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

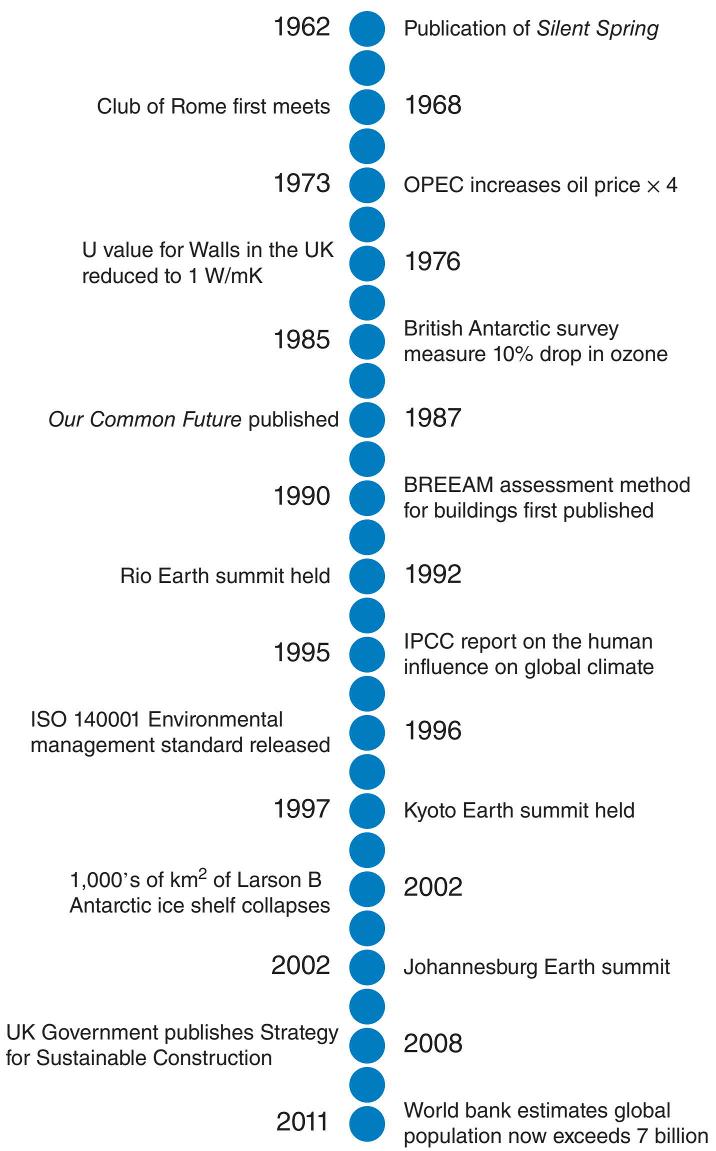

Figure 1.1 Events that have triggered or influenced the current economic, technological, social, and environmental situation.

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).

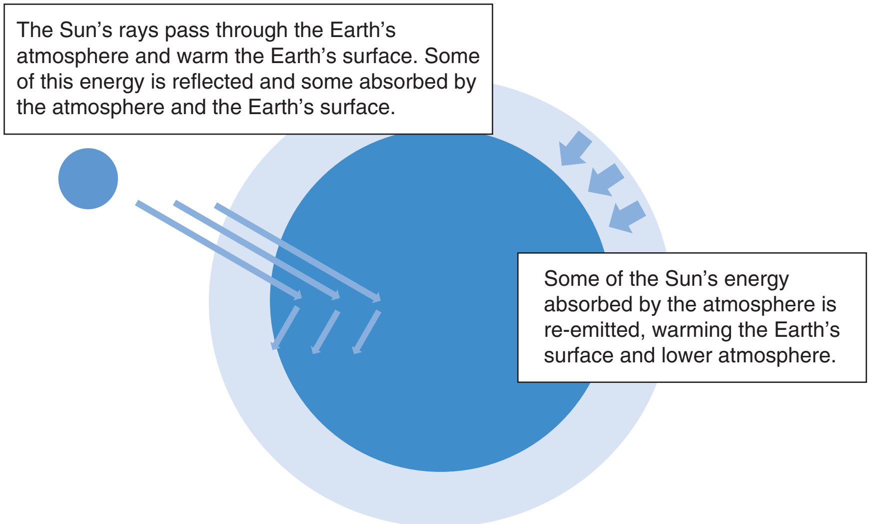

Figure 1.2 Greenhouse gases in the Earth's atmosphere absorb heat and warm the Earth's surface to a temperature that will support life, concepts based on information contained in NASA (2014).

