

Preface

Mankind has lived on the earth for hundreds of thousands of years in relative harmony with their natural surroundings. The earth and its climate were unaffected by the activities of early man. Within the last two hundred years, however, this peaceful co-existence has drastically changed as a result of our scientific knowledge and its widespread technological application. New agricultural techniques have greatly increased the productivity of the land and enabled the population to rise rapidly. The industrial revolution of the nineteenth century greatly increased the living standards in many countries, but at the same time it has polluted the earth to an unprecedented degree. This pollution is changing the face of the earth and its climate at an unforeseeable rate. If it is not checked our whole civilisation is in peril.

At the basis of these changes is the demand for more and more energy to drive our industries, to heat our homes and to power our transport and communications. All known ways of generating this energy affect the earth in one way or another, by using up the energy stored over geological timescales as coal or oil and by the pollution they cause. These sources of energy will ultimately be exhausted, but if we continue to rely on them we may well cause irreversible climate change. It is therefore a matter of urgency to find safe and clean ways of generating energy. At the same time it is necessary to reduce and if possible eliminate all the other sources of pollution.

When we look to the future it is useful to distinguish between ensuring adequate energy for our needs, and the effects on the earth of the methods we use to obtain that energy. Considering the astonishing technological developments of the twentieth century and the impossibility of predicting the advances that will be made in the twenty-first century, it is unrealistic to look more than about fifty or a hundred years

ahead when considering energy generation. When however we are considering the effects on the earth itself what we do now often has effects that will persist indefinitely. If the earth is polluted, it often remains polluted for a very long time. It is therefore of vital importance to ensure that current and future methods of energy generation do not irrevocably degrade the earth. To explore both these problems in more detail, the methods of generating energy by non-renewable and renewable sources are considered in Chapters 2 to 4, safety in Chapter 5 and the corresponding effects on the earth in Chapters 6 and 7. The associated political and moral problems are considered in the remaining chapters.

There is intense debate about the choice of new energy sources; should we rely on nuclear power, or could we get the energy we need from the so-called renewable sources, particularly wind and solar? As in most technological decisions, a balance has to be struck between the competing demands of cost, safety, reliability and effects on the environment. As these are incommensurable there is no easy way to reach a generally acceptable decision. It would be difficult enough to decide the optimum balance of energy sources by a dispassionate objective analysis but the whole decision process is made far worse by psychological, emotional and political forces. This makes it very likely that the wrong decisions will be taken, with disastrous effects in the future. Since countries differ greatly in their natural resources and industrial capacity no one solution is generally applicable; each country has to decide its own energy policy. Inevitably this has a great effect on international relations, particularly concerning the availability of oil during the next few decades, and of coal thereafter. In addition, the increasingly sophisticated energy technologies originate in the developed countries and are then exported worldwide. This implies continuing dependency, and with it the dangers of economic imperialism.

These decisions are not just matters of economics or politics; they raise serious moral problems. How, for example, do we decide whether to increase the level of expenditure on safety measures, or on protecting and conserving the environment, knowing that this inevitably means less money for education or the medical services? To what extent should we take account of people's emotions and fears, knowing that to a large extent they are unjustified and have been stirred up for political purposes?

The technological problems concerned with energy production are highly complex, and adequate understanding of them requires extensive scientific knowledge. It is one of the perils of democracy that vitally important decisions have to be taken by people who lack this knowledge. This problem is extremely difficult, but at least some of the worst effects can be mitigated by scientists providing whatever information they can. It is thus the responsibility of scientists to make their knowledge available by writing, lecturing and generally contributing to the public discussion of these vital issues.

This responsibility was keenly felt by those scientists who had participated in the development of the atomic bomb during the second world war. They knew that the discovery of fission and the chain reaction had irreversibly transformed the whole future prospects of the human race. On the one hand, the atomic bomb provided a weapon of unprecedented power that could, given time, be made by any medium-size industrialised country. On the other hand, nuclear power opened the way to the provision of world energy needs as the current sources, coal and oil, became exhausted. Immediately after the war, the scientists who had worked on the bomb formed organisations to inform the public of these developments; the Federation of Atomic Scientists in the USA and the Atomic Scientists' Association in the UK. They were supported by practically all the most eminent nuclear physicists, and were soon joined by scientists working in related areas. These scientists, and many others, wrote articles for magazines, organised exhibitions and gave lectures on the potentialities of the new knowledge of the atomic nucleus. The two organisations mentioned above published the *Bulletin of the Atomic Scientists* and the *Atomic Scientists' Journal* containing articles, discussions and book reviews.

