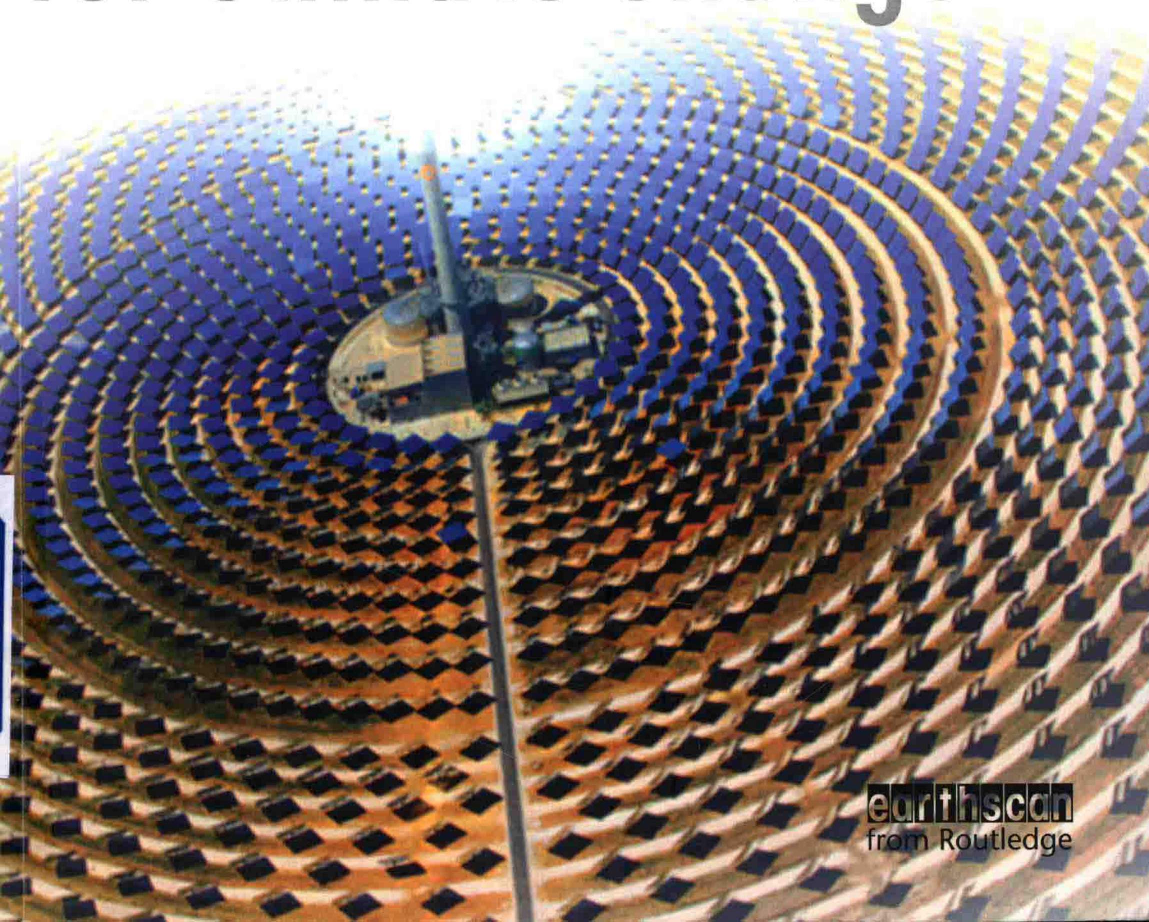
Mark Diesendorf

SUSTAINABLE ENERGY SOLUTIONS

for climate change



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MARK DIESENDORF is Associate Professor and Deputy Director of the Institute of Environmental Studies at the University of New South Wales in Sydney, Australia. He is researching scenarios for 100 per cent renewable electricity for Australia. His previous books include *Greenhouse Solutions with Sustainable Energy* (2007) and *Climate Action: A campaign manual for greenhouse solutions* (2009).

