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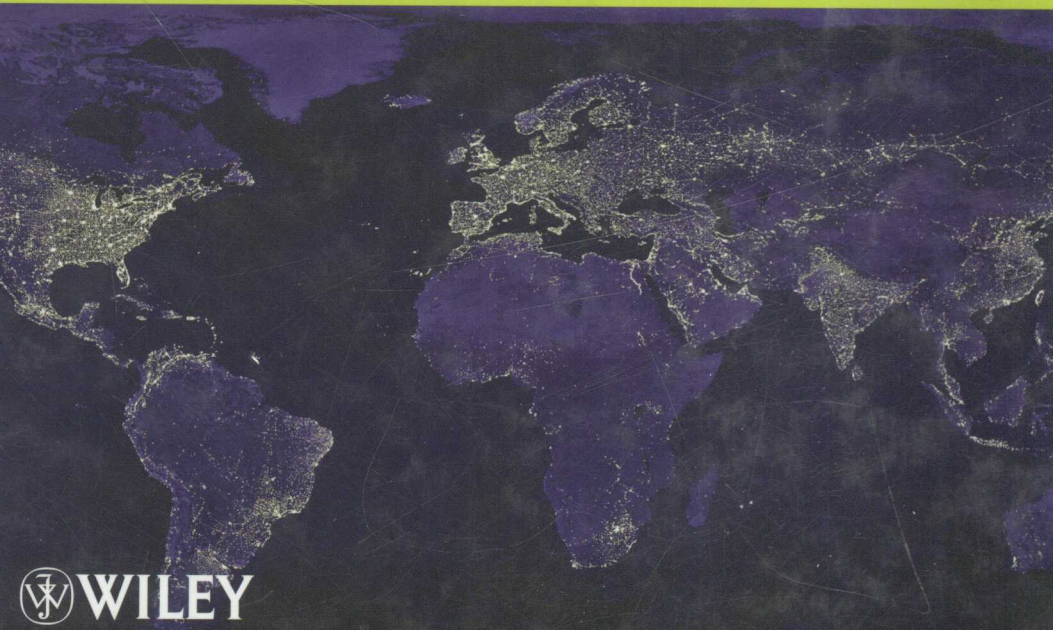
OUR ENERGY FUTURE

RESOURCES, ALTERNATIVES, AND THE ENVIRONMENT

Christian Ngô and Joseph B. Natowitz



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OUR ENERGY FUTURE

PREFACE

Energy availability is a real concern for everyone. Without energy or with access to much less energy than we currently use, we could not live in the same way, and life would not be easy. For example, before the French Revolution in 1789, the average life expectancy in France was below 30 years and in the United States it was 34 years. Now it is 80 years in France and 78 years in the United States. This is due in a significant measure to a ready access to energy which spurred the development of the agricultural, industrial, and medical resources that played a key role in increasing this life expectancy. Unfortunately, energy resources are not evenly distributed throughout the world and a large part of the world's population has a very low standard of living and a short life span. The poorest among them have life expectancies just slightly above that of an inhabitant of France in 1789.

Since 1789, the world population has increased dramatically, from a bit less than a billion inhabitants to above 6.5 billion. The average energy needs of these inhabitants are much greater than those of two centuries ago. In addition, after a long period in which energy was relatively cheap, its price is now increasing, and this is very likely just the beginning of a long trend. As a consequence humankind is no longer a small perturbation on planet Earth, and every day we face the possibility of increasingly negative consequences of human activities for the environment. It is time to take care of our planet and to make use of its wealth more carefully than before.

In this new paradigm, energy plays a central role. Building an energy future which assures ample supplies of energy to meet our needs should be a major priority and of concern to all. But in order to do that rationally we need to be adequately informed. Energy supply is a complex subject and many considerations come into play: science, technology, the economy, politics, the environment, energetic independence, national security, and so on. Reflecting this, there already exist, in papers, reports, newspapers, and books and on the internet several millions of pages devoted to the subject. Some of these sources are general but most are devoted to a particular aspect of energy technology or energy policy. Of these, some are written to advocate particular agendas and present only the positive features of their subject matter. They avoid presenting information about some of the drawbacks. This book is devoted to energy. As part of the Wiley Survival Guides series, this book aims to provide the reader with a fundamental working knowledge of this subject

matter. It is not encyclopedic. In writing this volume the authors felt that it was important to adopt a broad approach to discussing the problem of assuring an adequate future supply of energy. The reason is that there is no single solution to the problem but a choice of solutions that depend on many different parameters: the availability of energy reserves or resources and their location, existing or promising future technologies and their cost, the needs of individual consumers, the needs of the country or region, and the externalities which are not normally accounted for in the price. For example, when health considerations are taken into account, what is the real economic impact of a coal-powered electricity-generating plant?

We have tried not to be overly technical in our approach, but we have been determined to provide sufficient quantitative information and tools to allow the reader to make realistic comparisons of the different technologies. Being able to make reasonable first-order estimates to evaluate the suitability of a particular technology for the application under consideration is of primary importance in judging whether or not a given energy solution applies. The economic aspects of the problem are also of great importance. Except for a very small and very committed minority, people want access to energy at the lowest possible price. Finally, the impacts of greenhouse gas emissions and other pollutants are important issues in energy generation and they can be expected to take on increased importance in the future. The environmental and health impacts of the different energy technologies are dealt with throughout the book.

Harnessing energy resources and exploiting them to improve our living conditions are natural endeavors. Wasting energy resources or adopting energy supply solutions which have a large negative impact on health and on the environment is, given options, both foolish and unethical. We do believe that there exist sustainable energy supply solutions for each situation. The goal of this volume is not to try to promote any specific technology but rather to provide adequate background to prepare the readers to participate in choosing energy supply solutions appropriate to their own future needs and to those of the society they live in.