Initially, these activities were welcomed by the public, and journalists wrote enthusiastic articles on the coming atomic age. Scientists, wishing to spend more time on their research and thinking that their work was done, gradually slackened their activities. They hoped that their work would be continued in a responsible way by the new generation of scientifically-trained journalists. In this they were sadly mistaken. As will be related in more detail, the public debate was soon overshadowed by political forces, and the scientists were no longer listened to. This situation persists to the present time, to the great peril of our society.

Subsequently, the Atomic Scientists' Association was wound up, and its activities transferred to the newly founded Pugwash Movement, which continues today. This provides a worldwide forum for a much wider discussion of science and public affairs. Its members now include physical and biological scientists, politicians, military men and all those concerned with international relations. Initially its main concern was to prevent the outbreak of nuclear war, and it arranged high-level meetings between Soviet and Western scientists. These were able to agree on basic scientific issues, and by communicating them to their respective Governments helped to encourage realistic policies. In the following years its activities broadened to include studies of a wide range of subjects concerned with the effects of science on human society.

I first became involved in these activities as a young graduate student, was a member of the Council of the Atomic Scientists' Association from 1951 to 1955 and edited the Atomic Scientists' Journal from 1952 to 1954. Subsequently I joined the Pugwash Movement and participated in some of its activities. This has given me some insight into the problems associated with the application of scientific ideas to the needs of society, and I am grateful to many colleagues in this work, especially to Joseph Rotblat, for their inspiration and example.

For many decades the development of nuclear power has been bitterly and successfully opposed by advocates of various renewable energy sources, particularly wind and solar. They maintain that these 'green' energy sources are less harmful to the earth and are capable of supplying all our energy needs. This claim needs to be critically examined for if it is true then it is clearly the best way forward, but if it is not then we are imperilling our future by advocating it. This debate between the proponents of the nuclear and the renewable energy sources is one of the principal themes of this book.

Many of the debates concerning the energy crisis, global warming and climate change are driven more by political convictions than by knowledge of the relevant scientific and technological facts. In many areas these facts are established beyond reasonable doubt, and in others there are still grounds for legitimate disagreement. There are disagreements about how long the coal and oil will last, and about the reality of global warming and climate change. It is therefore vital to distinguish between established facts, reasonable disagreements and pure speculation, always bearing in mind the likelihood that our judgements may be

affected, whether we realise it or not, by our political and moral beliefs. Finally there are aesthetic beliefs for example about the beauty of windmills and wildernesses that cannot be resolved by any rational criteria.

Even the appointment of a Royal Commission, the time-honoured way of tackling, or quite often postponing, a decision is not always objective, as much depends of who is included in its membership. Thus the Royal Commission on 'Environmental Pollution: Energy, the Changing Climate' was chaired by an eminent biochemist and 12 of its 16 members were environmental or life scientists. They made clear their instinctive aversion to nuclear power, and this influenced many of their judgements. Nuclear power was seen only as a possibility to be accepted if all else fails. The scenarios they consider assume carbon sequestration (see Section 2.2) or final energy demands in 2050 50% lower than expected on present trends. They accepted the sensational accounts of the Chernobyl accident rather than the scientific assessment of the United Nations Commission, which found that 'apart from non-fatal and treatable cases of thyroid cancer in children, there was no evidence of other radiation related health effects in the 14 years since the accident', whereas they admitted that in the same period 'there have been some 330,000 deaths related to fossil fuel combustion in the United Kingdom alone'. They say that 'new nuclear power stations should not be built until the problem of managing nuclear wastes has been solved to the satisfaction both of the scientific community and the general public', thus ignoring the view of the OECD Nuclear Energy Agency that 'there is broad scientific consensus that the disposal of high-level long-lived radioactive wastes in deep geologic formations is an appropriate and safe means of isolating it from the biosphere for very long timescales' (see Section 4.6). If the Commission had a different membership the conclusions would probably have been quite different (Nuclear Issues 22, September 2000).

It is important to recognise that it is very easy by selective quotation to make a strong case either for or against subjects like the desirability of nuclear power, the existence of global warming or the so-called population explosion. These are complex issues and it is impossible to reach a sound conclusion without extensive knowledge. Lacking this, the next best thing is to follow the conclusions of panels of experts convened by scientific societies such as the Royal Society and the National Academy of Sciences. Otherwise it is easy to be misled by the

many accounts that are published by scientists who are indeed very distinguished, but generally not in the speciality they are writing about. Further investigation may show that they are influenced by political or financial considerations. There is, for example, the well-known case of a distinguished solid state physicist who distributed large sums from the tobacco industry to researchers who found no harmful effects of smoking. Extreme care is necessary to obtain an impartial and balanced view.