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,

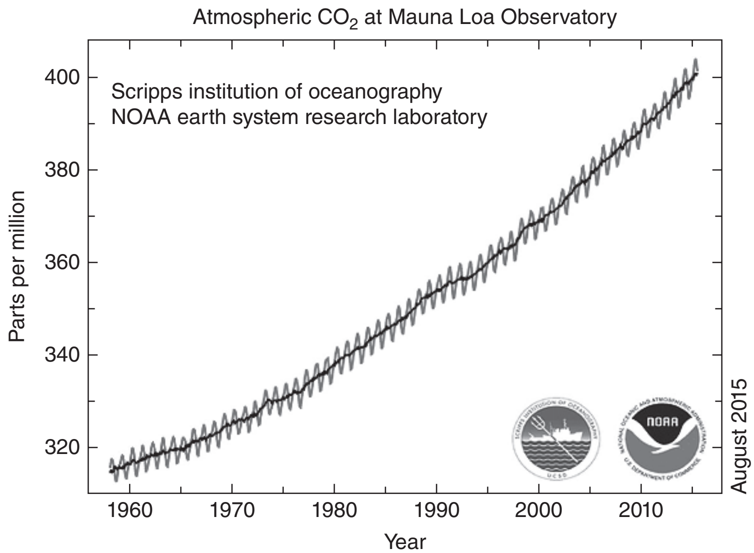

Figure 1.3 Atmospheric carbon dioxide measurements at Mauna Loa Observatory, Hawaii (NOAA 2015).

in chemical equilibrium, only traces of the original gases remain. For example, if oxygen is present together with methane, a reaction could take place that would use the oxygen in the presence of sunlight to form carbon dioxide and water. Therefore, without new sources of methane and oxygen to replace these gases, they would eventually become exhausted, as is probably the case for Venus and Mars (see Text Box 1.1). Thus, according to Lovelock, it is very likely that living organisms through their bodily processes and activities keep the Earth's atmosphere in the unique state that permits life to survive (The Gaia hypothesis). If living organisms can be linked to the development of the concentration of gases in the past, it is not illogical to link the present activities of living organisms to the same changes.

Of all the greenhouses gases in the Earth's atmosphere only carbon dioxide has a global warming potential of 'one' but is one of those most associated with human activities. Through measurements made since the 1950s at an observatory in Mauna Loa, Hawaii, an increasing trend of CO_2 atmospheric concentrations can be seen (Figure 1.3).

Hawaii, whilst being in the northern (most industrialised) hemisphere, is also a long way from any sources of CO_2 that could have an impact upon these measurements. They can therefore be assumed to be a reasonably true reflection of how CO_2 atmospheric concentrations are increasing globally. Figure 1.4 (IPCC 2007) shows global temperature observations for land and oceans alongside simulated temperature predictions, with both natural forcings and natural and anthropogenic forcings. It is quite evident that the upward path of the global temperature observations follows the approximate path of the simulation that includes emissions from human-derived sources.