FOREWORD

This is a handbook for a better future. It reminds us that the unprecedented economic development of the 20th century was fuelled by plentiful cheap energy. The world is now completely different. Analysts established more than 50 years ago that conventional oil production would peak early in the 21st century. The energy source which now powers almost all our transport will become steadily more expensive. Supply interruptions are very likely. So the near-term future will require a new approach to transport. The second challenge for future energy use is global climate change. Our burning of fossil fuels is causing serious problems for all human societies as well as drastic consequences for the natural world. The Millennium Assessment Report warned that we are losing species at an accelerating rate as the driving forces of habitat loss, introduced species and chemical pollution are supplemented by climate change. The report stated that we could lose between 10 and 30 per cent of all mammal, bird and amphibian species this century. These are alarming consequences that demand a concerted international response.

At the same time, the global economic system is still showing the impacts of the 2008 Global Financial Crisis. The World Economic Forum has observed that the problems of fuel, food and finance are three 'canaries in the mine', indicating that the current economic system is simply not sustainable. We are now seeing the outcomes modelled for the Club of Rome over 40 years ago. Their report *Limits to Growth* projected that continuing existing growth trends would see environmental, social and economic collapse in the early to middle decades of this century. As the reports in the United Nations series on the Global Environmental Outlook have been warning for 15 years, the present approach is not sustainable, so doing nothing is not an option.

This book shows that there are realistic and cost-effective solutions. We can move rapidly to renewable energy supply systems. We can also improve dramatically the efficiency of turning energy into goods and services. We live at a level of material comfort that our grandparents could only dream about, made possible by enormous energy flows. Australian energy use is equivalent to us each consuming about 6 kilowatts continuously, about the energy that would be needed for every one of us to drive a small car 24 hours a day. Energy doesn't just light our homes, heat our water and propel our transport vehicles; it is a vital input to providing our food, our drinking water, our dwellings, our clothes and every other aspect of modern life. We don't actually need energy itself; as Amory Lovins said, we don't want energy, we want hot showers and cold beer! We demand the material comfort that is provided by the use of energy.

The technical and political challenge is to find ways of providing our material needs without depleting irreplaceable resources, polluting the air and changing the global climate. This book shows that a clean future is technically and economically achievable. It is possible to live at the same level of material comfort as we do now, using half as much energy or less. We can get all that energy from a mix of renewable energy supply technologies, using the resources of direct and indirect solar energy that will not be exhausted for billions of years. Reducing the environmental impacts of our energy use is only one of the urgent changes we must make, but it is the critical first step because energy provides most of our needs. It is also a significant step on the path to a future that could be genuinely sustainable.

The future is not somewhere we are going, but something we are all creating. At any given time, there are many possible futures. From that wide range, we must be trying to shape a future that is sustainable, at least in principle. At the moment we are fulfilling our desires in ways that reduce options for future generations, by depleting resources. We are essentially stealing from our own descendants. We are also meeting our needs in ways that radically change the global climate and precipitate a collapse of human civilisation. It is criminally irresponsible, but that is the approach we are now following. This book shows that a better future is possible. It is a call to action and a guide for responsible living.

Professor Ian Lowe AO FTSE
Emeritus Professor, School of Science, Griffith University
President, Australian Conservation Foundation

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I dedicate this book to my sons Thor, Danny and Joey, and my grandchildren Bede, Asha and Oliver.

INTRODUCTION

> In the last ten years ... the most powerful and technically advanced society in human history ... has been confronted by a series of ominous, seemingly intractable crises. First there was the threat to environmental survival; then was the apparent shortage of energy; and now there is the unexpected decline of the economy. These are usually regarded as separate afflictions, each to be solved in its own terms: environmental degradation by pollution controls; the energy crisis by finding new sources of energy and new ways of conserving it; the economic crisis by manipulating prices, taxes and interest rates.
>
> Barry Commoner[1]

Over the past million years our planet has provided excellent environmental conditions for nurturing the emergence of human beings and the development of human societies. But, as our societies evolved from hunter-gatherer to industrial, we have increasingly damaged the system upon which we are totally dependent, the biosphere, comprising all life on Earth and its non-living environment. We have impacted severely on air, land, waterways, other species and our fellow humans.

