2014). However, the most often encountered definitions in the field of sustainable construction refer to sustainable development, and definitions are evolving continually. In 1987 the United Nations Commission on Environment and Development (the Brundtland Commission) drew attention to the fact that economic development often has a detrimental effect on society and the planet. The report defined sustainable development as 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development 1987).

This definition contains two key concepts:

- the concept of needs, in particular, the essential needs of the world's poor, to which overriding priority should be given, and
- the idea of limitations imposed by technology and social organisation on the environment's ability to meet present and future needs (IISD 2015).

In 1995 the definition was further refined, highlighting three interconnected elements of sustainability:

> Economic development, social development and environmental protection are interdependent and mutually reinforcing components of sustainable development, which is the framework for our efforts to achieve a higher quality of life for all people.
>
> (World Summit on Social Development 1995)

This clarification leads to a concept of sustainability that includes three core components, known as the three E's of sustainable development. These are equity, environment, and economics. So, sustainability can be viewed in the broadest sense as balanced living within the three pillars of sustainable development: economic growth, social progress, and environmental protection. This is also sometimes known as 'the triple bottom line', which could be described as an expanded baseline for measuring performance, adding social and environmental dimensions to the traditional monetary yardstick. Some further development of the triple bottom line also includes governance—how to enact the three pillars—although to a certain extent this is implied in the triple bottom line. A number of other commentators have introduced a fourth pillar, this varying in focus from culture to administration, reminding us that sustainable development has to be culturally appropriate and enacted. (Due to the varying scope of these proposed fourth pillars, here we will stick to three).

Although the three E's model is commonly accepted as the basis for any analysis of sustainability, the Forum for the Future has provided a more penetrating model for analysis of sustainability. Much of this model also takes detail from another system called the Natural Step. More information concerning the Natural Step can be found in Chapter 6.

The model comprises categories of analysis within five broad forms of capital (Forum for the Future 2013):

1. Manufactured capital comprises material goods, or fixed assets that contribute to the production process rather than being the output itself.
2. Natural capital is any stock or flow of energy and material that produces goods and services; this can include carbon sinks that absorb, resources that provide, and processes that maintain.
3. Human capital consists of people's health (both physical and mental), knowledge, skills, and labour—all the things needed for productive work.
4. Social capital concerns the human relationships, partnerships, and institutions that help us maintain and develop human capital in partnership

with others, for example, families, communities, businesses, trade unions, schools, and voluntary organisations.
5. Financial capital is the assets that can be owned and traded, such as shares, bonds, notes, and coin. These play an important role in our economy, enabling other types of capital to be owned and traded.

Using the separate categories described above, the implications of the actions and processes chosen for a construction project or the activities of a construction company can be analysed. However, collective decisions over a period of time can indicate the stance of a company or individual. The reactions of people and organisations in turn can be divided into four very broad leadership or cooperative stances. As they are sometimes used to classify actions or attitudes it is useful to understand their meanings.

1. The Thomist position (coming from the term 'doubting Thomas'), leading from the broad-based doubts concerning any link between environmental problems and our way of life.
2. The 'business as usual' or the 'Macawber syndrome', by which people accept that there are problems with the world's systems but believe that solutions will 'turn up', so they do not need to concern themselves unduly.
3. The 'no-regrets' philosophy. This approach notes the problems with the world's systems and takes the view that concerted action might be helpful as long as it does not 'break the bank'.
4. The precautionary principle. This precautionary principle takes the logical argument that many resources will have to be employed to reduce the impact of unsustainable development, and if in doubt we should take whatever reasonable action is necessary to avoid disaster.

None of these stances have set boundaries, and in some instances people or organisations can exhibit traits that could be ascribed to more than one of these positions.

Now that sustainability has been defined in a general sense, it is appropriate to understand the drivers—environmental, historical, social, and economic—that push governments, companies, and individuals toward a sustainable approach.

1.3.1 Drivers for environmental sustainability

Many drivers for the environmental element of the three pillars exist. Geographically some are close to home: the visible impacts of agricultural land being built upon, or increases in local traffic flow. Others are regional: increased emissions from regional power stations, or the global impact of increasing long-haul air traffic. Often the actions that are taken in everyday life, particularly when constructing a building, can have an impact upon the local, regional, and global stages. The next section of this chapter will introduce some of the science and evidence behind those effects. Figure 1.1 shows a number of events that have triggered or influenced the current economic, technological, social, and environmental situation. It can be