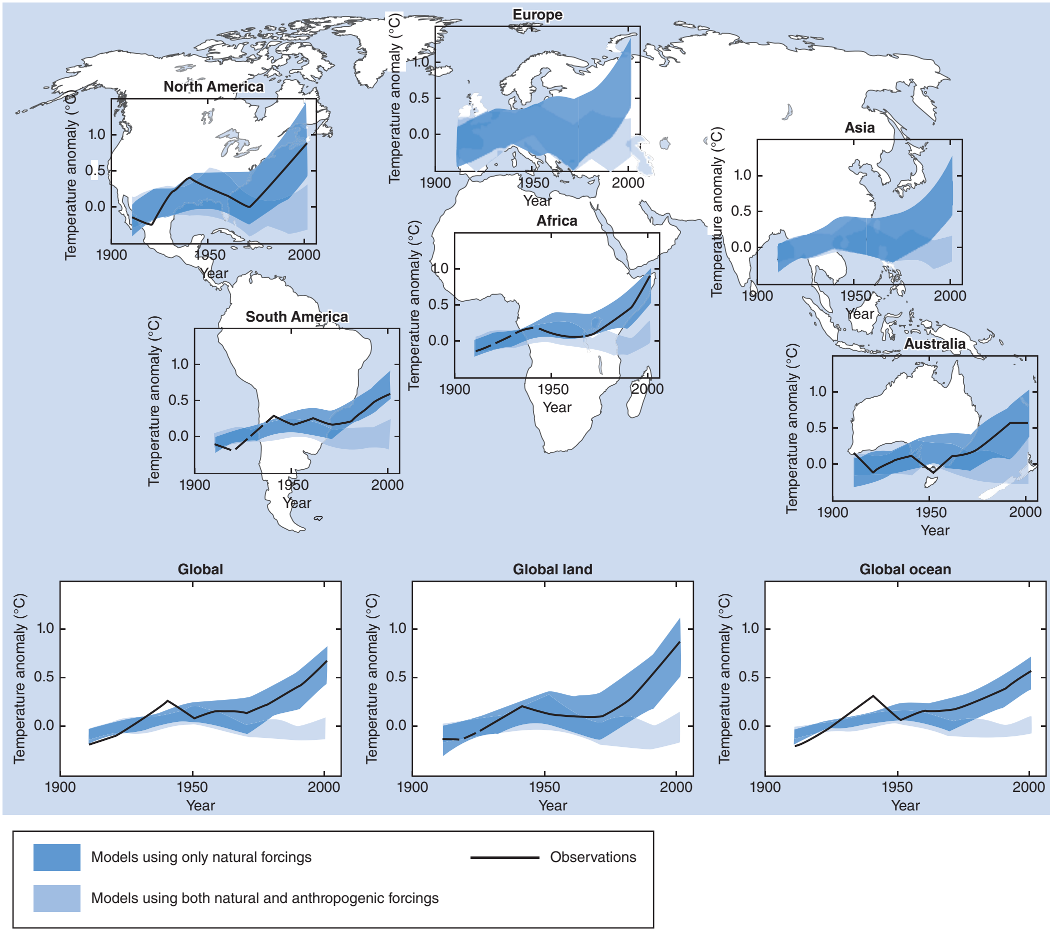

Figure 1.4 Global temperature observations for land and oceans alongside simulated temperature predictions both with only natural forcings (blue shading) and natural and anthropogenic forcings (dark blue shading).

1.3.3 Historical influences on the environment

So if the evidence points to a link between recent CO_2 and global temperature rise, how much of this may be attributed to the activities of mankind? When did this influence start? Various different methods of recording climate and temperatures alongside older atmospheric CO_2 measurements have resulted in a pattern of relatively stable CO_2 measurements until the end of the 18th and beginning of the 19th centuries. The timing of these indicators and much of the influence upon the global environment can be traced back to two transformations: the UK's agricultural and industrial revolutions. The first of these two followed the enclosure of much of the UK's commonly owned land and the development of new agricultural technologies. In the medieval period farming in the British Isles was undertaken in open fields, where tenant farmers tended small strips of land. From Tudor times these separate strips of land were merged into individually owned or rented fields. From 1750 onwards the enclosure of the land by parliamentary act was common. In the period between 1604 and 1914 over

5,200 enclosure bills were enacted by the English and UK Parliaments, which related to just over a fifth of the total area of England, amounting to some 6.8 million acres (UK Parliament 2015). These developments allowed more food to be produced from the existing land, consequently permitting greater population growth.