Arguably the greatest and most destructive change is what we have wrought on the climate. The emission of greenhouse gases (GHGs) from burning fossil fuels, clearing forests and imposing destructive agricultural systems has placed us on a trajectory that could heat this planet to 4 degrees Celsius (°C) or more above the pre-industrial average by 2100 and drive big changes to precipitation patterns. Impacts include more frequent and more severe droughts, heatwaves, wild fires and floods; rising sea levels damaging coastal infrastructure; loss of biological diversity, including decimation of marine life by acidification of the oceans and the bleaching of coral reefs; declining global food production; and possibly an increase in the frequency of severe storms. Most of these impacts are already being observed.[2]

In addition, local and regional air pollution is a serious environmental and health impact of fossil fuels.[3] You might think filters to reduce air pollution emissions from power stations and catalytic converters to reduce emissions from motor vehicles will go some way to addressing the problem. But the technological improvements are offset by the huge growth in the number of power stations and motor vehicles. Land degradation from open-cut coal mines and mountain top removal is severe.[4] Even underground coal mining can have devastating environmental impacts on the surface, for example where longwall mining causes subsidence.[5]

Energy security was already a concern in the 1960s, when the peak in global oil discovery was passed. It became a more serious issue in 1971, when the USA passed its peak in oil extraction. Australia's modest oil production peaked in 2000. Nowadays many major oil producing countries have already passed their production peaks, suggesting that the world peak of production is now imminent and in future the rate of production will be in terminal decline.[6] Meanwhile, oil consumption by the rapidly growing economies, especially China and India, is growing far above their respective domestic productions. As a result, oil prices are likely to rise steeply as economies recover from the Global Financial Crisis (GFC) and growth in consumption resumes. The struggle for the declining reserves of Middle Eastern oil has already imposed huge costs in terms of the lives of people in the region and the economic burden of US military interventions. Recent claims by journalist George Monbiot and others that peak oil is dead[7] are based on their uncritical acceptance of a flawed analysis.[8]

Won't other fossil fuel technologies save us from peak oil?

There is no cheap, easily produced substitute for conventional oil with comparable volumetric energy density (see Table 7.2). With the exception of natural gas and possibly coal seam methane, all fossil fuel substitutes[9] have comparable or higher GHG emissions and other environmental impacts. The environmental hazards and resulting economic impacts of deep water drilling have already been demonstrated in the Gulf of Mexico.[10] Apart from a temporary glut of shale gas in the USA, substitutes for conventional petroleum-based fuels are all more expensive, thus pushing up prices of transport, food, plastics, etc. Furthermore, recent studies suggest that a global peak in coal production could be reached before 2050.[11] So, even if coal-fired power stations with carbon capture and storage eventually enter the market, there may not be sufficient low-cost fuel to operate them.

The post-World War II economic crises alluded to by Barry Commoner have been dwarfed by the continuing GFC of 2008 onwards. At the time of writing, the crisis is still having severe impacts – in terms of unemployment, under-employment and falling wages – in Spain, Portugal, Italy, Greece, Ireland, Iceland and the USA.

Thus, all the global crises identified by Commoner in 1976 have become much worse. This suggests that technological fixes, while necessary, are not sufficient for solving the linked problems of energy, the environment and the economy. Digging deeper, anthropogenic (human-induced) climate change and the other environmental impacts of fossil fuel use are symptoms or outcomes of three fundamental driving forces: population, consumption per person (sometimes called 'affluence') and inappropriate technology.

Driving forces of climate change

At one level, we can understand the driving forces of human-induced climate change in terms of a simple mathematical identity (see Glossary), proved in Box I.1:

$$\textit{CO}_2\ \textit{emissions} = \textit{Population} \times \textit{Consumption per person} \times \textit{Technology impact}$$

Guided by this relationship, we can understand that total emissions from energy generation in the USA are very high because of very high consumption per person, high population (316 million in 2013) and quite a high proportion of fossil fuel in the energy mix. Total emissions from China are very high, despite low average consumption per person, because of a very high population (about 1300 million) and a very high proportion of fossil fuel, especially coal, in the energy mix. Australia's total emissions are much lower than those of the USA and China because of its relatively low population, 23 million in 2013, but Australia's unenviable record-breaking per capita emissions, the highest among industrialised nations, results primarily from its very high use of coal for electricity generation.