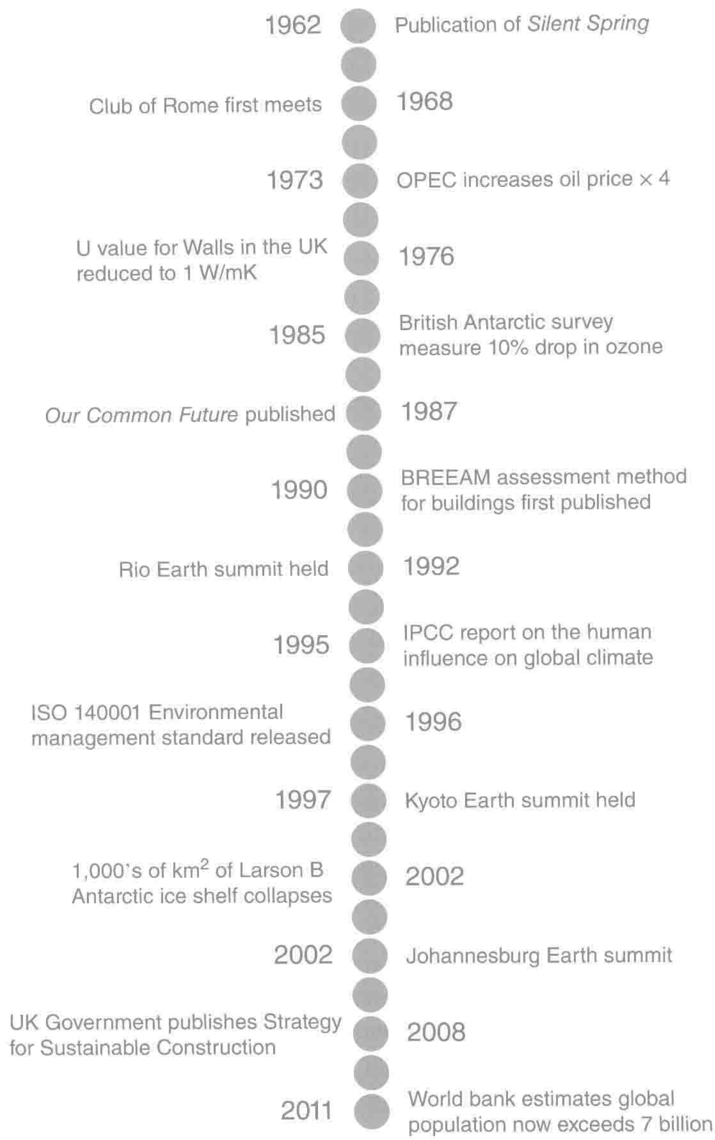

Figure 1.1 Events that have triggered or influenced the current economic, technological, social, and environmental situation.

seen that the publication of evidence linking human activity with environmental change has been interspersed with interventions, governance, standards, and agreements to introduce sustainable construction.

One of the most often-quoted drivers for sustainable construction is climate change and the underpinning influence, the greenhouse effect. The 2014 IPCC Climate Change 2014 Synthesis Report states:

> Anthropogenic greenhouse gas emissions have increased since the preindustrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide,

methane, and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century (IPCC 2014).

It is therefore logical to look at the wider context and science behind this effect.

1.3.2 Climate change

The temperature of interstellar space is approximately −250°C, whereas the range of surface temperatures of the Earth is between −25°C and 45°C (NASA 2000). The Earth orbits the Sun, a large source of many wavelengths of electromagnetic radiation (including infrared 'radiant' heat); as radiant heat hits any surface, such as the surface of the Earth, depending on the surface's characteristics, some of that radiant heat will be absorbed, raising the temperature on and around that surface. The closer the surface is to the source of radiant heat, the more infrared energy will be absorbed. This influence can account for most of the difference in temperature between space and the Earth's surface, but the Moon (a body approximately the same distance from the Sun, albeit smaller in mass) can experience temperatures lower than −100°C on its dark side (more details in Text Box 1.1). The main physical attributes that differentiate the Earth from other planets in the solar system are related to its atmospheric gases, which account for the less extreme close-to-surface temperature variations.

Water vapour (H_2O), carbon dioxide (CO_2), and methane (CH_4), which are the most important and often naturally generated greenhouse gases, are transparent to short wavelength radiation (produced at high temperatures from the Sun) but opaque to longer wavelengths of infrared radiation (heat radiation from the relatively cooler Earth's surface; see Figure 1.2).

The net result is that radiant heat from the Sun is allowed through our atmosphere to warm the Earth's surface, but the infrared radiation of a longer wavelength emitted from the Earth's surface accounts for the extra 30°C on our planet's surface.

The 'greenhouse effect' is perfectly natural; however, concern is centred on the rapid increase in greenhouse concentrations due to man's (anthropogenic) activities over and above those that are naturally present.

The principal greenhouse gases to which man contributes are carbon dioxide (CO_2; 57% fossil fuel emissions; 17% deforestation, decay of biomass; 3% other), chlorofluorocarbons (CFCs; 1%, assuming the Montreal protocol maintains its effectiveness), methane (CH_4; 14%), agricultural activities, and waste management (IPCC 2007). Other types of emissions include nitrous oxide (4%, often associated with vehicle emissions), ozone (O_3), and black carbon (BC are particulates of carbon, not a gas that can contribute to atmospheric warming) (Table 1.1).

1.1 Want to know more? What might be the effect upon Earth in the future? Why are greenhouse gases so important?

The Earth, the third planet from the sun in our solar system, is surrounded by a gaseous atmosphere and supports life. To understand our environment fully, it is helpful to build a picture of the planet's physical position in space.

