Chapter 2
Buildings and Climate Change

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Abstract This chapter provides the global context for the need to reduce energy and GHG emissions associated with buildings. It starts by highlighting the target of containing the average increase in global temperatures to 2 °. Furthermore, it demonstrates the important role that buildings (their services and appliances) and building energy policy play in this area. Substantial investment is required to implement such policies however much of this will earn a good return. The chapter goes on to examine differences between the developed world (where improving the efficiency of existing buildings is the main challenge) and the developing world (where new buildings are more important). The cost of intervention is later explored. Low cost options such as basic home insulation are the first priority. However, meeting the 2° target will undoubtedly eventually require the adoption of higher cost options, such as installing heat pumps. Finally, this chapter underlines the need for further research and development, including pilot schemes to pioneer more advanced technologies and systems that are needed to realize the deepest carbon emissions cuts. *Learning outcome*: On successful completion of this chapter, readers will be able to: (1)demonstrate a basic understanding of the role that buildings play in tackling carbon reduction targets; (2) have knowledge of the principle mechanisms in reducing energy in buildings; (3) appreciate response differences in reducing carbon emissions in buildings between the developed and developing world; (4) reflect on the complexities, challenges, and need for further work in this area in order to better understand the future role of buildings.

Keywords Building efficiency · Carbon reduction cost · Climate change · Low carbon policy · Low carbon development

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2.1 Introduction

Buildings provide the physical framework of our lives and of almost all our energy use. Even our needs for transport are framed by the layout of the villages, towns, and cities in which we live. Unfortunately, the living standards that we enjoy in the developed world are currently underpinned by a stock of buildings that is oriented toward high energy consumption; developed countries however only represent about one sixth of the world's population. The rapid economic progress and enhancement of living standards that is taking place in countries such as India and China is also, in part, a transformation of the built environment. If we fail to curb the energy intensity of our own buildings in the developed world, and if the developing world follows in our footsteps, the consequences for energy demand and for CO_2 emissions will be disastrous. This means that understanding the sustainability of buildings, the subject of this book, is critical for the future of our planet.

2.2 The Climate Change Crisis

Global temperatures are already rising due, in large measure, to energy related CO_2 emissions. The *Copenhagen Accord*, which was ratified by world leaders at the *Copenhagen Climate Summit* in 2009, established a target of containing the average increase in global temperatures to 2 °C. That target is, almost certainly, already beyond reach. It would require global emissions to peak before 2020 whereas, even taking account of the Copenhagen national targets, they are not now likely to peak before 2035. According to the *International Energy Agency* (IEA), either the 2020 targets would have to be revisited or the speed of the transformation that would be required after 2020 would need to be extraordinarily rapid (IEA 2010c).

The world may therefore be on course for an increase in average temperatures in excess of 3.5 °C (IEA 2010c). This assumes that governments will actually meet their own national targets, also announced at the 2009 climate summit, for curbing the growth of CO_2 emissions. If governments do not adopt the necessary policies, we may be heading for a temperature increase in excess of 6°. This scenario conjures up an alarming picture. Even a rise of 3.5 ° could well have severe effects on water supply and crop productivity and lead to coastal flooding, the extinction of species, and the spread of disease. There is considerable uncertainty about the full extent of these effects, but we do know that they are likely to be concentrated in some of the poorest parts of the world, for instance in Asia and Africa. The consequences of a 6° rise are unthinkable (Green Alliance 2011).

This grim environmental outlook is the result of the global spread of the industrial revolution which, in other respects, has been, and should continue to be, a great blessing for mankind. For the first time in history there is the prospect of decent living standards for the majority and not just for the minority. China alone, by sustaining a breathtaking level of economic growth in recent decades has achieved*: 'the most rapid decline in absolute poverty ever witnessed'* (UNDP 2010). Nevertheless, China still has a huge population living in poverty.

On average, people in the Organisation for Economic Co-operation and Development (OECD) countries consume more than twice as much energy per capita as the global average and, for instance, more than five times as much as the average person in Asia. It is inevitable that, without a radical change in technology, the advance of living standards in the developing world toward those in the OECD will imply a huge increase in energy supply and fossil fuel consumption, a fact that is all too evident in current trends.