So the basic identity helps us resolve the debate about which driver of environmental impact – population, consumption per person or technology choice – is the most important. Depending on the circumstances, any one of these factors can be dominant. In rich countries growth in consumption per person, coupled with polluting technology, is generally dominant, while population growth, where it is occurring, is a secondary driver. In poorer countries population growth, coupled with polluting technology, is generally the main problem, and economic growth among the wealthier elite may be a secondary driver. The identities are also useful because they show that we can reduce CO_2 emissions by addressing each of the three driving factors with separate sets of policies: population with the non-coercive policies (Ch 8, 'Ending population growth without coercion'), energy use per person with programs to foster energy conservation and efficient energy use (Ch 4), and technology with programs to foster both efficient energy use and renewable energy (RE) (Chs 2, 4, 5).

BOX I.1 Disaggregating environmental impact

Let's consider carbon dioxide (CO_2) emissions C, resulting from energy generation E and population P, as a proxy for the environmental impacts of climate change. Energy consumption per person is E/P and technology impact can be measured by carbon emissions per unit of energy use C/E. Then we can disaggregate CO_2 emissions into three factors:

$$C = Population \times Consumption\ per\ person \times Technology\ impact$$

$$= P \times (E/P) \times (C/E) \qquad \text{(Equation I.1)}$$

Clearly this relationship is identically true, because we can cancel the Ps and Es to obtain the identity $C = C$. If we double any one of the factors on the right-hand side of the identity – population, consumption per person or technology impact – then CO_2 emissions are doubled. If we double all three factors, then CO_2 emissions are multiplied by $2 \times 2 \times 2 = 8$. The above identity is a special case of the well-known identity created by environmental scientist Paul Ehrlich and physicist John Holdren,

$$I = P \times A \times T \qquad \text{(Equation I.2)}$$

that disaggregates environmental impact I into the product of population P, affluence (consumption per person) A and technology impact T. In this general case consumption is generally given by gross domestic product and measured in terms of money.

Climate science is robust

As a scientist involved in the public communication of science, as well as in scientific and technological research on energy systems, I often receive packages from members of the public containing plans for miraculous machines that will perpetually generate useful energy from nothing. If I can find the time, I write back explaining that their invention violates the Law of Conservation of Energy, one of the fundamental laws of physics (see Ch 1).

Though science can tell us very little about beauty, love and ethics, it is the best framework for understanding the structure and functions of natural systems. Based on painstaking observation and experiment, scientists have uncovered fundamental laws of nature, used them to make predictions, tested the predictions and thus identified the limits of validity of the laws. For instance theoretical physicist Albert Einstein has shown that the Conservation of Energy must be modified for bodies travelling at speeds close to that of light, for which it becomes the Conservation of Mass-Energy; other scientists have shown that similar modifications are needed on the scale of fundamental particles. But the original law remains valid under normal conditions of human experience. Many scientists spend a great deal of time, effort and ingenuity in seeking alternative ways of interpreting observations. They consider themselves to be genuine sceptics. However, they generally prefer not to spend a lot of time questioning results that are very well established, unless there is clear evidence based on repeatable observations.

As human beings, the vast majority of scientists do not wish to be seen as 'radical' or alarmist. Therefore, in their public statements about a problem, they tend to be cautious and conservative. For instance, in presenting the results of their very detailed and complex models of Earth's climate systems, climate scientists rarely mention that the models only take into account one of the many positive feedback effects (see Glossary) that amplify global warming resulting from the increasing concentration of GHGs in the atmosphere. The following positive feedbacks are already being observed:

- melting of Arctic ice reduces reflection of sunlight from Earth, thus amplifying global warming
- melting of permafrost releases the GHGs methane and CO_2, amplifying warming
- warming of the Arctic Ocean releases methane, amplifying warming
- warming soils release CO_2, amplifying warming

- global warming increases the prevalence and intensity of wild fires which release CO_2, amplifying warming
- the warming atmosphere holds more water vapour, a GHG, which amplifies warming.

At present, due to the lack of quantitative data on a global scale, only the last of these positive feedbacks is included in climate models. Very few negative feedbacks are known.