The UK's Industrial Revolution was initiated in the 18th century and the associated developments in power generation, production techniques, technological advances, and increases in urban populations influenced a range of aspects of everyday life. These included new methods of transportation for both goods and people, the availability of reasonably priced mass-produced items, increases in population (Text Box 1.2), and the wider use of high-calorific energy sources.

To attribute all environmental issues to one point in history could be seen as essentially meaningless, but if the progress of technology is mapped over time it allows the accompanying economic and social/societal impacts to be seen.

A series of technological innovations that occurred within a relatively short period of time contributed to the Industrial Revolution and in turn may be

1.2 Want to know more? Population

In 1798 Thomas Robert Malthus published 'An Essay on the Principle of Population', an evolutionary social theory of population dynamics as they had acted steadily throughout all previous history (Malthus 1798). This essay stated that as human population increased, food production would increase more slowly and that this would place limits on human productive behaviour (Hodgson 2004).

A number of sources publish current and historical population data, including the World Bank and most country's governmental statistical offices. The data below were downloaded from the World Bank website (World Bank 2015) and can be accessed in a variety of formats.

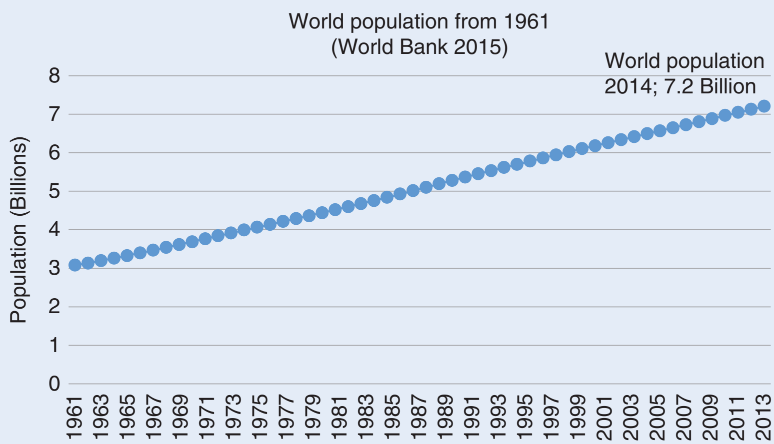

Figure 1.5 World population since 1961 (World Bank 2015).

responsible for the CO_2 and global temperature rise in the last 200 years. In 1733 John Kay invented the flying shuttle, possibly the first efficient modern mechanical manufacturing device, allowing the beginning of mass production of textiles; many people view this as the beginning of the Industrial Revolution. From this date, various inventions improved and accelerated the ease by which clothing could be produced, including the patent of improvements to steam engines by James Watt in 1769. At this point the UK Industrial Revolution could be said to have begun in earnest with related important worldwide milestone dates such as those shown in Text Box 1.3.

1.3 Want to know more? Historical technological landmarks

1811	MacAdam demonstrates a new road surface
1825	Stockton-Darlington Railway opens
1829	First omnibus appears in London
1831	Michael Faraday discovers electromagnetic induction and develops the electric generator and the electric motor
c. 1850	Laws of thermodynamics defined
1856	Bessemer steel-making process invented
1876	British River Pollution Control Act makes it illegal to dump sewage into a stream
1879	Thomas Alva Edison publicly exhibits the first electric light bulb
1884	Parsons develops the first steam turbine to provide lighting for ships
1885/6	Gottlieb Daimler and Karl Benz produce the first successful motor car in Germany
1891	Henry Ford begins work at the Edison Illuminating Company (in Detroit, USA, supervising the generators)
1895	The diesel engine is invented
1895	Sewage cleanup in London (means the return of some fish species—grilse, whitebait, flounder, eel, smelt—to the River Thames)
1896	Marconi perfects wireless technology
1896	Henry Ford produces the quadricycle—the first Ford motor car
1903	Ford Model A hand-built motor car produced
1903	First aeroplane flight by the Wright brothers
1909	Ford Model T production line starts up
c. 1920s	Thomas Midgley, Jr. discovers lead components to be an efficient antiknock agent in gasoline engines (first banned from use in Japan 1986) and develops chlorofluorocarbons (CFCs) as a non-toxic refrigerant. The first warnings of damage to stratospheric ozone were published by Molina and Rowland 1974. The Antarctic 'ozone hole' was discovered by Joe Farman in 1985, instigating the Montreal protocol in 1987.
1930–1940	The Dust Bowl: widespread land degradation due to drought in the North American prairie
1958	Mauna Loa Observatory initiates monitoring of atmospheric carbon dioxide (CO_2) levels. The time series eventually becomes one of the main references related to global atmospheric change.