Most of the projected growth in energy demand in the coming decades is attributable to developing countries, including China, India, Brazil, and South Africa (IEA 2010c). These countries are aware of the threat that climate change poses and of the need for mitigation. Furthermore, they are all signatories of the Copenhagen Accord (2009). This Accord contains the 2 ° target but it also recognizes, specifically, that: *'social and economic development and poverty eradication are the first and overriding priorities of developing countries'*. The Accord also contains a commitment by the developed countries to mobilize $100 billion per annum by 2020 to help developing countries to address their mitigation needs.

In spite of the dominant role of developing countries in future emissions growth, it is the relatively rich OECD countries that will need to act first. This is because it was the OECD countries which initially created the problem (being responsible for the majority of greenhouse gas in the atmosphere today), because the level of emissions per head in the OECD is so much higher than in the developing world, and because, at present, it is the OECD countries that have the resources necessary to tackle the problem.

Developing countries are willing to follow the 'rich' countries in pursuing carbon reduction policies, but only if they are certain that this will not stand in the way of poverty alleviation and raising living standards. From this point of view, the adoption of low cost improvements in the efficiency of buildings represents a particularly attractive option because it can free up energy supplies, which are often tightly stretched, to meet other development needs.

With current policies, global energy related CO_2 emissions (which make up about 70 % of all greenhouse gas emissions) are set to double from about 28 billion tons per annum today to 57 billion tons per annum in 2050 (IEA 2010a). By contrast, a strategy for containing global warming to around 2–3 °C requires a halving of today's emissions to 14 billion tons in 2050. The reduction needed in projected 2050 emissions is greater than total emissions today. Of course, developed countries will have to make a much greater proportional contribution. For instance, the statutory target set by the UK is for an 80 % reduction in emissions by 2050.

While renewables, nuclear power, and carbon capture and storage (CCS) all have to make major contributions, the greatest potential CO_2 reductions will need to come from greater efficiency in the way we use fuel and electricity. This is estimated by the IEA to be nearly 40 % of the total (IEA 2010a). Buildings, together with the equipment and appliances they contain, have a crucial role in this.

2.3 The Building Sector

Achieving the necessary level of carbon reduction within the buildings sector is a monumental global challenge. The first stage involves effective regulation and enforcement to ensure that all currently available low cost carbon saving options are achieved. Particularly for developing countries, this means stronger regulation and the development of effective national and regional enforcement agencies. Subsequent stages require focusing onto the application of more advanced, and sometimes costly, measures and technologies required to reduce emissions to significantly lower levels.

The IEA's (Blue Map) low carbon case suggests that \$7.9 trillion of additional investment is needed in buildings within the residential sector between now and 2050 and \$4.4 trillion within the service sector. These are huge sums, but they equate to less than 1 % of global GDP. Savings of 5.8 billion tons of CO_2 emissions are intended to be created by these investment measures. Together with a saving of 6.8 billion tons of CO_2 from the decarbonization of electricity used in the sector, this achieves an 83 % reduction in buildings related emissions in 2050 (IEA 2010a).

The majority of this immense expenditure on buildings efficiency will eventually earn a good return in fuel savings. The total estimated value of the fuel savings to 2050 is \$51 trillion. In time, the value of efficiency gains will exceed initial capital investments, even at a commercial discount rate of 10 % (IEA 2010a).

These figures not only illustrate the scale of the task, but also the vast range of opportunities for business and employment that will arise from its achievement. They also highlight the fact that the buildings sector offers some of the most cost-effective measures available for addressing climate change.

In spite of the great opportunities it presents, the buildings sector often appears as a poor relation in the climate change debate and governments have found it extraordinarily difficult, in practice, to reap the carbon savings on offer: 'between the idea and the reality falls the shadow'. The climate mitigation debate tends to be dominated by the supply side, in which nuclear power and renewables contend for dominance with carbon capture and storage. The importance of buildings is often not adequately reflected in *pie* and *wedge* charts in which savings in the buildings sector appear as unspecified efficiency gains, or in the case of heating electrification, are attributed to low carbon generation.