In the public debate about climate change many people who reject the science and claim to be sceptics are actually deniers of well-established scientific evidence. They cannot offer an alternative interpretation of the data that stands up to scientific scrutiny. A genuine sceptic, who is a member of the public, would not assume that climate models are over-estimating global climate change. At the very least they would have to acknowledge that they could be under-estimating the changes.

There isn't enough space in this book on sustainable energy to critique the many myths being disseminated by climate science deniers. Scientists have examined these myths and refuted them again and again. The refutations are given on the websites of Skeptical Science[12] and Real Climate.[13]

Just as detectives and forensic scientists identify a criminal by a fingerprint left at the scene of a crime, climate scientists have identified the human responsibility for climate change from the 'fingerprint' of independent observations. Some of the elements of this fingerprint are:

- the average warming of Earth's surface, ocean and troposphere (lower atmosphere)
- cooling of the stratosphere
- night-time minimum temperatures rising faster than daytime maxima
- northern winters warming faster than northern summers
- solar radiation constant over past 50 years, apart from the well-known 11-year solar cycle
- land surface warming faster than ocean surface

- high latitudes (especially Arctic and Antarctic) warming faster than tropics.

Climate science deniers do not have a credible alternative mechanism to that of climate science that satisfies these observations. In particular, variations in the energy output of the Sun or volcanic eruptions could never explain them. The Intergovernmental Panel on Climate Change states that during the last 50 years 'the sum of solar and volcanic forcings would likely have produced cooling, not warming'.[14] The evidence is overwhelming that global warming is real, human-induced and continuing. As a consequence of the emerging positive feedbacks and the high rate of GHG emissions, it must be mitigated urgently.

'Do the math!'

Since the industrial revolution the atmospheric concentration of CO_2 in the atmosphere has increased from around 280 to 400 parts per million or about 43 per cent. As a result the average temperature of the Earth's surface has increased so far by 0.8°C above the pre-industrial level. However, equilibrium has not yet been reached so that, even if emissions could somehow be stopped today, the temperature would continue to rise until it had increased by about 1.3°C, assuming that air pollution (which has a cooling effect) remains constant, or possibly 2.4°C if air pollution decreases.[15] Current emission trends have put the planet on a path towards warming of at least 4°C before the end of the century.[16] The internationally agreed target adopted by the United Nations Climate Change Conference in Copenhagen in 2009 is to keep the average global warming below 2°C, although this will not necessarily avoid dangerous climate change.

How much CO_2 could we emit and still stay below the 2°C guideline temperature increase? A team of scientists from the Potsdam Institute for Climate Impact Research and several universities have calculated that there would be a 25 per cent probability of exceeding this level if we could limit the cumulative CO_2 emissions over the period 2000–50 to 1000 gigatonnes (Gt), where 1 Gt is 1 billion tonnes.[17] Over the period of 2000–13 nearly half of this budget was already emitted. Assuming a constant emission rate of 36.3 Gt CO_2 per year, the remaining budget would be exhausted in 14 years. In the words of author and climate activist Bill McKibben, 'Do the math!'.[18] The above calculation does not take into account future growth in the emission rate or emissions from GHGs other than CO_2.

If we burned existing reserves of fossil fuels equivalent to about 2800 Gt of CO_2, we would far exceed the budget. Yet several countries are developing large reserves of fossil fuels. China has the highest production of coal in the world; Canada is extracting oil from a large field of tar sands; the USA is developing gas from shale; and Australia, already the world's biggest coal exporter, is planning to greatly expand its existing coal exports and also to export coal seam methane on a large scale. Clearly the need to stop these and other dangerous developments is very urgent.

Who is responsible for the climate crisis?

To some degree we are all responsible for GHG emissions through our consumption of fossil fuels and the products and services made from them. However, the principal culprits are large energy-intensive corporations (discussed below) and individuals who are affluent, in the sense of having high consumption per person, and are living in a society with greenhouse-intensive technologies[19] and activities. These include burning fossil fuels, living and working in energy-inefficient buildings, logging native forests, and eating cattle and sheep. Nevertheless, we must be careful about blaming individuals, because most people have limited control over their emissions, in the face of existing institutions, cultures and technology choices available to us.

Large corporations are powerful forces in shaping the economy by lobbying governments and fostering consumer demand through