Preface

This is a book about the extraordinary opportunities to reduce our use of non-renewable energy in buildings, both in new buildings and as a result of renovations of existing buildings. It is motivated by the realization, stemming from my own involvement in climate and carbon cycle modelling research over the past 25 years, that unrestrained use of fossil fuels and associated emissions of greenhouse gases (GHGs) pose a serious threat of eventual catastrophic climatic change. Indeed, it is likely that GHG concentrations have already increased to the point that significant negative impacts will eventually occur. It is therefore of the utmost urgency that GHG emissions be reduced as quickly as possible, so as to stabilize concentrations at the lowest possible levels and thereby minimize future damage. This requires simultaneous dramatic improvements in the efficiency with which energy is used in all sectors, so as to reduce total energy demand, combined with a rapid increase in the deployment of renewable sources of energy, leading to an eventual complete phase-out in the use of fossil fuels. Closing the gap between energy demand and that which can be supplied from renewable energy sufficiently rapidly to limit the carbon dioxide concentration to 450 parts per million by volume (ppmv) (the significance of which is discussed in the first chapter of this book) is likely to require overall reductions in energy intensity (the energy use per unit of economic activity) in industrialized countries by a factor of four by 2050. If this reduction is applied proportionally to the industrial, transportation and buildings sectors – each of which accounts for roughly one third of GHG emissions from industrialized countries – then a factor of four reduction is also required from buildings. It is not evident, a priori, that this is possible. In industrialized countries, buildings account for about half of total electricity use. With anticipated improvements in the efficiency of generating electricity, the required reduction in the average energy intensity of buildings (on-site energy use per unit of floor area) is a factor of 2–3 by 2050. This is an average of new buildings and of present buildings still in existence by 2050.

This book began as a comprehensive assessment of the potential to dramatically reduce the energy use of new buildings compared to current conventional practice, and to dramatically reduce the energy use of existing buildings through advanced renovations and retrofits. In order to provide a rigorous assessment, this book systematically examines all uses of energy in buildings and shows, based on documented and accessible case studies, how much better we can do than current practice. The conclusion is that overall energy intensity reductions in the building sector in the order of a factor of 2–3 are indeed possible. To lend credibility to this conclusion, a major focus of the book has been in explaining *how* energy saving technologies and an integrated approach to building design can achieve such large reductions in energy use, without compromising on building comfort or services. This explanatory approach is augmented with the judicious use of equations that present the key relationships between the technical parameters of buildings or equipment, and energy use. At the same time, the major practical issues that can prevent achievement of these savings in reality are addressed. In these ways, this book provides much more of a 'nuts and bolts' level of detail compared to what is found in, for example, the energy scenario literature or in many of the books on 'sustainable' architecture, but provides less 'nuts and bolts' detail than needed for practical implementation by people who actually build or design buildings. An annotated appendix provides sources for this next, higher level of detail.

That having been said, this book will be of great value to architects and engineers because (1) it brings together, in one place, a discussion of all the various ways in which energy is used in buildings, and of the full spectrum of opportunities to reduce the use of fossil fuel and electrical energy in buildings; (2) it provides the reader with a solid grounding in the physical principles underlying energy use and energy savings opportunities in buildings; and (3) it treats buildings as systems in their own right, and as part of larger energy supply and use systems. Much of the energy used in buildings today can be displaced, in new buildings, with various forms of solar energy, generated on-site as part of the building fabric and structure. The remaining energy use can be dramatically reduced through more efficient technology or, in many cases, by an intelligent re-arrangement of the existing components that constitute the various energy-using systems within buildings. The net result is the opportunity, in new buildings, to reduce on-site energy use by a factor of 4–5 compared to the current stock average in industrialized countries or compared to recent, energy intensive, western-style buildings in developing countries, while renovation of the existing building stock can readily achieve reductions of 50 per cent and often much more. Together, this can achieve the required overall reduction in on-site energy intensity by a factor of 2–3.

Almost everything needed to do to this is already known, but it is buried among widely scattered academic journals, conference reports or research institute reports in the various engineering libraries of universities around the world; or in the experience of the limited number of practitioners who have designed and overseen the construction of extremely low-energy buildings. A number of books on ‘green buildings’ have been published in recent years, and these have included sections on energy use. There are also a number of technical design manuals and guidelines that describe in considerable detail what is needed to achieve deep reductions in energy use in specific areas of building energy use, such as lighting, ventilation and cooling, or heating. What is often lacking is a straightforward explanation of the underlying physical principles, which are generally simple. However, buildings are systems, and systems can behave in ways that might not have been anticipated from the properties of the individual components. Buildings can also be linked to one another through district heating and cooling systems, and can be linked to various sources of waste heat and to systems for large-scale, seasonal storage of thermal energy. Doing so has implications for the design and operation of individual buildings.

This book deals with technologies and practices that are already well established, with new approaches and technologies that have only recently become commercially available, and with technologies that are still under development. In this way the book is deliberately forward looking, documenting what is already established but also providing a ‘heads up’ for products that may soon enter the marketplace. Only general cost information is given for technologies that have already been commercialized, as costs can change rapidly and can vary significantly with location or, in many cases, with the specific circumstances. Explicit consideration is given to the different challenges facing buildings in cold, hot-dry, and hot-humid climates.

In writing this book, I have drawn upon my own background in computer climate modelling, a background that is rather helpful in writing a book on energy-efficient buildings. In climate modelling, especially the schematic models that I have worked with, one attempts to capture the essence of the phenomenon being modelled in a simple, physically justified manner. A similar philosophy is useful in understanding how buildings and, in particular, passive heating, cooling and ventilation features, operate. This philosophy has guided the explanations given in this book and the various side boxes. In climate modelling, we often find that simple models give answers to within 10–20 per cent of the most complicated, computationally intensive models available, and the same seems to be true with regard to most features of building simulations. This is useful, because it allows one to construct simple models that can be used to guide the design process. Both climate modelling and understanding the heating, cooling, ventilation or lighting of buildings requires a consideration of the basic principles of radiative energy transfer, latent and sensible heat, heat exchange by moving air or water and the buoyancy forces created by temperature differences. So, in the end, the differences between computer modelling of climate and computer modelling of buildings are not great.

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