It is quite extraordinary that many excellent books on the energy crisis, global warming and climate change, such as those by Gore and Maslin, make only the briefest references to nuclear power, brushing it aside with a few critical remarks about nuclear accidents and the disposal of nuclear waste. Conferences arranged by the British Government on the best ways to tackle global warming have many sessions devoted to wind, solar and wave power, with strong recommendations to improve energy efficiency, but fail even to mention nuclear power. The mass media show a similar bias, giving front-page publicity to the most minor nuclear accidents, while barely mentioning major disasters claiming hundreds of lives in dam bursts, oil rig fires and collapse of coal mine tunnels. Since nuclear power is a major source and is non-polluting, it would seem that it is necessary to consider their arguments against it, instead of ignoring it entirely. There seems to be a widespread and deep-seated psychological aversion to nuclear power. To redress the balance this book takes nuclear power seriously and discusses it in some detail. The emphasis is on the scientific and technological aspects, while some of the economic aspects concerning the buying and selling of companies building reactors receive only a brief mention.

One might expect there to be strong correlation between the scientific and technological feasibility, cost, reliability and safety of an energy source and its public approval, together with Governmental support for its development. This is far from the case. Political and psychological pressures are often far more influential than proven scientific data. It is possible to ignore reality for a time, but the longer this is done the more severe the ultimate reckoning. As Feynman remarked, Nature cannot be fooled.

These problems are of serious concern to the more well-developed countries, but they are a matter of life and death for the poorer ones. Already climate change is believed to be causing widespread drought,

and with it famine and disease. Most of these countries lack both the will and the means to improve their situation, so it can be maintained that it is the duty of the developed countries to do all they can to improve the living standards of the people in the poorer ones. There are many serious difficulties in achieving this, but they need to be urgently tackled.

In all discussions related to energy it is essential to express the quantities discussed numerically as accurately as practicable. The capacities, reliabilities and costs of the various energy sources can be expressed fairly accurately, and also to some extent their safety, expressed as the numbers of persons killed or injured. It is more difficult to express the effects on the environment, as these involve aesthetic criteria about which legitimate differences exist. The numbers I quote are the best that I could find, and I will be grateful to receive better ones. It is unfortunately inevitable that in the present situation where events are changing rapidly that many of the numbers are outdated, but nevertheless they serve to indicate general trends.

My main concern throughout is to draw attention to some of the most pressing problems of the present time, to stimulate discussion and to emphasise the moral aspects. The primary responsibility of scientists is to explain the scientific facts and their technological implications. In some cases, once the facts are known, the way forward is obvious, in others any attempt to provide an answer would be premature. Scientists as such have no responsibility to decide moral questions; that is the responsibility of the whole of society, including the scientists in their capacities as citizens. In order to reach sound decisions on moral questions expert and authoritative guidance is needed, and this should be provided by moral theologians and Church leaders. In order to give this guidance, it is essential that they are fully aware of the relevant scientific and technological facts. This seems so obvious that it might be considered to be hardly worth saying, but what is nearly always lacking is a full appreciation of what this really means. The necessary knowledge cannot be obtained easily; it requires years of study and research. The lack of understanding of this basic point has rendered worse than useless most of the statements by doubtless well-meaning Church leaders.

When I first became interested in these problems the main concern was to ensure that there is sufficient energy to maintain our standard of living and to raise that of the people in poorer countries to the same level.

It gradually become clear that there are sufficient energy resources to do this, mainly in the form of coal and uranium, but then the pollution caused by fossil fuels became the subject of concern, together with the likelihood of gradual and perhaps catastrophic climate change. To avoid this outcome very drastic action has to be taken and the main concern now is whether it is politically or psychologically possible to make the necessary changes to our styles of living in time to avert disaster.

During the last decade scientists have made increasingly accurate forecasts of the dangers threatening the world and the actions that must be taken to avert them. More and more people are becoming convinced that these actions are necessary, but virtually nothing has been done. Governments have indeed set up committees to examine these problems and make recommendations, but they are subsequently ignored if it seems politically expedient to do so. We are heading into disaster with our eyes open.

In writing this book I have used the information in many books and articles particularly those of Lomborg, MacKay and Maslin, and also the periodicals *Nuclear Issues* and *Speakers' Corner*, and the SONE (Supporters of Nuclear Energy) news sheets.

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