It is true that if we had at our disposal, unlimited supplies of low cost carbon free electricity, the decarbonization of buildings would not be a problem. In reality, however, none of the options for low carbon electricity is likely to be cheap or easy to deliver on the scale required. This means that for the foreseeable future we will continue to rely on policies for reducing energy in buildings, as well as policies for low carbon energy supply.

2.4 The Developing World

The need to supply decent homes for large numbers of poor people is one of the primary drivers of economic development in major developing countries such as China or India. Indeed, largely for this reason, almost half of the world's construction is currently taking place in China. This is where the megacities of the future are now being created. China is now producing more than half of the world's cement, and as a result, China's cement industry alone is emitting almost twice as much CO_2 as the entire UK economy (IEA 2010b). Construction is nearing its peak in Eastern China, and will probably peak in Central and Western China within the next 10–20 years. Furthermore, Chinese buildings standards are generally lower than in the West. Reputedly, there is inadequate buildings inspection and anecdotal evidence suggests that a proportion of new buildings fall far short of planning specification, insulation thickness being a typical example.

These buildings exemplify the concept of 'lock in', where high levels of CO_2 emissions are inherently produced for many years until major refurbishment. Alternatively, those of the poorest quality may need to be replaced, bearing in mind that average building life in China is only about 30 years. Either outcome will place a heavy burden on the environment.

Berkeley Laboratory in the USA has famously estimated that by 2020, tough new standards for appliances in China will be delivering efficiency improvements equivalent to more than five times the output of the *Three Gorges Dam*, the world's largest hydro-electric plant (Fridley and Zheng 2010). There is a strong case that Governments concerned with reducing the global level of carbon emissions should concentrate on supporting the efforts of cities and provinces in China's Central and Western regions to enhance building quality, especially by training and deploying a strong force of buildings inspectors.

2.5 The Developed World

While new buildings present the greatest opportunities for carbon savings in the developing world, only a small percentage of the housing stock is replaced each year in the developed world, 1 % in the UK (DCLG 2011), and therefore it is the upgrading, or retrofitting, of existing buildings that is most important.

Basic measures to provide adequate insulation, to install quality doors and windows, exclude drafts, and install best practice systems as standard (such as condensing boilers), will radically improve the efficiency of most homes in the UK. This also holds true for achieving energy efficiency in other temperate parts of the world. These are mostly low cost measures that incorporate well-established technologies with acceptable or good payback periods.

The irony associated with high performance buildings (or the results of building retrofitting) is the *rebound effect* or *take-back factor*. This is characterized by improved levels of comfort, often in the form of higher internal temperatures, taken at the expense of energy savings. Historically in the UK, when homeowners switched from open coal fires to gas central heating, many took extra comfort in the form of day and night heating of the whole house (Hawkes et al. 2011).

2.6 Low Cost Options

The IEA has listed the basic measures which governments need to take in order to promote greater energy efficiency in buildings. They include: the strengthening and enforcement of codes for new buildings; better information on the efficiency of existing buildings; mandatory building standards whenever a building is sold, rented, or constructed; and high efficiency windows and other glazed areas. The IEA's latest estimate is that overall, their member countries achieved 43 % full or substantial implementation, but that 57 % of those measures are at best, work in progress (IEA 2011).

However, in most countries these measures, which are largely voluntary, have so far only scratched the surface of the problem. Only a small proportion of existing houses have been significantly affected and there is a lack of rigorous measurement of the fuel savings actually achieved. Solid wall housing, where additional insulation has to be applied to the inside or the outside of external walls, represents a particular problem. For instance, the UK's 'Fourth Carbon Budget' for 2023–2027, stipulates that approximately 8 million solid wall dwellings must be insulated through the 2020s and beyond.

One promising approach is to progressively tighten regulations for existing buildings through systematic retrofitting, implemented on a 'street by street' basis. However, in a democracy, and perhaps other forms of government too, such measures are politically unfeasible in the absence of a real public sense of crisis over climate change.