Change occurs slowly in the energy domain. It takes time to build a new power plant, to exploit oil from a newly found resource, to build or extend the electrical or natural gas grid, and so on. If we want to have the right energy at the right time and the right place, we have to anticipate our needs. It can take decades of research and years of development before significant technological changes are implemented. If we do not anticipate our future needs, we may be obliged to accept poor solutions to meet our energy requirements.

We start, in Chapter 1, by presenting basic energy concepts and discuss the evolution of the energy demand through the ages. Our standard of living and life expectancy have increased as our energy consumption increased. Many energy sources are available to us, but today's world is extremely dependent upon fossil fuels (oil, gas, and coal), which exist in finite quantities in the earth.

Issues of environmental impact, energy independence, and national security which are associated with our energy use practices are introduced in this chapter.

Fossil fuels (oil, natural gas, and coal) have allowed a vigorous development of our civilization. They currently satisfy most of our energy needs. Any change in price or decrease in the production of these fuels has significant consequences for the world economy. Chapters 2 and 3 describe the properties, production of, reserves of, transportation of, and utilization of fossil fuels. The problem of an impending peak in oil production is discussed. We also treat unconventional fuels, sources such as extra heavy oil, tar sands, oil shale, and so on. Impacts on the environment are also discussed. Climate change due to an increase of greenhouse gas emissions coming from human activities is a major concern. Since today we cannot avoid using fossil fuel to satisfy our energy demand, the issue of capturing, transporting, and sequestering CO_2 is presented. The greenhouse effect and its consequences are discussed in Chapter 4.

For a very long time renewable energies were the only energy sources that humans used to produce work or heat. Two such sources remain extensively used in current times: hydro power to produce electricity and biomass to provide heat. These sources produce a nonnegligible part of the world's total primary energy. They are examined in Chapters 5 and 6. Chapter 5, devoted to energy harnessed from water, deals with hydropower and the energy derived from the sea. Chapter 6 deals with biomass, which is extensively used today in many energy applications, for example, power generation, heating, and biofuels. The promise of new biofuels, in which there is presently a great interest, is considered in detail.

The renewable energies—solar energy, geothermal energy, and wind energy—are examined in Chapters 7, 8, and 9, respectively. Solar energy seems to promise a bright future. Geothermal energy is not renewable in the exact sense but is rather inexhaustible at the human level since 99% of the mass of the earth is at a temperature greater than 200 °C. Wind energy is currently seeing a very strong development. Renewable energies will take on more and more importance in the future and people must be prepared to use energy in a different way. They should also be ready to spend significant amounts of money to install such systems at home before they can get low-priced electricity or heat during operation of those systems. Unfortunately, some renewable energy sources are often available only intermittently and are currently expensive compared to fossil fuels. This is the case for wind energy and solar energy. Both of these also have relatively low energy densities and delivered power is sometimes not sufficient to satisfy modern-day energy needs. This may change in the future as improved technologies are developed.

Commercial nuclear energy is relatively new, having been available for only about 50 years. The principles of nuclear energy and nuclear reactors are explained in Chapter 10. Advantages and disadvantages of nuclear energy will be described and the issue of available resources addressed. The questions of

dealing with radioactive waste and reprocessing of spent fuel and the possibility of incidents and accidents as well as other safety issues are also considered in this chapter. We finish the chapter with a consideration of controlled thermonuclear fusion, which offers a truly exciting prospect as a future energy source.

Electricity is an energy vector more and more widely used. This is reflected by the fact that the demand for electricity increases at a larger rate than the demand for primary energy. Chapter 11 is devoted to this important energy vector and to the specific problems associated with producing and distributing it, the main one being that demand must be balanced by production in real time.

Storing energy is an important issue. This is the subject of Chapter 12. As far as electricity is concerned, it is important to be able to store electricity in very large quantities at off-peak hours to use it at peak hours. This allows smoothing the energy production and decreasing the installed power capacities which are usually dimensioned to meet peak demands. Intermittent renewable energies also demand methods of electricity storage. For heating or cooling purposes thermal energy storage is also an important issue. Being able to store heat in the summer to use it in the winter or cold in the winter for use in the summer would allow great progress in thermal energy management.

Transportation (Chapter 13) and housing (Chapter 14) consume a large part of the total energy used today. Transportation is necessary for trade as well as for many other activities. Presently it relies mostly on oil-derived products (gasoline, diesel oil, jet fuel) which are more and more expensive and will become scarcer in the future. We are not very far from having one billion road vehicles in the world. Transportation and housing are connected since most people must travel from home to the work place, shopping place, and so on.

Housing requires a lot of thermal energy. It is used to heat or cool buildings and produce hot water. It would be relatively easy to save quite a lot of energy in this domain. Methods by which this could be accomplished are presented.

Chapter 14 treats the production, transport, and use of hydrogen in various energy applications. Hydrogen is a very appealing energy vector for the future. Much consideration has been given to using it for road transportation in fuel cell vehicles. Unfortunately the physical properties of hydrogen make this difficult in the short term. Many problems remain to be solved and hydrogen vehicles will probably not be used at a large scale for several decades. However, there is a great interest in obtaining large supplies of hydrogen for use in petrochemistry and to exploit all of the carbon atoms contained in the lignocellulosic biomass in order to produce second-generation biofuels.

CHRISTIAN NGÔ
JOSEPH B. NATOWITZ

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C. N.
J. B. N.

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