Each development of the UK agricultural and industrial revolutions had an impact, but the combination of these interconnected advances enabled the production and consumption of resources such as coal (and coal gas), treated water, steel, energy-intensive building materials, canned food, sheet glass, and a large range of a new sector of goods: consumer products. Workers in production plants and factories could in turn earn enough to buy these goods, many of which needed an energy source to function and had a limited working life, leading to a demand for replacements. Resources in the form of energy, materials, and people were then needed to meet these demands. Ultimately, these demands had, and continue to have, an impact upon the local, regional, and global environment. This has led to the publication of a range of texts that have built up a picture of past, current, and future views of the results of these impacts.

1.3.4 Important texts reflecting environmental thinking

A number of people and texts have called for action to be taken to address environmental issues. These authors have focused upon certain issues with different interpretive 'takes' on the data. Whether the subject matter was right for the time, the ideas or the new and/or shocking content chimed with particular generations, or a combination of these, seminal texts have led to changes in thinking about the environment, social issues, and economics. Whilst it is hoped the majority of these are listed below, please forgive any gross omissions (indeed, useful additions/amendments to the list would be gratefully received via the book's website URL for this book).

Historically, a number of authors have highlighted the impacts of industrialisation. As early as 1862, John Ruskin published the essay 'Unto This Last', which contains an indictment of the effects of unrestricted industrial expansion on both human beings and the natural world. Some historians have seen it as anticipating the Green Movement (Wall 1994). An influential and more recent text that brought the impacts of mankind's activities to the fore was *Silent Spring* by Rachel Carson (1962). As evoked by the title, this text examined the use of pesticides, particularly DDT, chlordane and dieldrin for agricultural means and their impact upon birds, animals and humans. It was one of the main drivers for the establishment of the US environmental movement and was, in part, a factor in the outlawing of the use of DDT. Carson's earlier work, *The Sea around Us* (Carson 1951), provided an equally insightful analysis of impacts upon the oceans. *A Sand County Almanac*, written by Aldo Leopold (1949), links 'the great outdoors' with the need to conserve the elements of such places that lead people to be drawn to them in the first place. The phrase 'land ethic', coined by Leopold, relates the need for conservation to the actions of people and the interconnected nature of all life. Victor Papenek's 1971 text, *Design for the Real World: Human Ecology and Social Change*, discussed responsible design with particular reference to resources and energy. Papanek examined the efforts by designers to combat unsafe and less useful products.

Limits to Growth, commissioned by the Club of Rome (Meadows *et al.* 1972) described the findings from an MIT-based computer model that looked at consumption and production on a global scale. The findings assisted a debate that focused upon the capacity of the planet to support resource use, leading to a 'global overshoot'. In 1973 E. F. Schumacher first published *Small Is Beautiful: Economics as if People Mattered*, a collection of essays that have an economic focus but also philosophise on the links between ecological and spiritual thinking. One of the most powerful aspects of this text is that its stance, analysing many environmental issues from an economic viewpoint, differs from the more ecologically focused texts. The arguments contained within the text provide the basis for questioning modern economics and its relationship to people and their surroundings. James Lovelock wrote *Gaia: A New Look at Life on Earth* (Lovelock 1979) to put forward the hypothesis that life on earth, whilst initiated by chance, functions to maintain or even create an environment suitable for living. In 2007 Lovelock published *The Revenge of Gaia: Why the Earth Is Fighting Back and How We Can Still Save Humanity*, a text that explored the consequences of our actions since the 1979 book. Much of the discussions revolve around a series of facts that force the conclusion that unless some drastic action on the parts of global organisations and individual government is taken, Gaia will have its revenge. He equated people with a plague. Within the text *Permaculture: A Designer's Manual*, Bill Mollison (1978) defined permaculture (or permanent agriculture) as 'the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems'. Mollison proposed the integration of plants and landscape with people, offering to provide their food, energy, and shelter in a sustainable way. *Cadillac Desert* (Reisner 1986) described the issues concerning water, rivers, damming, rights, and ecological and economic problems that arise from supplying water to the large west coast US cities, such as Los Angeles.