The Solar System
Approximate average distance from Sun (varies according to orbital position)

Mercury	60 million km (37 million miles)
Venus	110 million km (70 million miles)
Earth	150 million km (93 million miles)
Mars	225 million km (140 million miles)
Jupiter	800 million km (500 million miles)
Saturn	1,430 million km (900 million miles)
Uranus	2,900 million km (1,800 million miles)
Neptune	4,500 million km (2,800 million miles)
Pluto	5,900 million km (3,666 million miles)

To take a considered peek into the future of our planet with increased quantities of greenhouse gases it is logical to look at those planets that also orbit our Sun and see if there are any lessons that can be learned from their surface conditions in relation to the constituents of their atmosphere. As can be seen to the left, the known planets in our solar system extend from Mercury, very close to the Sun in solar distance terms, to Pluto, which is very distant. Naturally, the planets that are closer to an intense heat source (the Sun) have higher surface temperatures, but if we analyse the impact that atmospheres can have, there are some interesting estimates of surface temperature readings. It would be wise to compare the Earth with its nearest two neighbouring planets, both closer and farther from the Sun. Whilst Earth is a little larger than Venus and Mars, all three are similar enough in size and have orbits that are relatively close to each other to bear a valid comparison. Whilst Venus is the closest to the Sun of the three, the surface temperature of 450°C is high. Part of the explanation lies in the composition of the Venution atmosphere, which is composed mainly of carbon dioxide (96% and around 300 times the amount of CO_2 as Mars (NASA 2015a)). Much of the solar energy it receives is trapped by this atmosphere, resulting in high estimates of temperatures both on the sides of the planet facing to and away from the Sun (Goldsmith 1990). Mars has a thin atmosphere, again mainly carbon dioxide (96.5%) with an average surface temperature of about −50°C at night and about 0°C during a summer's day. The Martian poles can witness extremes of −153°C (NASA 2014).

The Earth's surface temperatures vary from −89°C to 57°C (Cain 2008a). So, if the Earth's atmosphere had low concentrations of atmospheric gases, then the temperature on Earth could be more like the Moon, which rises to as much as 116°C in the day and then dips down to as low as −173°C at night. Alternatively, with much more carbon dioxide and other greenhouse gases, it could be more similar to Venus (Cain 2008b).

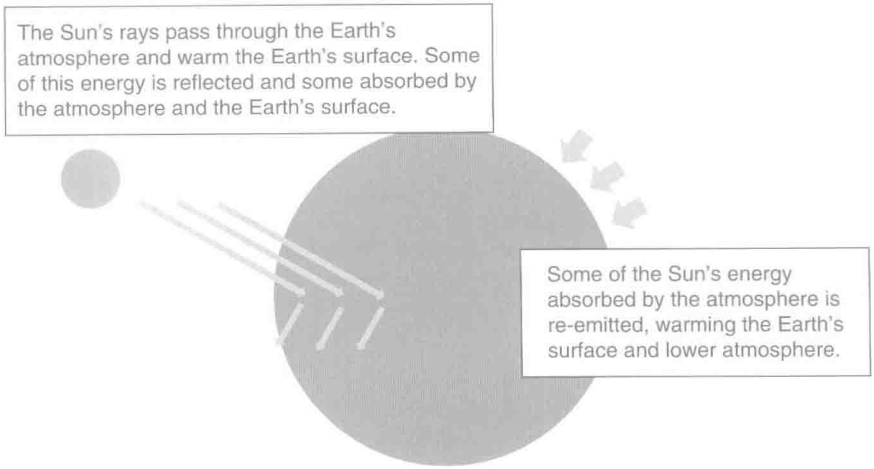

Figure 1.2 Greenhouse gases in the Earth's atmosphere absorb heat and warm the Earth's surface to a temperature that will support life, concepts based on information contained in NASA (2014).

Table 1.1 The global warming potential (GWP) of a small number of the more commonly quoted greenhouse gases (Data taken from Table 2.14 in the IPCC document *Climate Change 2007*, Working Group 1)

Substance	Chemical Formula	Atmospheric Lifetime (yrs)	GWP 20 years	GWP 100 years	GWP 500 years
Carbon dioxide	CO_2	Varies	1	1	1
Methane	CH_4	Varies but approx. 12	72	25	7.6
Nitrous oxide	N_2O	114	289	298	153
CFC-12 (controlled by the Montreal Protocol)	CCl_3F_3	100	11,000	10,900	5,200
HFC-32	CH_2F_2	4.9	2,330	675	205

The degree to which any particular greenhouse gas affects global warming depends on two factors:

- Its relative effectiveness (per unit of concentration) in blocking that low temperature radiation from the Earth
- Its concentration in the Earth's atmosphere

In some quarters a debate continues surrounding the link between human activities, the previously mentioned emissions of greenhouse gases, and the impact upon the climate. James Lovelock (Lovelock 2000) points out that the present chemical composition of the Earth's atmosphere is 'highly improbable', given the expectations of orthodox chemistry. It contains a mixture of gases that should react with each other so that,