Another irony is that the economic return on many energy efficiency measures in buildings is high by commercial standards and is higher than the rate of return required by power companies on their investment in energy supply. Efficiency measures are often not implemented due to high capital investment costs incurred by the homeowner; likewise, in the case of rented or leased property, both the tenant and landlord may fail to instigate any refurbishment due to the lengthy payback periods involved. A number of efforts have been made to overcome this barrier, for instance through energy service ventures. Most recently, the UK Government's *Green Deal* represents an ingenious attempt to improve the security available to utilities and other providers entering into service contracts with consumers.

2.7 Intermediate and High Cost Options

The previously mentioned, low cost options are only part of the story. If we are to limit expected global warming to 2 °C, as required by the Copenhagen Accord, we will need to reduce carbon emissions to exceptionally low levels. The basic low cost measures described above will not be sufficient to achieve this degree of carbon reduction and it is clear that more radical options will need to be adopted.

What options are available? Sustainable building design can maximize the use of *passive* strategies for heating, cooling, ventilation, and lighting, through careful management of solar heat gains for example. Sustainable design can also minimize heat loss and store heat in building structures using the property of thermal mass. There is a current trend for high performance homes to use *air source heat pumps* (ASHP) with a *heat recovery* system. Heat pumps, which concentrate low grade heat in the surrounding air or underground, can provide heating equivalent of up to five times the energy they require. District heating can distribute 'free' heat from power stations or industrial plant and can also exploit organic waste in biomass systems. If the energy demand of buildings could be reduced to exceptionally low levels, then energy generated by local or micro-renewables, including PV surfaces integral to the buildings themselves, could potentially meet this demand.

Technology optimization can be complex and is often case specific, dependent on factors such as climate, planning regulation, physical constraints, and financial implications. For instance, district heating might prove optimal where 'free' heat, or possibly biowaste, is available close to high demand locations and ground source heat pumps (GSHP) require access to suitable land for either boreholes or loop systems. Local renewables might include small scale hydro, wind, and gas from anaerobic bio digesters.

Complex interactions will inevitably arise in a low carbon built environment where a significant proportion of energy supply originates from renewables which provide intermittent generation, such as wind turbines and solar photovoltaic panels. In addition, the transport sector will employ an increasing quantity of electric vehicles which will place additional demands on electricity distribution networks. Smart grids of the future will continually balance demand and supply for electricity and the heat storage capability of buildings is expected to make an important contribution to the stability of the system, both locally and nationally.

Further research is needed to better understand the transition to such a sophisticated and dynamic energy future. In addition, research is also required to improve the performance, reduce the cost, and optimize the deployment of advanced low carbon technologies such as PV and heat pumps.

Is this kind of transformation feasible over the coming decades? It would be comparable to the almost complete replacement of household heating in the UK, from coal to natural gas, which commenced in the 1970s (Hawkes et al. 2011). The incentives for consumers were powerful in this particular case; natural gas proved more convenient and transformed comfort levels. For a similar transformation, the incentives would need to be exceptionally attractive or the regulation very tough, in order to achieve a comparable shift. Conclusions emerging from a recent Grantham/IEA workshop (Jennings et al. 2011) suggested that in an ultra-low carbon world, energy costs will be much higher and the social implications of this need to be addressed.

2.8 Conclusion

Reducing the carbon intensity of buildings and the services they provide, is a vital part of the struggle to mitigate climate change. It is essential to secure the benefits realized by conventional low carbon technology in the early stages. In achieving such aims, developed countries should take a lead role and support the developing nations to put in place proved strategies governed by sound regulatory bodies. Additionally, developed countries should also commit the investment in research and development (R and D), and pilot schemes, to pioneer the more advanced technologies and systems that are required to bring about very deep level CO_2 reductions for the future built environment. The policy options are diverse and implementing tough legislation that is practical and cost- effective will be challenging for governments in developing, and developed countries alike. This book addresses the key themes of sustainable design within the built environment and is an essential aid to those who are studying and researching in this area; and working on the monumental challenge ahead of us.

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