A more collective seminal publication is the UN's *Our Common Future*, a report of the World Commission on Environment and Development (1987). This report was released in March 1987 and is often described as the Brundtland Report since the foreword is by Chairperson Gro Harlem Brundtland, former Norwegian Prime Minster. The report focuses on a wide range of issues at the core of sustainable development. Part I is entitled 'Common Concerns' and describes a threatened future, then moves towards sustainable development and the role of the international economy. The second part describes a series of common challenges, including people, food, species, energy, industry, and cities. The final part, Part III, focuses upon common endeavours: how we should manage the common places of the planet, the oceans, space, and Antarctica. Part III finally describes reasons for and impacts of conflict, with a call to action and legal change. Arguably the most influential quote from this document (referred to in section 1.2 of this text) comes from Chapter 1, 'A Threatened Future', paragraph 49, which begins, 'Sustainable development is development that seeks to meet the needs of the present without compromising the ability of future generations to meet their own needs'.

Earth in the Balance (Gore 1992) describes environmental issues from a global point of view and, further, outlines a range of policies that would tackle the most important of those issues. Written by a US vice president, this volume had some influence and good sales whilst also having some negative press. Many of the predictions concerning climate change, habitat loss, water quality, and so forth that were described in this text have proven to be accurate. *Cradle to Cradle: Remaking the Way We Make Things*, by William McDonough and Michael Braungart (2002) calls for a radical change in the industrial pattern of making, using, and disposing of things. The authors propose a change from a cradle-to-grave use pattern to a cradle-to-cradle focus, proposing the manufacture of products that can be and have been upcycled. The use of a lifecycle development philosophy recommends that when products have reached the end of their useful life, they either degrade to 'biological nutrients' or are used again as 'technical nutrients'. The collective power of these texts and scientific reports such as those from the previously mentioned IPCC, reinforced by images such as 'Earthrise', taken of the Earth from the Moon (NASA 2015a), have led to a feeling that our planet and its resources are precious. To quantify this preciousness of the Earth and its relationship to human activities, researchers have introduced an assessment referred to as ecological footprinting.

1.3.5 Ecological footprinting

One of the major drivers for sustainable construction is the need for people, countries, and continents to be able to build, renovate, and operate buildings within the available supply of natural resources (often termed 'natural capital'; for further detail, see section 1.2). Factors affecting the supply of natural capital include the more apparent depletion of finite fossil fuels or the less easily quantified areas of land needed to deal with waste from human activities. An original study undertaken in 1997 focused upon the relationship between natural capital and the consumption and activities of most of the earth's human population (Wackernagel *et al.* 1997). This study laid the foundations for the later, more detailed, footprinting methodologies and reviewed data from the 52 nations that represent 80% of the global population and generate 95% of the worldwide domestic product. Mathis Wackernagel, one of the first proponents of establishing a tool for measuring our need for natural capital, describes ecological footprinting as 'an accounting tool that can aggregate ecological consumption in an ecologically meaningful way. It gives us, therefore, a realistic picture of where we are in ecological terms' (Wackernagel *et al.* 1999, p. 389, section 5 conclusions).

The methods used to calculate ecological footprints are relatively straightforward. The activities/consumption of the population of each nation are estimated in terms of areas of agricultural or biological production and area needed to assimilate any wastes generated. This process is aided by the readily available data (most from UN or national sources) that describe ecological productivity, resource production, and trade.

The Global Footprint Network has the most current data for 2010 (published in 2013). Ecological footprints can also be combined with other measurements or assessments such as the Human Development Index (HDI) to extend the ability to analyse the performance of nations or regions. The HDI is a summary measure of human development and it measures the average achievements in a country in three basic dimensions of human development:

- A long and healthy life, as measured by life expectancy at birth
- Knowledge, as measured by the adult literacy rate (with two-thirds weight) and the combined primary, secondary, and tertiary gross enrolment ratio (with one-third weight)
- A decent standard of living, as measured by GDP per capita (PPP US$) (UNDP 2004)

Table 1.2 Human Development Index (HDI) and ecological footprint of selected countries of varying incomes (Moran *et al*. 2008; Global Footprint Network 2010)

Country	HDI	Ecological Footprint of Consumption (gha per person)[a]	Footprint to Global Biocapacity Ratio[b]
Norway[c]	0.96	5.9	3.2
UAE	0.85	11.9	6.5
Panama	0.80	1.9	1.0
India	0.60	0.8	0.4
Bangaladesh[d]	0.52	0.5	0.5
Niger	0.28	1.1	0.6

[a] gha = global hectares. This is a measure of how much land and sea are needed to supply all the resources consumed by one individual.

[b] This ratio shows how much larger the per capita demand on resources is compared to the per capita biocapacity available worldwide. It represents the number of planet Earths that would be required to support the current population at that country's level of consumption (assuming no biological productivity is reserved for the use of wild species).

[c] Highest and lowest HDI score of reported countries.

[d] Highest and lowest ecological footprint per capita of reported countries.

Table 1.3 Ecological footprint and biological capacity (all data from public domain figures)

Level of average income per capita	Population (million)	Ecological Footprint of Consumption (gha per person)[a]	Total Biocapacity (gha per person)	Ecological Deficit
High income countries	1031.4	6.1	3.1	−3.0
Middle income countries	4323.3	2.0	1.7	−0.2
Low income countries	1303.3	1.2	1.1	−0.1
World	6671.6	2.7	1.8	−0.9

[a] gha = global hectares. This is a measure of how much land and sea are needed to supply one human with the resources he or she consumes.

Source: Global Footprint Network (2010).

Moran *et al.* (2008) show the HDI and ecological footprint of selected countries using 2003 data, and this is described in Table 1.2. The HDI column shows a gradual numerical reduction in the human development index alongside the corresponding ecological footprint. The final column shows a deficit in relation to ecological area. This is the discrepancy between consumption and capacity for the whole Earth. This deficit is not evenly shared between the different development levels of the Earth's countries. The deficit includes high development/income countries, such as Norway, which on average have a footprint to global biocapacity ratio of three planets and low development/income countries such as Niger with a 0.6 footprint to global biocapacity ratio. These figures help communicate a stark message: as populations rise and development across the globe puts more pressure upon the global natural capital, we are increasingly living beyond the ability of our planet to supply our needs. Whilst there is no single solution, sustainable development, including sustainable construction, is a large part of any resolution to these problems.

Other extensions of footprinting directed at construction materials and processes are developing at a rapid rate, and some of these are discussed in Chapter 6, which is devoted to assessment systems (Gilroy-Scott *et al.* 2013). One of the debates associated with reducing ecological footprints is related to our behaviour and choices and how much these might cost, both now and in the future.

1.3.6 Economic drivers for actions to reduce the impact of climate change

One of the more effective methods of evaluating the connections between behaviour and the decisions people make is to link the environmental consequences of an action to economic impact. This is by no means a perfect linkage; something that might make economic sense might not be an effective solution in many other ways. However, when longer term economic impacts are linked to environmental and social impacts—and these less basic monetary issues are given a price tag—the gravity of some situations can be made more apparent. This was highlighted by a speech by the governor of the Bank of England, Mark Carney, who in September 2015 stated, 'The far-sighted amongst you are anticipating broader global impacts on property, migration, and political stability, as well as food and water security' (BBC 2015). Carbon taxes and issues related to sequestration (set-aside farming land) could all be seen to be economic levers that authorities or governments are using to alter behaviour in relation to the more environmental and social aspects of behaviour. They are, however, end-of-stream monetary interventions. An overview of the linkages between the environment and economics was provided by the *Stern Review* (Stern 2006).

The Stern report came from an independent review, commissioned by the UK's Chancellor of the Exchequer and reported in 2006. The review examines the evidence related to the economic impacts of climate change, explores the economics of stabilising greenhouse gases in the atmosphere through an international perspective, and considers policy challenges to manage the transition to a low-carbon economy and climate change adaption.

The review establishes that long-term greenhouse-gas emissions need to be cut to a level of 550 ppm CO_2e (see Chapter 3 for an explanation of CO_2e as opposed to CO_2) in four ways and acknowledges that the costs associated with each will differ considerably depending on which combination of the following methods is used, and in which sector:

1. Reducing demand for emissions-intensive goods and services
2. Increased efficiency, which can save both money and emissions
3. Action on non-energy emissions, such as avoiding deforestation
4. Switching to lower-carbon technologies for power, heat, and transport

Construction and buildings can play a significant part in all: through their design, their specification, their construction, their use, and their removal.

The conclusions of the report were many and complex, but risking a sound-bite approach, one quotation is especially impactful:

> Resource cost estimates suggest that an upper bound for the expected annual cost of emissions reductions consistent with a trajectory leading to stabilisation at 550 ppm CO_2e is likely to be around 1% of GDP by 2050.
>
> (Stern 2006)

One percent of GDP is obviously a variable figure, implying a larger cost to more wealthy countries (as defined by GDP) than less wealthy countries. For any country this figure will represent a considerable expenditure, but when judged against the whole wealth of a country, it can be considered modest. Since the review was completed, the key measured environmental indicators have provided a better view of the trends associated with the state of the environment. This has understandably changed and caused Sir Nicholas Stern to reflect upon the 1% figure:

> Looking back, I underestimated the risks. The planet and the atmosphere seem to be absorbing less carbon than we expected, and emissions are rising pretty strongly. Some of the effects are coming through more quickly than we thought then.
>
> (Stewart & Elliott 2013)

This statement is amplified by a further, more pointed, comment:

> This is potentially so dangerous that we have to act strongly. Do we want to play Russian roulette with two bullets or one? These risks for many people are existential.
>
> (Stewart & Elliott 2013)

The economic case can therefore be stated as being considerable, and through the judgment of the Stern Review, environmental, and by inference, socially related expenditure makes good sense.

1.4 The environmental importance of design, construction, and care of buildings

According to the Organisation for Economic Co-operation and Development (OECD), buildings have levels of consumption and impact upon waste that focus attention upon most aspects of their design, construction, and after-care (Hartenberger 2011). These impacts can all be linked to the result of decisions made by building professionals. Those decisions will be influenced by the traditional needs of the construction industry, the restrictions imposed by legislation, and guidance and the needs of the clients for those buildings and projects. How to mesh the need to reduce the impacts of the industry in the widest sense and remain true to those traditional client needs is one of the main drivers of this book.

1.5 Where next?

It can be seen that whilst there are uncertainties associated with the extent of anthropogenic environmental impacts, it is clear that a sustainable course needs to be charted. This will involve a number of changes to the way that we design, build, maintain, and run our buildings. The following chapters take the reader through procurement of a sustainable building and the contractual issues linked to this. The design-related issues are then discussed with a general split in focus between energy and materials. The construction process is examined, discussing the importance of actions taken at the different stages of the building process. Assessment systems and the part they play in encouraging and maintaining compliance of the performance of buildings is described and debated. The actual use of sustainable technologies is assessed, along with the ways in which designers, clients, contractors, and facility managers can ensure those systems work to their advantage. Finally, the future aspects of sustainable construction are examined, and an attempt is made at the dangerous but fun task of guessing in an informed way what the construction industry might be most employed in thinking about most in 25 years' time (or less).

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